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# The association between physical activity and cognition in a racially/ethnically diverse cohort of older adults: results from the Kaiser Healthy Aging and Diverse Life Experiences (KHANDLE) study

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## Abstract

**Background:** Most prior research on physical activity (PA) and cognition is based on predominantly White cohorts and focused on associations of PA with mean (average) cognition versus the distribution of cognition. Quantile regression offers a novel way to quantify how PA affects cognition across the entire distributions.

**Methods:** The Kaiser Healthy Aging and Diverse Life Experiences (KHANDLE) study includes 30% White, 19% Black, 25% Asian, and 26% Latinx adults age 65+ living in Northern California (n=1,600). Frequency of light or heavy PA were summarized as two continuous variables. Outcomes were z-scored executive function, semantic memory, and verbal episodic memory. We

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tested associations of PA with mean cognition using linear regression and used quantile regression to estimate the association of PA with the $10^{th}$-$90^{th}$ percentiles of cognitive scores.

**Results:** Higher levels of PA were associated with higher mean semantic memory (b = 0.10; 95%: CI 0.06, 0.14) and executive function (b = 0.05; 95% CI: 0.01, 0.09). Associations of PA across all three cognitive domains were stronger at low quantiles of cognition.

**Conclusion:** PA is associated with cognition in this racially/ethnically diverse sample and may have larger benefits for individuals with low cognitive scores, who are most vulnerable to dementia.

### Keywords

Physical activity; Cognition

## INTRODUCTION

Prior evidence suggests that older adults who engage in physical activity (PA) have better cognition, less brain atrophy, larger brain volume (white matter and gray matter volume), and lower risk of dementia, compared to those who live a sedentary lifestyle.[1,2,3,4] However, the importance of PA for population-level prevention of dementia depends on whether PA is protective for individuals at greatest risk of dementia. The prevalence of Alzheimer's disease and related dementias (ADRD) among adults 65 years and older is 19% among Black and 14% among Hispanic older adults, compared with only 10% of White older adults.[5,6] Most prior studies of PA and cognition have included predominantly White populations, despite higher risk of dementia in Black and Latinx older adults. Further, by restricting focus to associations between PA and the mean of cognitive function (i.e., linear regression), studies have not evaluated whether older individuals at highest risk of impairment – specifically among those with lower levels of cognitive function--- may reap larger benefits from PA.[7–9]

The few prior studies evaluating differences in the association of PA and cognition across many racial/ethnic groups were characterized by small sample sizes, with limited power for subgroup analyses.[7–9] The largest diverse studies, such as REGARDS, which included 7,098 older adults with an average age of 70 years old, only assessed Black and White individuals, without information on Latinx or Asian older adults.[7] In addition, the Honolulu-Asia Aging Study (HAAS) assessed 2,263 Japanese American men living in Hawaii, however the sample did not include other racial or ethnic groups or women.[10] Racial/ethnic identity, a social construct defined by structural forces designed to promote a racial hierarchy, is one of many potential dimensions of heterogeneity in the association between PA and cognition. Individuals racialized as Asian, Black, or Latinx are more likely to experience systemic and interpersonal racism affecting schooling, occupational settings, financial precarity, housing, environmental toxins, health care, and many other social determinants of health. Such major risk factors, with different prevalence across racial/ethnic groups, may plausibly either offset or intensify any potential benefit of any other risk factor, such as PA, on cognition.[11]

Early life cognition also influences dementia risk and may thus also either enhance or reduce the importance of PA in maintaining healthy cognition in late life.[12,13] The possibility

that the potential benefit of PA is larger (or smaller) among people with high underlying vulnerability to dementia is especially important to evaluate, but not easy to test with conventional linear regression methods.[14,15] Ordinary Least Squares (OLS) regression methods assess whether the *mean* cognitive scores differ by PA level. Quantile regression is less commonly used but offers a novel way to quantify how PA affects cognition for people at high and low quantiles of cognition. Because prior cognition is among the strongest known risk factors for incident dementia, larger benefits of PA for individuals at low versus high quantiles of cognition suggest PA is an especially promising strategy to reduce population dementia risk.[16–18] PA includes a wide variety of domains with different levels of intensity such as exercise, leisure-time, work-related, and yard or house-work related activity. These different types of PA may have different effects across our three cognitive domains; therefore, we evaluated the association between light and heavy PA.[19,20] Additionally, in this paper, we use quantile regression analysis in a racially/ethnically diverse sample, allowing the effect of PA to vary for different quantiles among three cognitive domains.

