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Effect of early adult patterns of physical activity and television viewing on midlife cognitive function

Tina D. Hoang, MSPH, **Jared Reis, PhD**, **Na Zhu, MD, MPH**, **David R. Jacobs Jr, PhD**, **Lenore J. Launer, PhD**, **Rachel A. Whitmer, PhD**, **Stephen Sidney, MD**, and **Kristine Yaffe, MD**
Northern California Institute for Research and Education (TDH), San Francisco CA; Division of Cardiovascular Sciences (JR), National Heart, Lung, and Blood Institute, Bethesda, MD; Divisions of Epidemiology (NZ, DRJ), School of Public Health, University of Minnesota, Minneapolis, MN; Laboratory of Epidemiology, Demography, and Biometry (LJL), National Institute on Aging, Bethesda, MD; Division of Research (RAW, SS), Kaiser Permanente of Northern California, Oakland, CA; Departments of Psychiatry, Neurology, Epidemiology and Biostatistics, University of California, San Francisco, CA and San Francisco VA Medical Center (KY), San Francisco, CA

Abstract

Importance—Sedentary behaviors and physical inactivity are not only increasing worldwide but also are critical risk factors for adverse health outcomes. Yet few studies have examined the effects of sedentary behavior on cognition or the long-term role of either behavior in early-to-middle adulthood.

Objective—To investigate the association between 25-year patterns of television viewing and physical activity and mid-life cognition.

Design, Setting, and Participants—Prospective study of 3,247 adults (black and white race, aged 18-30 years) enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) Study (March 25, 1985 to August 31, 2011).

Main Outcome and Measures—We assessed television viewing and physical activity at repeated visits (≥3 assessments) over 25 years using a validated questionnaire. A 25-year pattern of high television viewing was defined as watching TV above the upper baseline quartile (>3 hours/day) for more than two-thirds of the visits, and a 25-year pattern of low physical activity was defined as activity levels below the lower, sex-specific baseline quartile for more than two-

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Corresponding author: Tina Hoang, 4150 Clement St, VAMC 116-H, San Francisco, CA 94121, Phone: (415) 221-4810 x3792, Fax: (415) 379-5624, tina.hoang@va.gov. Alternate corresponding author: Kristine Yaffe, MD, kristine.yaffe@ucsf.edu.

Author Contributions
Dr. Yaffe had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Hoang, Yaffe
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Drafting of the manuscript: Hoang, Yaffe
Critical revision of the manuscript for important intellectual content: Hoang, Reis, Zhu, Jacobs, Launer, Whitmer, Sidney, Yaffe
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Obtaining funding: Sidney, Yaffe
Study supervision: Yaffe

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thirds of the visits. We evaluated cognitive function at Year 25 using the Digit Symbol Substitution Test (DSST), Stroop Test, and Rey Auditory Verbal Learning Test.

Results—Compared with participants with low television viewing, those with high television viewing during 25 years (323 of 3247 [10.9%]) were more likely to have poor cognitive performance (<1 SD below the race-specific mean) on the DSST and Stroop test, with findings reported as adjusted odds ratio (95% CI): DSST, 1.64 (1.21-2.23); Stroop, 1.56 (1.13-2.14) but not the Rey Auditory Verbal Learning Test adjusted for age, race, sex, educational level, smoking, alcohol, body mass index, and hypertension. Low physical activity during 25 years in 528 of 3247 participants (16.3%) was significantly associated with poor performance on the DSST, (1.47 1.14-1.90). Compared with participants with low television viewing and high physical activity, the odds of poor performance were almost 2 times higher for adults with both high television viewing and low physical activity in 107 of 3247 (3%) (DSST, 1.95 (1.19-3.22) and Stroop test, 2.20 (1.36-3.56)).

Conclusions and Relevance—High television viewing and low physical activity in early adulthood were associated with worse midlife executive function and processing speed. This is one of the first studies to demonstrate that these risk behaviors may be critical targets for prevention of cognitive aging even before middle age.

INTRODUCTION

Increasing observational evidence and results from randomized clinical trials provide support for the beneficial effects of physical activity on cognitive function.[1-3] However, global surveillance data suggest that overall levels of physical activity are declining,[4] and the percentage of adolescents meeting recommended guidelines for physical activity is low with even more failing to maintain these levels in adulthood.[5,6] Over the life course, levels of physical activity tend to peak in childhood with large declines occurring during early adulthood in conjunction with major life transitions such as entrance into the workforce and parenthood.[7-9] Although early adulthood is a critical period for establishing life-long physical activity habits,[10] few studies have investigated the association between physical activity in early adulthood and cognitive function later in life.[11-13]

Coupled with the increasing prevalence of sedentary or screen-based activities, such as watching television, these trends are of particular concern for upcoming generations of young people.[14,15] In middle-aged and older adults, low levels of physical activity and high sedentary behavior are associated with cognitive impairment and dementia,[16-18] but the long-term risks associated with these lifestyle behaviors require further investigation. In particular, the longitudinal association of television viewing with cognitive function is not well defined. Understanding the effects of these modifiable risk factors across the life course could be crucial for the development of effective population-based strategies for optimal cognitive aging.

