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Changes in moderate intensity physical activity are associated with better cognition in the Multilevel Intervention for Physical Activity in Retirement Communities (MIPARC) study

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Abstract

Objectives: We investigated if the physical activity (PA) increases observed in the Multilevel Intervention for PA in Retirement Communities (MIPARC) improved cognitive functions in older adults. We also examined if within-person changes in moderate to vigorous PA (MVPA), as opposed to low-light and high-light PA, were related to cognitive improvements in the entire sample.

Design: Cluster randomized control trial.

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Conflicts of Interest: No Disclosures to Report.

Setting: Retirement communities in San Diego County, USA.

Participants: Three hundred and seven older adults without a formal diagnosis of dementia (mean age=83; age range 67-100; SD=6.4 years; 72% women) were assigned to the PA (N=151) or healthy education control (N=156) groups.

Intervention: Interventions were led by study staff for the first 6 months and sustained by peer leaders for the next 6 months. Components included individual counseling & self-monitoring with pedometers, group education sessions & printed materials.

Measurements: Measurements occurred at baseline, 6, and 12 months. Triaxial accelerometers measured PA for a week. The Trail Making Test (TMT) parts A & B and a Symbol Search test measured cognitive functions.

Results: There were no significant differences in cognitive functions between the MIPARC intervention and control groups at 6 or 12 months. Within person increases in MVPA, and not low-light or highlight PA, were associated with improvements in TMT parts B, B-A, and Symbol Search scores in the entire sample.

Conclusions: Findings suggest that MVPA may have a stronger impact on cognitive functions than lower intensity PA within retirement community samples of highly educated older adults without dementia.

Keywords

Physical activity; cognition; aging; intervention; retirement community; free-living environments; accelerometry; older adults

OBJECTIVE

Given an aging population expected to more than double in the United States by the year 2050[1], developing interventions to promote cognitive health and prevent dementia is an important public health goal. Epidemiologic studies have indicated that midlife physical activity is associated with lower risk of cognitive decline and dementia later in life[2,3]. Similarly, a metaanalysis of randomized controlled trials of exercise found that aerobic exercise was associated with modest improvements in attention and processing speed, executive function, and memory performance[4], although this was not always the case[5,6]. Proposed mechanisms by which physical activity may improve cognitive functions include increases in brain volume[7,8], changes in functional brain activity [9] and connectivity[10], changes in cerebral blood flow[11–13], and changes in neurotrophic factors that promote brain plasticity, angiogenesis, and neurogenesis[14,15].

Findings from community-based trials remain equivocal however, with many suggesting improvements in cognitive functions[16–21], while others, such as the LIFE and MAX trials, have not found such effects between intervention and control groups[22,23]. Sensitivity analyses within the LIFE trial however, reported benefits of increased physical activity within the cognitive function of certain sub-groups, such as those 80 years or older or with poorer physical performance at baseline[22]. Inconsistencies in the literature may be due to the variety of methods employed by different studies, different tools used to measure cognitive function, type and intensity of physical activity being performed, risk level of the target population for cognitive decline, and the length and setting of the intervention. Moreover, given the many challenges associated with the objective measurement of physical activity in real world settings, few physical activity interventions have objectively measured physical activity in free-living environments[24,25]. To our knowledge, no community-based physical activity intervention studies have yet investigated a dose response in the associations between different intensities of objectively-measured physical activity with cognitive outcomes in free-living environments, which have higher potential for wide scale dissemination of physical activity programs.

Most home-based physical activity interventions have not studied cognitive function as an outcome of interest and, of those that have, most reported cross-sectional or baseline cognitive associations with physical activity rather than intervention results[26,27]. In contrast to home-based exercise trials, many supervised randomized controlled trials of exercise in older adults (group settings, gyms, laboratory-based, etc) with cognition as a main outcome, have suggested that interventions of three months to a year in duration can improve brain structure and/or function with concomitant changes in cognition, especially memory and executive functions[8,9,11,28]. Most of these supervised interventions have targeted at least moderate intensity levels of physical activity and have aimed to improve cardiorespiratory fitness, which may be needed to exert the necessary neural changes to improve cognition[29]. Thus, supervised interventions have more consistently found improvements in cognition as a function of increased physical activity in older adults, while findings of community-based interventions are scarce and less consistent. This is possibly due to the many challenges associated with strict variable manipulation in free-living environments and that participants may not be achieving changes in moderate to vigorous physical activity (MVPA) levels (activity performed at ~50-85% of maximum heart rate or ≥ 3.0 METs).