## METHODS

### Study design and sample population

The Kaiser Healthy Aging and Diverse Life Experiences (KHANDLE) is a cohort study of 1,712 community-dwelling older adults residing in the San Francisco Bay and Sacramento areas of California, that aims to evaluate how race/ethnicity and life course health and sociocultural factors influence late-life brain health and cognitive decline. Eligible participants were long-term members of Kaiser Permanente Northern California (KPNC), age 65 years or older on January 1, 2017, spoke English or Spanish, did not have an electronic medical record diagnosis of dementia or other neurodegenerative disease, did not have another health condition that would impede participation in study interviews, and had previously participated in Kaiser Permanente multiphasic health checkup exams between 1964 and 1985. The older adult population (aged 65+) from KPNC is generally similar to the population residing in Northern California regarding medical history of chronic conditions, asthma and lifestyle factors.[21–24]

The KHANDLE study was approved by the human subjects' institutional review boards of the Kaiser Permanente Northern California Division of Research and the University of California Davis. All respondents provided written informed consent.

### Measures

**Cognition—**Cognitive performance was assessed using the Spanish and English Neuropsychological Assessment Scales (SENAS)[25,26], a battery of cognitive tests that has previously undergone extensive validation for comparisons of cognition across racial/ethnic and linguistically diverse groups.[27] Language of administration was assigned by a decision rule that incorporated preferred language, as well as information about the language used in several everyday situations. The SENAS assesses executive function using a component tasks of category fluency, phonemic (letter) fluency, and working memory (digit-span backward, visual-span backward, list sorting). Semantic memory composite scores were

derived from verbal (object-naming) and nonverbal (picture association) tests. A verbal episodic memory composite score was derived from a multi-trial word-list-learning task. Details of the administration procedures, development, and psychometric characteristics have been extensively described.[25–27] For the present study, each cognitive domain was z-standardized using the baseline sample mean and standard deviation.

**Physical Activity—**Participants' frequency of light or heavy PA were each self-reported through three Likert-scale questions with five options (every day or almost every day, several times a week, several times a month, several times a year, and never). Physical activity was based on six questions about how frequently (every day, or almost every day; several times a week; several times a month; several times a year; never) they currently participate in the following activities: "Light, work-related demands (standing, walking, etc.)", "Light house or yard work (tidying, dusting, sweeping, laundry, gardening, etc.)", "Light exercise or sports (walking, dancing, softball, bowling, etc.)", "Heavy, work-related demands (carrying, lifting, moving, etc.)", "Vigorous house or yard work (vacuuming, mopping, mowing, lawn, etc.)", and "Vigorous exercise or sports (cycling, jogging, swimming laps, tennis, etc.)". We summarized light PA based on the "light" PA three items and heavy PA based on the "heavy/vigorous" PA items, taking each individuals' mean score across the three items ranging from 0–4 with higher scores indicating more frequent PA.

**Covariates—**We evaluated race/ethnicity (classified as self-reported Asian, Black, Latinx, or White identity) as a possible modifier of the association between PA and cognition because many social risk factors for dementia are strongly stratified by race/ethnicity in the United States.

Our covariates included factors that we thought could influence both PA and cognition, including: age, sex (male/female), education (self-reported based on the participants highest level of school they completed, reported as actual years for <12, and estimated based on education/degree beyond 12 years, ranging from 13–20, current employment status (employed for pay/not employed for pay), global sleep quality (created using a modified version of the Pittsburgh Sleep Quality Index which assessed subjective sleep quality, latency, duration, disturbances, sleep medication use, and daytime dysfunction), and income (range reported in 13 categorical responses, assigned the category midpoint and log transformed). Due to a large proportion of the sample missing data for income, we used the missing-indicator method to retain observations. Because some of these covariates may be consequences of PA rather than causes – and we do not have the lifecourse longitudinal data that would be necessary to establish predominant causal direction – we present results with adjustment for only demographic variables and models adjusted also for all covariates.