The objective of this study was to examine the association between long-term patterns of physical activity and television viewing time during young adulthood with cognitive function in mid-life. We hypothesized that patterns of low physical activity and high television viewing time will be associated with worse cognitive impairment at mid-life.

METHODS

Study population

Young adults (aged 18-30 years) were recruited from population-based samples of 4 US cities (Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California) and enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) study. Between 1985 and 1986, the baseline examination (Year 0) was completed for 5,115 participants, Follow-up examinations were completed every two to five years over 25 years, 1987-1988 (Year 2), 1990-1991 (Year 5), 1992-1993 (Year 7), 1995-1996 (Year 10), 2000-2001 (Year 15), 2005-2006 (Year 20), and 2010-2011 (Year 25). At each examination, participants provided written informed consent, and study protocols were reviewed by institutional review boards at each study site, as well as the CARDIA coordinating center at the University of Alabama, Birmingham, and at the University of California, San Francisco. Further details of study recruitment and design are available elsewhere.[19,20]

Of the 5,115 participants, 3,499 completed the Year 25 visit. To assess long-term patterns of physical activity and television viewing time, we included those participants with at least three assessments of physical activity, three assessments of television viewing time, and a cognitive assessment at Year 25. The final analytic cohort included 3,247 participants. Participants not included in the analytic cohort had lower educational level, were more likely to be Black, male, smokers, and to have diabetes mellitus ($p<0.05$).

Physical Activity

At baseline and each follow-up visit, the Physical Activity History Questionnaire, which provides a reliable measure of habitual physical activity,[21,22] was used to assess participation in 13 types of vigorous-intensity (running or jogging; racquet sports; bicycling; swimming; exercise or dance class; job lifting, carrying, or digging; shoveling or lifting during leisure; and strenuous sports) and moderate-intensity (nonstrenuous sports, walking and hiking, golfing and bowling, home exercises or calisthenics, and home maintenance or gardening) physical activities in the past 12 months. Based on the duration of participation (2 to 5 hours/week) and intensity level (3 to 8 METs) of each activity, a total activity score was calculated as measured in exercise units. Further details on the questionnaire and scoring have been published.[22-24] Previous CARDIA analysis indicated that a cutpoint of 250 exercise units has 97.1% specificity and 70.4% sensitivity for meeting recommended guidelines of 150 minutes of moderate-intensity activity per week.[24] A long-term pattern of low physical activity over 25 years was defined as reporting levels below the bottom, sex-specific quartile (males=280 exercise units and females=148 exercise units) of baseline physical activity levels for more than two-thirds of the visits. Participants not meeting these criteria were categorized as having long-term patterns of moderate-high physical activity. A long-term pattern of very low physical activity over 25 years was defined as reporting activity levels of less than 50 exercise units for more than two-thirds of the visits.

Television Viewing Time

At Years 5, 10, 15, 20 and 25, participants were asked the average number of hours per day spent watching television in the past 12 months. A long-term pattern of high television viewing time over 25 years was defined as reporting activity levels within the top quartile of the Year 5 (baseline) visit (>3 hours/day) for more than two-thirds of the visits. All other participants were categorized as having a low to moderate pattern of television viewing time.

Physical Activity and Television Viewing Time

Based on patterns of physical activity and television viewing time, a categorical variable was created to examine the combined effects of both behaviors. Participants were categorized into 3 groups: (1) most active (Reference), including moderate to high physical activity and low to moderate television viewing time; (2) intermediate, including moderate to high physical activity and high television viewing time or low physical activity and low to moderate television viewing time; and (3) least active, including low physical activity and high television viewing time.

Cognitive function assessment

At Year 25, trained interviewers administered a battery of three cognitive tests: the Digit Symbol Substitution Test (DSST) which assesses processing speed and executive function (higher scores indicating better cognitive function); [25] the Stroop test which assesses executive function (an interference score was calculated with lower scores indicating better function);[26,27] and the Rey Auditory Verbal Learning Test (RAVLT), which assesses verbal memory (the delayed score was used with higher scores indicating better function).[28,29] We defined low cognitive performance as a race-specific score 1 SD worse than the mean.