To further elucidate whether changes in physical activity are associated with cognitive function in free-living environments, we used data from the recently published Multilevel Intervention for Physical Activity in Retirement Communities (MIPARC) study[26,30]. MIPARC was a 12-month cluster randomized trial of physical activity (primarily walking) within continuing care retirement communities. MIPARC was designed to study if a multilevel physical activity intervention increased objectively-measured physical activity in older adults living in retirement communities, compared to an education-based control condition. MIPARC was successful at significantly increasing light activities by 119 minutes/week and MVPA by 56 minutes/week on average in the intervention compared to the control condition[30]. As such, we examined whether there were also effects of the MIPARC intervention on cognitive functions. We hypothesized that those assigned to the physical activity intervention condition of MIPARC would have better cognitive function compared to the control condition after the intervention (condition x time interaction). Moreover, since previous supervised physical activity trials targeting MVPA have improved cognition, we explored the dose-dependent relationship of different levels of physical activity on cognition in a longitudinal analysis of the MIPARC data. We expected that within-person increases in time spent in MVPA in the entire sample, but not time spent in lighter physical activities, would be associated with higher cognitive scores over time.

METHODS

Study Setting and Procedures

MIPARC was a cluster randomized trial conducted in continuing care retirement communities in San Diego County to increase older adults' physical activity using a lifestyle-based approach. Design and randomization procedures have been described elsewhere[30,31]. In brief, each site was randomized to either the intervention or the healthy aging control condition. Site staff and residents helped to identify peer leaders who helped deliver the program within each retirement community over 12 months. Changes in cognitive function between the groups were a secondary outcome of the MIPARC trial and were not powered to detect significant group differences in cognition. The current analyses reflect an exploration of the dose-dependent effect of physical activity intensity on cognition.

Participants

Participants were recruited through presentations from UCSD staff, flyers, information tables, and peer leader outreach. Potential participants were eligible if they were over 65 years old and able to complete a 'timed up and go' test in less than 30 seconds, walk 20 meters without human assistance, talk over the telephone and obtain doctor permission to participate (intervention only). Those who had plans to move in the next year, reported a fall in the previous 12 months resulting in hospitalization, or were unable to comply with study device wear protocols were excluded. Furthermore, to rule out participants with cognitive concerns, potential participants had to accurately complete a post-consent comprehension test. No formal cognitive screener was used, so the sample could include individuals with mild cognitive impairment. In total 151 participants were assigned to the intervention condition and 156 were assigned to the control condition (only 153 participants in the control condition had available cognitive data). All participants provided written informed consent. Participant characteristics at baseline, 6, and 12 months are described in Table 1.

Intervention Group

The intervention was led by study staff for the first 6 months and sustained by peer leaders at each community for the next 6 months. All participants in the intervention arm were encouraged to gradually achieve a daily 3,000 step increase from their baseline over a period of 12 weeks (using a pedometer) and then to maintain that increase for the remainder of the study. Participants also attended 9 group education sessions, completed 4 one-on-one counseling phone calls, and participated in group walks co-led by UC San Diego staff and peer leaders for the first 6 months, with continuation by the peer leaders alone after 6 months. More details have been published elsewhere[30,31].

The main outcomes of the MIPARC intervention were changes in "lighter" physical activity (measured with an accelerometer cutoff of 760 counts per minute [CPM]), and MVPA (measured with an accelerometer cutoff of 1952 CPM), with cognitive function as a secondary outcome. Intervention effects on physical activity at both cutoffs have been reported elsewhere[10], but briefly, physical activity significantly increased in the intervention condition (56 min of MVPA per week; 119 min of light PA) compared with the control condition and remained significantly higher across the 12- month study.

Setting physical activity intensity goals was not the focus of MIPARC, hence the current study focuses on investigating whether the intervention (as it was implemented by increasing step goals) improved cognitive function (condition x time interaction), and whether within-person changes in different intensities of physical activity were associated with within-person changes in cognitive functions (dose dependent effect of different physical activity intensities).

Control Group

Participants in the control group received similar levels of attention from study staff as the intervention participants, although the focus of the control group was related to educational health. Participants received 9 group education sessions in the first 6 months on topics related to successful aging, diet, cognitive health, sleep, and communicating with doctors. Participants also received 4 general health calls with UC San Diego staff counselors to ensure equal attention from study staff over the telephone between groups.

Cognitive Assessment

Cognitive function was measured by the Trail Making Test (TMT) – Parts A and B (psychomotor speed and cognitive flexibility) and the Wechsler Adult Intelligence Scale – IV Symbol Search Test (psychomotor speed and visual scanning) at baseline, 6 months, and 12 months. These cognitive measures were selected because they have been typically included in the physical activity literature and can be considered tests of cognitive flexibility/executive functions (TMT B and B-A) and psychomotor speed/visual scanning (Symbol Search); cognitive abilities reported to change as a function of physical activity'[12–15]. Participants were allowed up to 180 seconds to complete TMT A and up to 300 seconds to complete TMT B. The time to complete each task yielded a raw score in seconds. TMT A scores were subtracted from TMT B scores to obtain a TMT B-A difference score that attempts to remove the speed element from the evaluation to reflect cognitive flexibility. Participants taking longer than the allotted time were assigned the maximum score. Thus, higher scores on the TMT indicate poorer (slower) performance. Participants were given 120 seconds to complete the Symbol Search Test. Incorrect responses were subtracted from the number of correct responses to obtain the total raw score. Higher scores indicate better performance. All participant assessments occurred at the retirement communities.