## Analytic strategy

We tested for nonlinearity of the light and heavy physical activity variables with cognitive test scores by fitting linear regression models for each cognitive outcome with indicator variables to assess whether there were approximately equal increments with each dummy variable to determine whether the relationship was approximately linear. We assessed the cross-sectional association of light and heavy PA with mean cognitive scores in each

cognitive domain using linear regression models with demographic-only or full-covariate adjustment. We first estimated analyses including data from all racial/ethnic groups and subsequently estimated models stratified by race/ethnicity. We additionally evaluated the heterogeneity in the associations of PA and each cognitive domain by including an interaction between PA and race/ethnicity. In these analyses, we used White participants as the comparison group and an F-test for whether the coefficients diverged significantly across race and ethnicity subgroups.

We additionally estimated the conditional association of PA (per SD) with the $10^{th}$-$90^{th}$ percentiles of cognitive outcomes using covariate adjusted quantile regression models. Quantile regressions are conceptually similar to OLS regressions but choose coefficients that minimize weighted sums of absolute residuals instead of minimizing the sum of squared residuals as in OLS. While an OLS regression coefficient is interpreted as the difference in mean value of the outcome associated with a unit increment in the exposure (conditional on covariates), a quantile regression for quantile $\tau$ is interpreted as the difference in the $\tau^{th}$ quantile of the outcome associated with a unit increment in the exposure (conditional on covariates). We report pooled results for quantile regression due to race-stratified models not converging. Analyses were conducted using R version 4.1.3.

## Results

From 1,712 individuals enrolled in KHANDLE, we derived a final analytic sample of 1,600 participants (see Figure 1). Mean age of the analytic sample was 75.9 years (SD = 6.7); 59% of participants were female; and participants averaged 14.7 (SD = 3.1) years of schooling (Table 1).

Of the sample, approximately 25% identified as Asian, 19% as Latinx, 26% as Black, and 30% as White. The frequencies of light and heavy PA were similar across racial/ethnic groups.

### Full Cohort Results

In demographic-adjusted linear regression models including the full cohort, each unit higher light PA (b=0.05; 95% CI 0.00, 0.10) and heavy PA (b=0.06; 95% CI: 0.02, 0.10) was associated with higher mean executive function scores. The association of heavy PA with executive function remained positively associated after full adjustment (Table 2). In demographic-adjusted models, both light and heavy PA were associated with higher mean semantic memory scores, and the association remained after full covariate adjustment. Estimates for the association of PA with verbal episodic memory were null, with wide CIs (Table 2).

### Race/Ethnicity Results

In race/ethnicity stratified models, heavy PA was positively associated with mean cognitive function across multiple domains among Asian, Latinx, and White participants. PA was not associated with mean cognitive function among Black participants.

Heavy PA was positively associated with mean executive function among Asian (β= 0.09; 95% CI: 0.01, 0.18) and Latinx (β= 0.13; 95% CI: 0.05, 0.22) participants but not Black (β= −0.03; 95% CI: −0.11, 0.05) or White (β= 0.06; 95% CI: −0.03, 0.14) participants in demographic-adjusted models. After adjustment for additional covariates, the association remained for Asian (β= 0.08; 95% CI: 0.00, 0.16) and Latinx participants (β= 0.13; 95% CI: 0.05, 0.21). Additionally, heavy PA was positively associated with mean semantic memory scores for Asian, Latinx, and White participants in demographic-adjusted models. For example, among Asian participants, each unit higher heavy PA was associated with a 0.16 (95% CI: 0.06, 0.26) standardized unit higher mean semantic memory score. These associations remained after full covariate adjustment for Asian, Latinx, and White participants (Table 3).

There was no evidence that light or heavy PA was associated with mean verbal episodic memory for Asian, Latinx, or Black participants. Both light and heavy PA were positively associated with mean verbal episodic memory among White participants (β= 0.08; 95% CI: 0.00, 0.16) in demographic-adjusted models, but these associations were attenuated after further adjustment (Table 3). The F-test showed that these differences in associations by race/ethnicity may be due to random chance ($F_{\text{Executive Function}} = 1.56$, $p = 0.20$; $F_{\text{Semantic Memory}} = 1.50$, $p = 0.22$; $F_{\text{Verbal Memory}} = 1.32$, $p = 0.26$).

In models with an interaction between PA and race, the estimated effect of light physical activity on mean verbal episodic memory was smaller among Latinx participants (interaction β= −0.16; 95% CI: −0.31, −0.01) compared to White participants. This association remained after further adjustment (Supplemental Table 1.) There was no evidence that light or heavy PA and semantic memory or executive function differed by race/ethnicity in both demographic and fully-adjusted models.

### Quantile Regression Results

In fully adjusted quantile regression results, associations of PA across all cognitive domains were stronger at low quantiles of cognition than at median or high quantiles. For example, at the $10^{th}$ percentile, each one-unit higher heavy PA was associated with 0.08 standardized units higher ($b_{10}$=0.08; 95% CI: 0.01, 0.15) verbal episodic memory score, while there was no association between heavy PA and median verbal episodic memory score ($b_{50}$= 0.02; 95% CI: −0.03, 0.07). Estimates for associations of heavy PA with semantic memory were also larger at low quantiles ($b_{10}$=0.12; 95% CI: 0.05, 0.20) compared with associations at the median ($b_{50}$=0.08; 95% CI: 0.03, 0.13) or higher quantiles. Similar trends were seen for the associations of heavy PA with executive function. At the $20^{th}$ percentile, each one-unit increase in heavy PA was associated with a 0.07 standardized units higher ($b_{20}$=0.07; 95% CI: 0.03, 0.13) executive function score. The results were less clear for the association between light PA across all cognitive domains (Figure 2).

## Discussion

The purpose of this study was to evaluate the relationship between PA and cognition in a racially and ethnically diverse population and evaluate whether PA was more strongly associated with cognition among those with the lowest cognitive domain scores. We found

that higher levels of heavy PA were associated with higher mean executive function and semantic memory scores. Additionally, we found that higher levels of light PA were also associated with higher mean executive function and semantic memory scores, however these were attenuated towards null after further adjustment. PA level was not associated with mean verbal episodic memory scores. Results were generally similar across racial/ethnic groups, although estimates were null for Black participants. Lastly, results from the quantile regression analysis show the strongest association between PA and cognition among those in the lower quantiles of cognitive function, who are likely to be at higher risk of incident dementia.

Our findings are consistent with previous work showing a positive relationship between PA and cognitive function, and that higher levels of PA are associated with better cognitive function across multiple domains.[20,28–31] Evidence from randomized controlled trails (RCTs) also suggests that sustained PA in older adults was associated with larger hippocampal volume compared to their counterparts.[30,32] Our study also found results consistent with previous work showing differences between higher levels of light and heavy PA.[19] Although PA is widely studied, there is an urgent need to evaluate associations with cognitive outcomes across racial/ethnic groups represented in the United States. For example, the Lancet review on dementia prevention prioritizes physical activity, based on two meta-analyses which included only a handful of studies including Black, Latinx, or Asian adults from the US.[33,34] We extend these findings with a diverse population with identical assessments of approximately equal size samples of Asian, Latinx, Black, and White participants. We found generally robust results for Asian, Latinx, and White participants, with notably smaller coefficients for Black respondents. We emphasize that racial/ethnic differences in the effects of PA are plausible due to the profound racial inequalities in social drivers of dementia risk driven by systemic racism, which could plausibly outweigh benefits of PA. The estimated differences in estimates by race/ethnicity were not significant and likely due to random chance, however, it is important that this be examined in other samples.

To our knowledge, our study is the first to investigate the association of PA and cognition across the distribution of the outcome. Because low cognitive scores are robustly associated with dementia risk, it is important to examine how PA impacts cognition across the entire outcome distribution.[16,17,18] We found that the differences in memory associated with PA were strongest at low quantiles of semantic and verbal episodic memory than at the median or high quantiles and remained robust after including additional covariates. The larger effect at lower levels of cognition suggests a particular benefit for prevention of dementia among those at highest risk of falling below impairment thresholds.