Physical Activity Assessment

Physical activity was assessed at baseline, 6 months, and 12 months using a triaxial accelerometer (GT3X+, ActiGraph, LLC, Pensacola, FL), which is a small, easy-to-wear device that yields valid estimates of physical activity intensity in controlled and free-living environments[36,37]. Participants wore the accelerometer on a belt on their hip for 6 days for a minimum of 10 hours per day at each assessment time point. Although accelerometer measurement periods of 1-week have been considered adequate to obtain reliable estimates of physical activity[38], a longer assessment period may have provided us with more accurate estimates. Data were processed using the ActiLife version 6 software (Pensacola, FL). The unit of measurement for accelerometers is counts per minute (CPM), with higher counts indicating higher intensity of movement. Data were aggregated to 60-second epochs so published cut points could be applied. To investigate the same intensity cutoffs reported in the parent MIPARC paper, we explored intensity effects for the following cutoffs: low-light physical activity (760 CPM), high-light physical activity (1041 CPM), and moderate to vigorous physical activity [MVPA] (1952 CPM)[37,39]. Minutes spent within each intensity level were averaged across days worn for each participant and entered into the within-person analyses described below.

Statistical Analysis

Scores on all TMT measures were log-transformed (log natural) given their non-normal distribution. As such, results for TMT-related variables are expressed as % in seconds while scores on the Symbol Search are expressed as raw scores. Analyses were conducted using R statistical computing software. An intention to treat framework was employed, which includes partially complete records in the model, avoiding biases associated with attrition and providing unbiased estimates under the assumption that data are "missing at random"[40]. Gaussian link, linear mixed-effects models (lme4 function in R) were employed to examine between group differences in cognitive functions over time (intervention effects) and within group changes in physical activity and cognition over time (within group effects). We adjusted the models for the effects of the following variables: age, gender, educational status, marital status, blood pressure, accelerometer wear time, and physical performance (Short Physical Performance Battery [SPPB] scores and 400m walk). We adjusted for these variables because they were either 1) significantly different (age, 400m walk, marital status) or marginally different (SPPB) between the groups at baseline, 2) to adjust for factors known to have changed over time as a function of the main MIPARC intervention (blood pressure, SPPB, and 400m walk), 3) and to adjust for variables that could affect the association of physical activity and cognition (gender, educational status).

Intervention effects on cognition (condition x time)

To examine whether the MIPARC intervention had a significant effect on cognitive function scores, we examined main effects of condition (intervention versus control) and time (baseline, 6, and 12 months), and a 2-way interaction (condition x time) as fixed-effects predicting TMT A, TMT B, TMT B-A, and Symbol Search scores. Inference was drawn from the condition x time interaction term. Educational group site was entered as a random effect. To determine if intervention effects on cognition were moderated by baseline levels of physical activity, we also modeled the interaction terms between condition x time x physical activity level for CPM: 760 (low-light), 1041 (high-light), 1952 (MVPA), and total counts per minute (TCPM) adjusting for all the variables mentioned above.

Within person changes in physical activity and cognition in the entire sample (dose-dependent effects)

To examine the dose-response effect of physical activity on cognition (hypothesized mechanism of change), within-person changes in low-light physical activity, high-light physical activity, and MVPA were associated with within-person changes in TMT A, TMT

B, TMT B-A, and Symbol Search scores in the entire MIPARC sample over time (irrespective of randomization group). Within person models were adjusted for age, gender, educational status, marital status, blood pressure, accelerometer wear time, 400m walk, and SPPB scores. To ensure that the effects were not confounded by total volume of physical activity, we also adjusted these models for total activity counts (TCPM). Educational group site was entered as a random effect.

Sensitivity Analyses

We conducted four different sensitivity analyses to better characterize our significant within group findings. We explored if the statistically significant within person effects of physical activity on cognition over time were moderated by age, gender, cognitive status, or condition (intervention versus control). These analyses were carried out since previous physical activity interventions have found differential results based on these variables and to ensure that within person analyses were not influenced by group assignment. Age groups were determined by a median split on the age variable. Those aged ≤ 80 were included in the "younger" group (N=141) while those aged 84+ were included in the "older" group (N=163). For gender, 0= female (N=220) and 1= male (N=84). For condition, 0= control (N=153) and 1= intervention (N=151). To determine cognitive groups, we calculated a cognitive composite score for each participant (by averaging across z-scores of all cognitive test). We then assigned those with cognitive composite scores ≤ −1 SD from the mean of the group to the "low cognitive function group" (N=44) and those with cognitive composite scores > −1 SD from the mean of the group to the "high cognitive function group" (N=260). Inference was based on the interaction term between physical activity and either age, gender, cognitive status, or condition.