Several plausible mechanisms may link PA to better cognition. PA can elevate neurochemicals levels that promote synaptic plasticity and neuronal survival, such as brain-derived neurotrophic factor (BDNF) and insulin-like growth factor 1 (IGF-1).[35] Inflammation can be reduced by lowering the levels of pro-inflammatory cytokines, a typical feature of cardiovascular and metabolic diseases.[36] PA may also improve vascularization by promoting protective physiological adaptations which increase diameter and dilation of the coronaries.[37] Lastly, Aβ deposition in older adults' brains may be reduced with PA.[36] A

2018 review of the PA guideline from the Physical Activity Guidelines Advisory Committee, focused on cognition and brain outcomes, suggested that moderate to intense PA levels can impact cognition in adults aged 50 years or older, with higher effect sizes on executive function, global cognition, and attention.[30] Our findings are consistent with these results and we provide further evidence that these associations persisted across a racially and ethnically diverse population.

We did not find any association between PA and verbal episodic memory in Asian, Latinx, or Black respondents. Alzheimer's disease typically manifests through a progressive loss of episodic memory.[38] Randomized trials of exercise intervention studies have highlighted the beneficial effects of aerobic exercise on episodic memory and other cognitive functions.[39] Our null results may reflect lower intensity/frequency of PA compared to participants in the prior studies or distinctive patterns observed in predominantly White samples in most prior research.

The most important limitation of our study was the cross-sectional design, precluding evidence of a temporal relationship between our exposure and lack of ability to estimate the effects on incident impairment or decline. Second, people who are healthier are more likely to be able to engage in physical activity which is hard to tease out in a cross-sectional study with a late life exposure. Therefore, we cannot rule out reverse causality. Third, PA was self-reported, which may lead to issues with recall bias or measurement error. Recall bias with self-reported PA is particularly relevant in our study because of the potential for cognitive function to impact over and under reporting of PA. Additionally, the PA measures used have imperfect reliability which could not be accounted for and therefore may have attenuated coefficients. Fourth, while our study used quantile regression to look at the relationship between PA across levels of cognitive function in the full cohort, our sample size was too small for race-stratified quantile regression analyses. Therefore, we do not know if the patterns seen are consistent across race/ethnicity. Chance may play a role in some observed associations: we report multiple effect estimates but did not incorporate multiple comparisons adjustments as this would reduce power to detect racial/ethnic differences. Finally, we did not adjust the models for several dementia risk factors related to cardiovascular health such as diabetes, hypertension, obesity, and cholesterol levels; as potential mediators, adjustment for these variables would inappropriately attenuate the estimated effect of PA but these factors may also partially confound associations.[40]

Given the higher risk of dementia in Latinx and Black populations in the US, there is a need to better understand how modifiable behavioral factors such as PA affect cognitive outcomes in older adults in minoritized groups. The present study adds to previous literature by demonstrating that PA is associated with better cognition in multiple cognitive domains and across Asian, Latinx, and White respondents. Our results for Black respondents do not demonstrate a strong association, and further evaluation of this is a high priority for future work. Additionally, our study highlights the effect of PA on individuals who – due to low cognitive scores – may be more vulnerable to developing dementia.

Future research should incorporate longitudinal assessments of both PA and cognitive function in diverse samples to improve evidence for causal effects across racial/ethnic groups.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Funding