RESULTS

At baseline, participants in the intervention condition were significantly more likely to be younger and married and performed better on the 400 m walk compared to those in the control condition. There were marginally significant effects for SPPB and scores on the Symbol Search test, with better performance in the intervention condition. All models were adjusted for these variables as described in the statistical analyses section. More details about baseline characteristics have been published elsewhere[30]. See Table 1 for participant characteristics at baseline, 6, and 12 months, and corresponding statistics.

Intervention effects on cognition (condition x time)

There were no significant effects of the MIPARC intervention (condition x time) on any of the cognitive variables after adjusting for covariates either at 6 or 12 months. Moreover, the intervention effects on cognition were not moderated by physical activity at either low-light, high-light, or MVPA intensities (all 3-way interaction terms p>.05, not reported). See Table 2 for statistical values of the condition x time interaction models **&** Figure 1 for a depiction of changes in the cognitive variables by condition, over time.

Within person changes in physical activity and cognition in the entire sample (dose-dependent effects)

Changes in low-light and high-light physical activity were not associated with changes in cognitive function for any of the cognitive variables. Contrarily, changes in MVPA were significantly associated with improvements in TMT B, TMT B-A, and Symbol Search scores. On average a within person increase of 10 minutes of MVPA was associated with a 5.6% improvement in TMT B completion time, with a 6.7% improvement in TMT B-A completion time, and with a .82-point improvement in Symbol Search scores. Refer to Table 3 for coefficients and p-values and Figure 2 for a depiction of significant within person changes in MVPA and cognition for the entire MIPARC sample.

Sensitivity Analyses

Results of sensitivity analyses conducted on the association of within person changes in MVPA and cognition indicated that the results were not significantly moderated age group or intervention condition (condition x time). Significant interactions were found for gender and cognitive function group. Gender moderated the effects of changes in MVPA on TMT B (B=.006, p=.014), whereby within person changes of 10 min in MVPA lead to a 7.7% improvement in TMT B performance in women and 2.9% improvement in men. The same was observed for TMT B-A (B=.01, p=.006) whereby within person changes of 10 min in MVPA lead to an 11.2% improvement in TMT B-A performance in women and a 4.1% improvement in men. For Symbol Search performance (B= −.83, p=.041), within person changes of 10 min in MVPA lead to a .78-point improvement in women and a 1.1-point improvement in men.

Similarly, cognitive function group moderated the effects of MVPA changes in TMT B performance (B=−.015, p=.05), such that within person changes of 10 min in MVPA lead to 2.3% improved TMT B performance in the high cognitive function group and to 1.2% worse TMT B performance for those in the low cognitive function group. The same was observed for the Symbol Search task (B=.271, p=.039), in which 10 min increases in MVPA lead to a .35-point improvement in performance for those in the high cognitive function group, and a 2.3-point decrease in performance for those in the low cognitive performance group.

CONCLUSIONS

Physical activity has been consistently associated with better cognitive functions in older adults, especially within studies that provide supervised or group physical activity. Studies investigating whether a multilevel physical activity intervention conducted in free-living environments can improve cognitive functions are scarce. Our results are consistent with those of the LIFE and MAX Trial interventions[22,23] and suggest that the MIPARC intervention, which focused on unstructured, unsupervised walking, and an “every step counts” approach was not sufficient to improve cognitive functions compared to the control group. A possible explanation for the lack of significant findings between the groups may be that the intensity of physical activity induced by the intervention was not enough to produce cognitive changes. This is plausible since MIPARC promoted an “every step counts” approach and did not focus on increasing time spent in MVPA. If MIPARC would have promoted greater increases in MVPA, it is possible that we could have observed group effects on cognitive functions. It is also possible that those assigned to the control condition increased their MVPA as well, thus reducing our ability to find significant effects. The social interaction at group sessions and attention from study staff and peer leaders received in both the intervention and control conditions may have also helped to maintain cognitive function over time for both groups, helping to explain why we found no intervention effects on cognition. We used an active and engaging control condition which could reduce social isolation and depression, two elements known to relate to cognitive decline[41]. Having a no treatment control condition would have yielded more information about the natural trajectory of performance. Similarly, compared to other studies that have found positive effects of physical activity interventions on cognitive function, our study sample is older, with a mean age of 83 years in which achieving substantial changes in MVPA may be more difficult. Moreover, the MIPARC sample was highly educated overall, which may have also affected our ability to detect group differences in cognitive function (less room for cognitive improvement). Since no formal screening of cognitive functions occurred, it is possible that some individuals included in this sample may have had mild cognitive impairment. Although we cannot address this limitation in the current study, future trials should thoroughly evaluate cognitive status at baseline to better characterize the sample and accurately evaluate intervention effects in different populations.

Studies promoting higher intensity physical activity (targeting between 60-80 % of maximum heart rate) under supervised conditions appear to have more favorable impacts on cognitive function[8,9,42,43]. Our within-person results support these findings, highlighting that those who increased their MVPA (1952 CPM or higher) had small, but significant improvements in cognitive flexibility, which was not the case for low-light or high-light physical activity. These results support our hypothesis that changes in higher intensity physical activity may be necessary to affect cognitive health and are consistent with the “supervised” physical activity literature. Previous physical activity intervention studies conducted under supervised conditions have consistently found changes in brain structure, brain functions, and cognitive performance when targeting moderate levels of physical activity between 60-80% of maximum heart rate[33,44]. The fact that we found effects of MVPA on cognition even within a cognitively normal sample and using tests that were not powered to detect significant changes in cognition, suggest that effects may be larger if more sensitive cognitive tests are implemented with larger community samples. This study provides evidence to support that changes in MVPA and not in lighter physical activities may have a higher impact in the cognitive functions of older adults with high levels of education who are living independently in retirement communities.

Sensitivity analyses of the within person effects of MVPA on cognition over time suggested that women performed better on tasks of cognitive flexibility/executive function compared to men, whereas men performed better than women on a task of psychomotor speed/visual scanning as a result of increases in MVPA over time. This is consistent with recent findings from a meta-analysis suggesting that women’s executive functioning may benefit more from exercise than men[32] The fact that increases in physical activity in men within the main MIPARC trial almost doubled those of women, can help explain why men performed better on the Symbol Search test compared to women in the current study[30]. Future studies should continue to evaluate the neurocognitive effects of different intensities of physical activity in older adults to best determine the dose response necessary to trigger the cascade of neuro-protective effects that can impact cognition.

MIPARC targeted lifestyle based unstructured walking because adherence to more intense and structured exercise programs are expensive, time intensive, difficult for older adults with limited mobility to attend, and less scalable at a public health level. Communities across the U.S. already offer a large number of exercise classes for older adults, but uptake is low, suggesting there are many barriers to participation[45]. This suggests a need for more independent unstructured programs to increase population levels of physical activity in older adults. However, there is a tradeoff between what the majority of older adults are able and willing to do (lighter intensity walking generally) and what seems to best promote cognitive improvements (more intensive physical activity, i.e. MVPA). As tools to measure heart rate intensity become more ubiquitous and affordable, it may be beneficial to give participants intensity goals, as well as step goals, to improve cardiorespiratory fitness in free-living environments.

In conclusion, we found no cognitive effects of a 12-month physical activity intervention in older adults without frank cognitive impairment, which may have resulted from the targeting of lower intensity physical activities in MIPARC. Despite the lack of an intervention effect on cognition, there was evidence that within person changes in MVPA in the entire sample were associated with improvements in cognitive flexibility/executive functions over time. These findings highlight the importance of MVPA to exert changes in cognitive functions and suggest that further research is needed to assess the dose response of physical activity in free-living communities.

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Highlights

- What is the primary question addressed by this study?

  This study investigated if the Multilevel Intervention for Physical Activity in Retirement Communities (MIPARC) improved cognitive functions in retired older adults and whether there was a dose-dependent relationship of physical activity intensity with cognition over time.

- What is the main finding of this study?

  The MIPARC intervention did not significantly improve cognitive functions when comparing the intervention and controls groups over time. In the combined sample, within-person increases in moderate to vigorous intensity physical activity were associated with improvements in executive functions compared to lighter activities.

- What is the meaning of the finding?

  Findings suggest that moderate to vigorous intensity activities performed in free-living environments may have a stronger impact on the cognitive functions of community-dwelling older adults than lighter activities.