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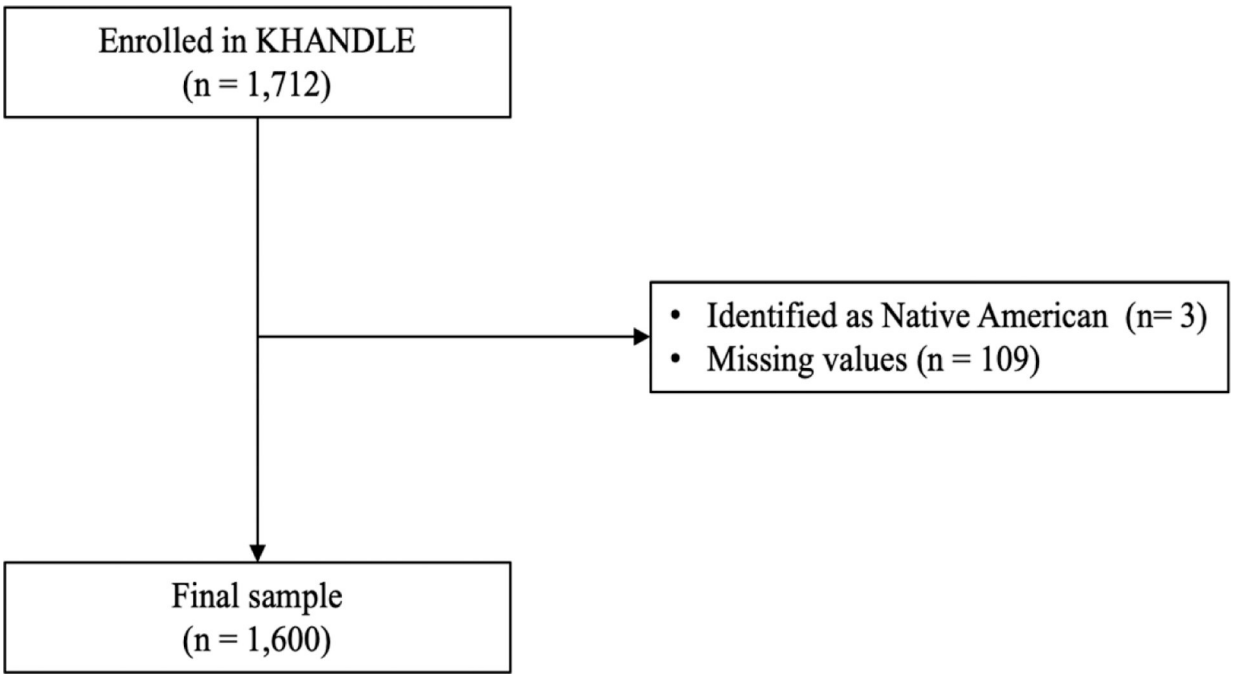