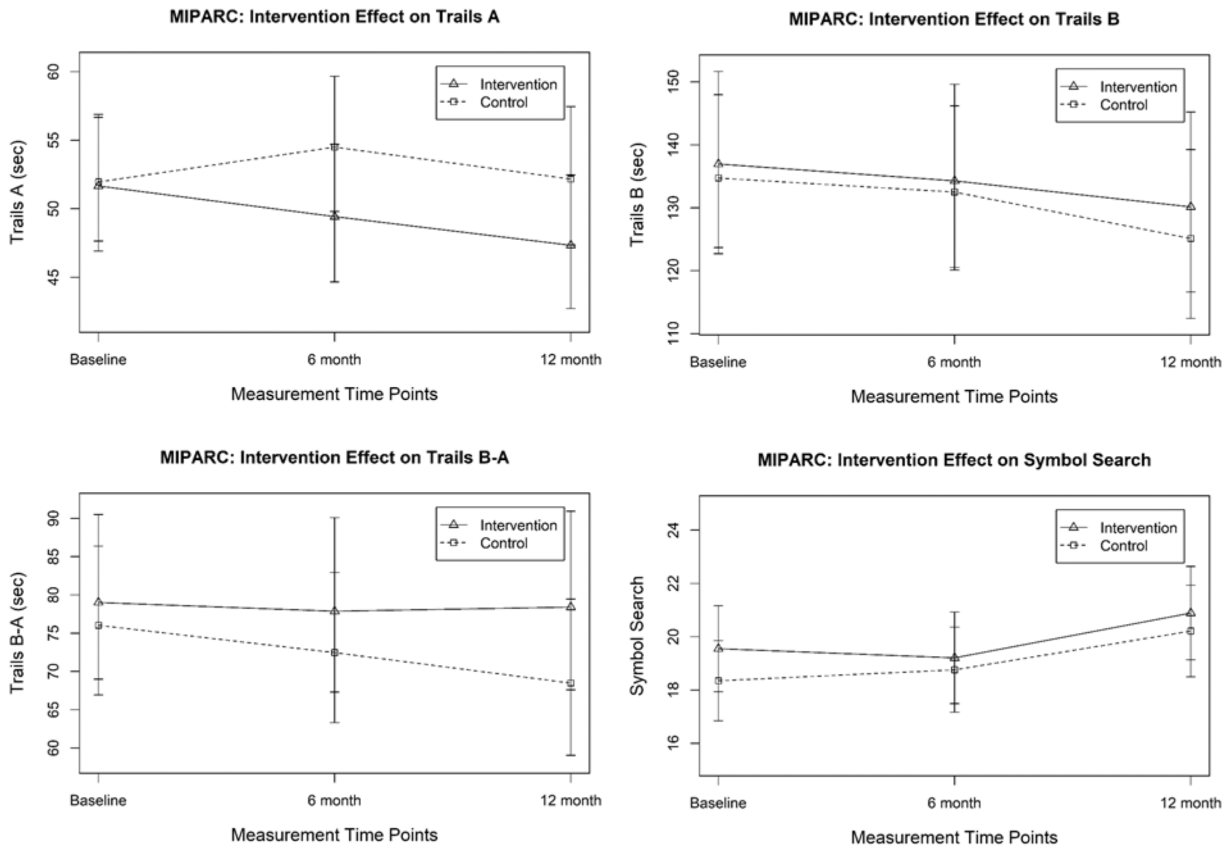

Figure 1.

MIPARC intervention effects on cognitive function adjusted for covariates. There were no significant effects of the MIPARC intervention on cognitive functions when examining the condition X time interaction. Error bars represent the 95% confidence interval.

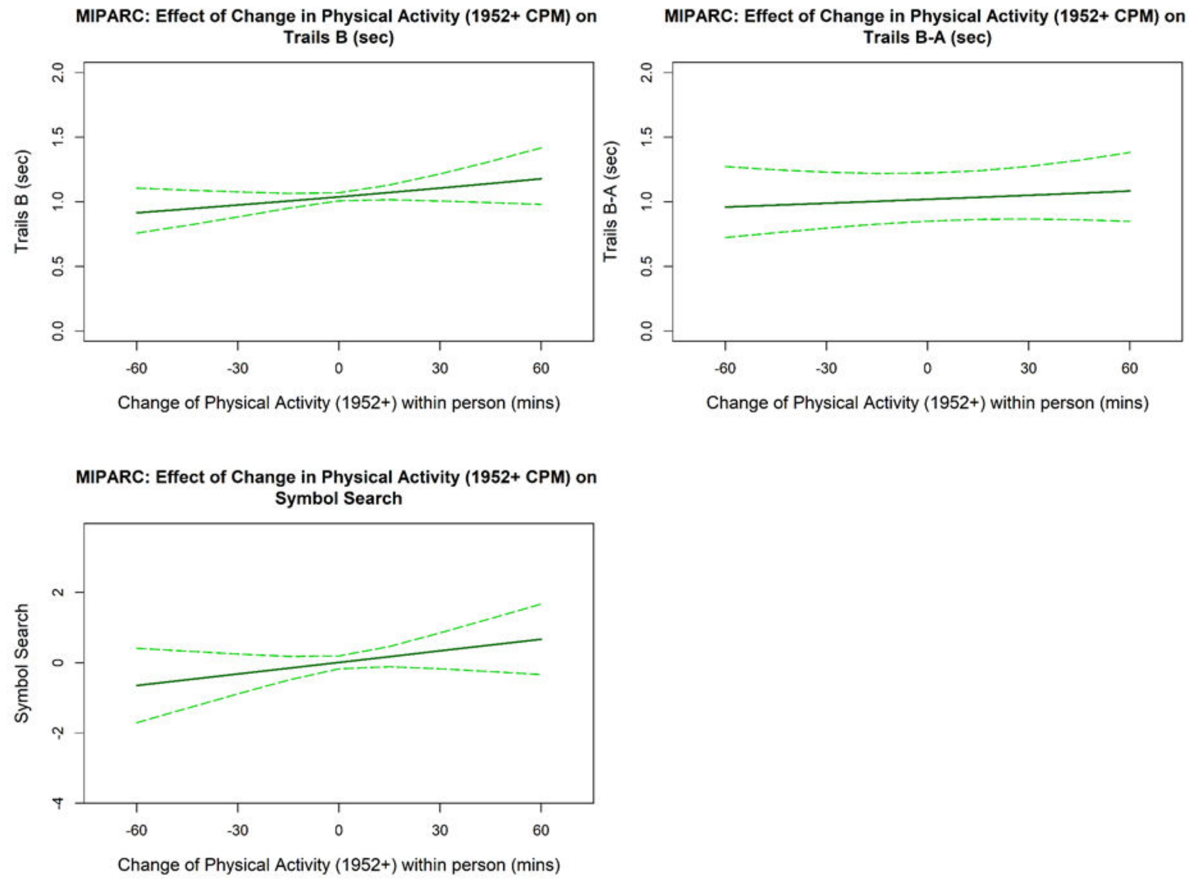

Figure 2.

Within person changes in MVPA and cognition adjusted for covariates among all MIPARC participants. The X-axis denotes within person change in MVPA minutes over time (increased or decreased relative to baseline). Y-axis denotes adjusted predicted values on cognitive tests. Lower scores indicate better (faster) performance for Trail Making Test parts A, B, and B-A. For Symbol Search, higher scores indicate better performance. Dotted lines represent the 95% Confidence Interval.

Table 1.

Participant Characteristics at Each Timepoint

	Baseline			
	Intervention (N= 151)	**Control (N=153)**		
	Mean (SD)	**Mean (SD)**	**T or χ2**	**p**
Age	81.9 (5.9)	85.33 (6.6)	−3.51	0.007
Gender (%female)	74	71	0.33	0.568
Education Group (% college and above)	69	60	2.20	0.138
Marital Status (% married)	52	29	14.58	0.000
Blood Pressure (Systolic)	132.06 (19.2)	130.7 (19.1)	−0.56	0.592
Blood Pressure (Diastolic)	69.24 (11.2)	67 (8.9)	0.25	0.811
SPPB Score	9.19 (2.7)	7.96 (2.8)	2.01	0.075
400 Meter Walking Speed (m/sec)	1 (0.2)	0.89 (0.2)	2.86	0.019
Symbol Search Total Score (#correct)	20.89 (7.3)	17.89 (7.2)	2.22	0.054
Trail Making Test Part A (sec)	51.94 (22.4)	57.58 (23.3)	−0.93	0.375
Trail Making Test Part B (sec)	141.67 (72)	155.47 (72.1)	−0.73	0.485
Trail Making Test B-A (sec)	90.19 (61.8)	98.16 (61.9)	−0.61	0.559
Average Daily Low-Light PA 760 CPM (min)	50.03 (29)	38.81 (28.2)	1.74	0.115
Average Daily High-Light PA 1041 CPM (min)	31.74 (23.1)	23.78 (20.5)	1.55	0.156
Average Daily MVPA 1952 CPM (min)	10.53 (13.6)	6.58 (10.2)	1.62	0.140
Total Daily CPM	141578.8 (64860.1)	118409.52 (61357.3)	1.79	0.107
Accelerometer Daily Wear Time (min)	805.06 (79.1)	820.75 (81.6)	−0.89	0.395
	6 months			
	Intervention (N=l 18)	**Control (N=123)**		
	Mean (SD)	**Mean (SD)**	**T or χ2**	**p**
Age	81.27 (5.9)	85.36 (6.4)	−3.95	0.003
Gender (%female)	77.0	73	0.31	0.576
Education Group (% college and above)	68.0	59	1.49	0.222
Marital Status (% married)	52.0	30	11.36	0.001
Blood Pressure (Systolic)	125.02 (16.7)	132.24 (18.6)	−1.87	0.094
Blood Pressure (Diastolic)	66.87 (10.7)	69.12 (14.5)	−1.36	0.206
SPPB Score	9.64 (2.5)	7.7 (3.1)	2.44	0.037
400 Meter Walking Speed (m/sec)	1.03 (0.2)	0.87 (0.2)	2.72	0.024
Symbol Search Total Score (#correct)	21.07 (7.2)	18.58 (7.5)	2.20	0.055
Trail Making Test Part A (sec)	48.06 (16.1)	60.65 (29.8)	−4.03	0.003
Trail Making Test Part B (sec)	135.1 (70.4)	152.28 (74.4)	−1.21	0.257
Trail Making Test B-A (sec)	87.04 (62.7)	91.93 (57.1)	−0.48	0.642
Average Daily Low-Light PA 760 CPM (min)	60.41 (40.1)	39.58 (25.2)	3.70	0.005
Average Daily High-Light PA 1041 CPM (min)	41.21 (32.9)	23.98 (18.2)	3.56	0.006
Average Daily MVPA 1952 CPM (min)	16.14 (20.4)	6.4 (8.7)	3.06	0.014
Total Daily CPM	165742.51 (90625.5)	117838.9 (52669.5)	3.82	0.004
Accelerometer Daily Wear Time (min)	822.87 (78.8)	815.77 (84.1)	0.77	0.461