**Figure 1.**
Flow chart of analytical sample.

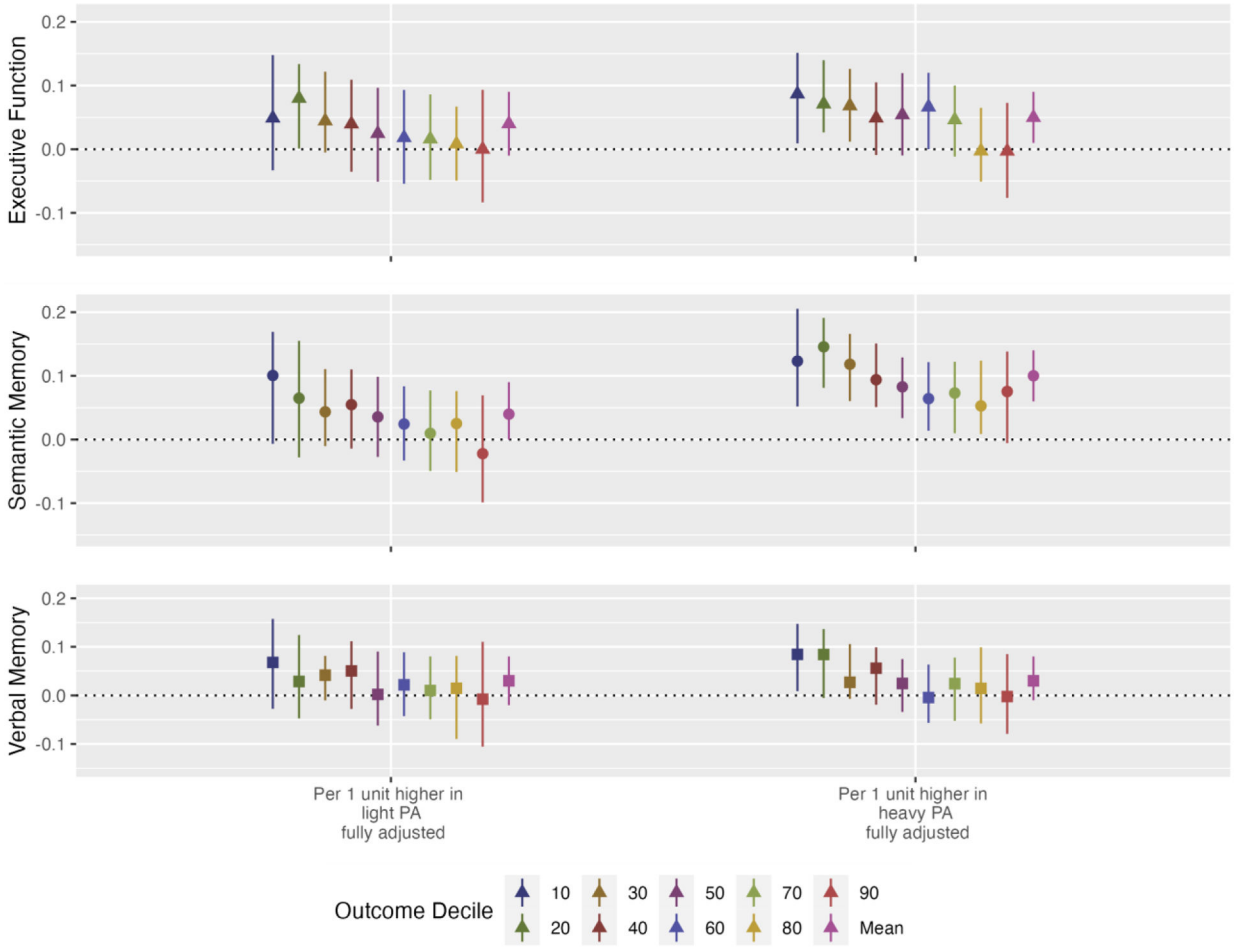


**Figure 2.**

Quantile Regression Model Results for Three Cognitive Domains. Points indicate the effect of the exposure on the outcome for the $10^{th}$-$90^{th}$ percentiles for each level of physical activity with fully adjusted covariates.

**Table 1.**

Characteristics of the analytic sample by race and ethnicity in the Kaiser Healthy Aging and Diverse Life Experiences Study (N = 1,600).

| | All participants | Asian | Latinx | Black | White |
|---|---|---|---|---|---|
| **Total N** | 1600 | 394 | 313 | 413 | 480 |
| **Age in years, mean (SD)** | 75.9 (6.7) | 75.6 (6.6) | 75.8 (6.5) | 75.1 (6.4) | 76.7 (7.2) |
| **Gender, n (%)** | | | | | |
| Male | 657 (41%) | 183 (46%) | 137 (44%) | 135 (33%) | 202 (42%) |
| Female | 943 (59%) | 211 (53%) | 176 (56%) | 278 (74%) | 278 (58%) |
| **Education in years, mean (SD)** | 14.7 (3.1) | 15.6 (2.5) | 13.4 (3.8) | 14.2 (2.7) | 15.2 (2.9) |
| **Light physical activity, mean (SD)** | 3.2 (0.8) | 3.2 (0.8) | 3.2 (0.8) | 3.1 (0.9) | 3.3 (0.8) |
| **Heavy physical activity, mean (SD)** | 1.6 (1.0) | 1.6 (1.0) | 1.5 (1.0) | 1.6 (1.0) | 1.6 (1.0) |
| **Employment status, n (%)** | | | | | |
| Working | 358 (22%) | 76 (19%) | 66 (21%) | 116 (28%) | 100 (21%) |
| Not working | 1242 (78%) | 318 (81%) | 247 (79%) | 297 (72%) | 380 (89%) |
| **Global sleep quality, mean (SD)** | 4.7 (3.1) | 4.5 (3.1) | 4.4 (3.1) | 5.4 (3.4) | 4.4 (3.0) |
| **Income (log), mean (SD)** | 11.1 (0.7) | 11.3 (0.6) | 11.0 (0.7) | 11.0 (0.6) | 11.2 (0.6) |
| **Executive Function** | 0.00 (1.0) | −0.19 (0.85) | −0.22 (0.87) | −0.26 (0.87) | 0.52 (1.10) |
| **Semantic Memory** | 0.00 (1.0) | −0.27 (1.00) | 0.08 (0.89) | −0.51 (0.87) | 0.61 (0.83) |
| **Verbal Memory** | 0.00 (1.0) | 0.15 (1.00) | −0.16 (0.97) | −0.13 (0.92) | 0.09 (1.06) |

*Note:* SD: Standard Deviation

**Table 2.**

Linear regression coefficients for light physical activity (PA) and heavy physical activity predicting z-standardized average executive function, semantic memory, and verbal episodic memory cognitive domains.