	Baseline			
	Intervention (N= 151)	Control (N=153)		
	Mean (SD)	Mean (SD)	T or $\chi 2$	p
	12 Months			
	Intervention (N=106)	Control (N=99)		
	Mean (SD)	Mean (SD)	T or $\chi 2$	p
Age	81.27 (5.9)	85.18 (6.7)	−3.38	0.008
Gender (%female)	75	74	0.00	1.000
Education Group (% college and above)	71	60	2.34	0.126
Marital Status (% married)	50	32	5.88	0.015
Blood Pressure (Systolic)	129.01 (18.8)	132.73 (18.8)	−1.02	0.336
Blood Pressure (Diastolic)	68.01 (10.9)	67.24 (11.2)	0.50	0.628
SPPB Score	9.45 (2.7)	7.83 (3.2)	1.70	0.123
400 Meter Walking Speed (m/sec)	1.05 (0.3)	0.87 (0.2)	3.63	0.005
Symbol Search Total Score (#correct)	23.03 (8.8)	20.01 (7.9)	2.26	0.050
Trail Making Test Part A (sec)	46.32 (20.9)	58.11 (32.9)	−2.39	0.041
Trail Making Test Part B (sec)	127.45 (64.4)	141.88 (73.3)	−1.25	0.244
Trail Making Test B-A (sec)	81.14 (52.3)	85.51 (56.6)	−0.57	0.584
Average Daily Low-Light PA 760 CPM (min)	57.88 (38.3)	38.41 (26.4)	2.99	0.015
Average Daily High-Light PA 1041 CPM (min)	38.26 (30.5)	22.91 (19.2)	3.10	0.013
Average Daily MVPA 1952 CPM (min)	13.64 (17)	5.64 (9.1)	3.72	0.005
Total Daily CPM	158216.23 (84387.9)	114765.34 (56435.6)	3.35	0.009
Accelerometer Daily Wear Time (min)	816.97 (86.9)	806.45 (89.3)	0.92	0.380

Comparisons between Intervention and Control groups at each time point for all relevant variables. Degrees of freedom for all continuous variables = 9 (general linear mixed-effects models with adjustment for site level clustering as a random effect. 11 sites total). Degrees of freedom for Gender, Education Group, and Marital Status = 1 (Chi-squared tests). SPPB=Short Physical Performance Battery. MVPA=Moderate to Vigorous Physical Activity. CPM= Accelerometer Counts per Minute. Higher scores on the Symbol Search test indicate better performance. Higher scores on the Trail Making Test indicate worse (slower) performance.

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Table 2.

MIPARC intervention effects on cognition (condition x time interaction)

	6 Months				12 Months				
	B	**SE**	**t-value**	**p-value**	**B**	**SE**	**t-value**	**p-value**	***df***
Trail Making Test Part A	−0.09	0.06	−1.46	0.15	−0.09	0.07	−1.39	0.17	640
Trail Making Test Part B	0.00	0.07	−0.04	0.97	0.02	0.08	0.30	0.76	631
Trail Making Test B-A	0.03	0.11	0.31	0.76	0.10	0.11	0.85	0.39	631
Symbol Search	−0.75	1.25	−0.60	0.55	−0.53	1.30	−0.41	0.69	640

Results of general linear mixed-effect models for intervention effects on cognition (group x time interactions) adjusted for age, gender, education, marital status, blood pressure, accelerometer wear time, SPPB scores, and 400m walk, with a random effect of site. Results were not moderated by physical activity at any level (i.e., 760 Counts per Minute [CPM], 1041 CPM, 1952 CPM, or Total CPM). SPPB=Short Physical Performance Battery. B=Regression coefficient. SE=Standard error. df=degrees of freedom.

Table 3.

Within person change in physical activity and cognition in the entire sample (within person effects)

	Low Light PA (760 CPM)				High Light PA (1041 CPM)				MVPA (1952 CPM)				
	B	**SE**	**t**	**p**	**B**	**SE**	**t**	**p**	**B**	**SE**	**t**	**p**	**df**
TMT A	−0.001	0.001	−0.896	0.370	−0.003	0.002	−1.696	0.090	−0.003	0.002	−1.768	0.078	642
TMT B	−0.001	0.002	−0.565	0.573	−0.003	0.002	−1.262	0.207	−0.006	0.002	−2.644	0.008**	633
TMT B-A	−0.001	0.002	−0.508	0.611	−0.003	0.003	−0.876	0.381	−0.007	0.003	−2.128	0.034*	633
Symbol Search	−0.016	0.027	−0.584	0.559	−0.006	0.034	−0.182	0.856	0.082	0.037	2.246	0.025*	642

Statistically significant at p<.05*, p<.01**. Linear mixed effects models were adjusted for age, gender, education group, marital status, blood pressure, total activity counts, accelerometer wear time, 400m walk (meters/sec), and SPPB scores. CPM= Accelerometer counts per minute. B= Adjusted regression coefficient. SE= Standard error. TMT= Trail Making Test.