| | Demographic-adjusted models β (95% CI) | Fully-adjusted models β (95% CI) |
|---|---|---|
| **Executive Function** | | |
| Light PA | 0.05 (0.00, 0.10) | 0.04 (−0.01, 0.09) |
| Heavy PA | 0.06 (0.02 0.10) | 0.05 (0.01 0.09) |
| **Semantic Memory** | | |
| Light PA | 0.05 (0.00, 0.10) | 0.04 (−0.00, 0.09) |
| Heavy PA | 0.11 (0.07, 0.15) | 0.10 (0.06, 0.14) |
| **Verbal Episodic Memory** | | |
| Light PA | 0.04 (−0.02, 0.09) | 0.03 (−0.02, 0.08) |
| Heavy PA | 0.04 (−0.01, 0.08) | 0.03 (−0.01, 0.08) |

*Note:* Demographic-adjusted models were adjusted for age, sex, years of education, and race/ethnicity. Fully adjusted models adjusted for demographic variables, employment status, global sleep quality, and income.

**Table 3.**

Linear regression models for light and heavy physical activity (PA) predicting z-standardized average executive function, semantic memory, and verbal episodic memory cognitive domains, stratified by race/ethnicity.

| | ASIAN | | LATINX | | BLACK | | WHITE | |
|---|---|---|---|---|---|---|---|---|
| | **Demographic-adjusted models β (95% CI)** | **Fully-adjusted models β (95% CI)** | **Demographic-adjusted models β (95% CI)** | **Fully-adjusted models β (95% CI)** | **Demographic-adjusted models β (95% CI)** | **Fully-adjusted models β (95% CI)** | **Demographic-adjusted models β (95% CI)** | **Fully-adjusted models β (95% CI)** |
| **Executive Function** | | | | | | | | |
| Light PA | 0.06 (−0.04, 0.15) | 0.06 (−0.04, 0.15) | 0.02 (−0.08, 0.12) | 0.02 (−0.08, 0.12) | 0.03 (−0.05, 0.11) | 0.03 (−0.06, 0.11) | 0.10 (0.01, 0.21) | 0.08 (−0.02, 0.20) |
| Heavy PA | 0.09 (0.01, 0.18) | 0.08 (0.00, 0.16) | 0.13 (0.05, 0.22) | 0.13 (0.05, 0.21) | −0.03 (−0.11, 0.05) | −0.03 (−0.11, 0.05) | 0.06 (−0.03, 0.14) | 0.05 (−0.04, 0.14) |
| **Semantic Memory** | | | | | | | | |
| Light PA | 0.03 (−0.09, 0.15) | 0.02 (−0.10, 0.14) | 0.09 (−0.01, 0.18) | 0.08 (−0.01, 0.18) | 0.06 (−0.02, 0.14) | 0.05 (−0.03, 0.14) | 0.04 (−0.04, 0.12) | 0.10 (−0.06, 0.10) |
| Heavy PA | 0.16 (0.06, 0.26) | 0.15 (0.05, 0.25) | 0.16 (0.08, 0.24) | 0.15 (0.07, 0.23) | 0.04 (−0.04, 0.12) | 0.04 (−0.04, 0.12) | 0.07 (0.01, 0.14) | 0.07 (0.01, 0.13) |
| **Verbal Episodic Memory** | | | | | | | | |
| Light PA | 0.06 (−0.06, 0.17) | 0.06 (−0.05, 0.18) | −0.03 (−0.15, 0.08) | −0.04 (−0.15, 0.08) | 0.01 (−0.08, 0.10) | −0.01 (−0.10, 0.08) | 0.11 (0.01, 0.21) | 0.10 (−0.01, 0.20) |
| Heavy PA | −0.02 (−0.11, 0.08) | −0.01 (−0.11, 0.09) | 0.08 (−0.02, 0.19) | 0.8 (−0.02, 0.18) | 0.01 (−0.08, 0.09) | 0.00 (−0.09, 0.09) | 0.08 (0.00, 0.16) | 0.07 (−0.01, 0.16) |

*Note:* Demographic-adjusted models adjusted for age, sex, years of education, and race/ethnicity. Fully-adjusted models adjusted for demographic variables, employment status, global sleep quality, and income.