Covariates

We assessed baseline demographic characteristics, cigarette smoking, and alcohol use using self-reports. At baseline, height and height were measured, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Hypertension at baseline was defined as systolic blood pressure ≥140mmHg, diastolic blood pressure ≥90mmHg, or receiving anti-hypertensive medication, and diabetes mellitus at baseline was defined as fasting plasma glucose ≥126 mg/dL or use of diabetes medications. Isoelectric focusing and immunoblotting techniques were used to determine the apolipoprotein E4 phenotype from year 7 blood samples.[30,31]

Statistical analysis

Baseline characteristics were compared by patterns of physical activity and television viewing, using 2-tailed t-tests, Kruskal-Wallis, and chi-square tests as appropriate. We used logistic regression to determine the association between patterns of physical activity, television viewing, and a combination of the two during young adulthood with poor cognitive performance in middle age. Multivariable models were adjusted for age, race, sex, educational level, smoking, BMI, and hypertension. In addition, we assessed interactions with race, sex, obesity, and APOE4 phenotype, as well as between physical activity and television viewing. We also evaluated associations between patterns of activity and cognitive performance in linear models. The level of significance was set at $p<0.05$. SAS v9.4 (SAS Institute Inc., Cary, NC) was used for all analyses.

RESULTS

At baseline (Year 0), the mean age (SD) of the CARDIA participants was 25.1 (3.6) years, 1836 (56.5%) were female, 1771 (54.5%) were White, and 3015 (92.9%) had completed High School. A total of 528 (16.3%) of participants met the criteria for a long-term pattern of low physical activity and were more likely to be Black (314 [59.5%]) compared with those reporting moderate-to-high physical activity (1162 [42.7%]); ($p<0.001$). Participants with low physical activity were more likely to have hypertension (25 [4.7%]), and reported as mean (SD) had a slightly lower educational level (13.7 [2.2]; $p<0.001$), drank less alcohol (10.7 [21.8]; $p=0.001$) (Table 1).

Compared with participants with moderate-to-high long-term patterns of physical activity, those with low physical activity were more likely to have poor cognitive performance at mid-life on the DSST (Low: 21.6% vs Moderate-high: 14.5%; OR=1.62, 95% CI 1.28-2.04) and Stroop test (Low: 16.2% vs. Moderate-High: 12.3%; OR=1.37, 95% CI 1.06-1.78) but not on the RAVLT (Low: 22.1% vs. Moderate-High: 19.5%; OR=1.17, 95% CI 0.93-1.47, Table 2). After adjusting for age, race, sex, educational elevel, smoking, alcohol use, BMI and hypertension, the association between low physical activity and poor cognitive performance remained significant for the DSST (OR=1.47, 95% CI 1.14-1.90). The results of linear models were consistent with cognitive impairment models.

In a sensitivity analysis, we further adjusted for APOE and this did not significantly alter the results. In addition, there were no significant interactions with race, sex, obesity, or APOE for the association between physical activity patterns and poor cognitive performance ($p>0.05$ for all). We also investigated patterns of very low or almost no physical activity. Only 53 (1.6%) participants reported very low patterns of physical activity, and after multivariable adjustment, associations with DSST (OR=2.43, 95% CI, 1.23-4.79), Stroop (OR=2.02, 95% CI, 1.05-3.89), and RAVLT (OR=2.01, 95% CI, 1.05-3.83) were significant.

A total of 353 participants (10.9%) met the criteria for a long-term pattern of high television viewing. This high level was associated with poor cognitive performance at Year 25 on all cognitive tests (Table 3). In unadjusted models, the odds of poor cognitive performance werebetween 1.5 and 2 times higher for participants reporting high levels of television viewing over time compared to with low to moderate viewers (DSST: High: 27.4% vs Low-Moderate: 14.3%; OR=2.26, 95% CI 1.75-2.93; Stroop: High: 21.4% vs Low-Moderate: 12.0%; OR=2.01, 95% CI 1.52-2.66; RAVLT: High: 27.1% vs Low-Moderate: 19.1%; OR=1.58, 95% CI 1.23-2.04). After multivariable adjustment for age, race, sex, educational level , smoking, alcohol use, BMI and hypertension, the association was attenuated but significant for poor performance on the DSST and Stroop test (DSST: OR=1.64, 95% CI 1.21-2.23; Stroop: OR=1.56, 95% CI 1.13-2.14). However, high television viewing time was no longer associated with poor cognitive performance on the RAVLT (OR=1.14, 95% CI

0.86-1.53). Further adjustment for APOE did not significantly alter the association with DSST but the effect size with the Stroop test increased slightly (1.81 1.29-2.53). There were no consistently significant interactions with race, sex, obesity, or APOE for the association between television viewing time and cognitive performance. In models that also adjusted for long-term physical activity patterns, effect sizes for both physical activity and television viewing time were only slightly attenuated, and similar patterns were observed. The interaction between television viewing and physical activity was not significant.

When physical activity patterns and television viewing time were combined, 2473 participants (76.2%) reported Most Active patterns of moderate-high physical activity and low-moderate television viewing, 667 individuals (20.5%) reported Intermediate patterns with low physical activity and low-moderate television viewing or moderate-high physical activity and high television viewing time, and 107 participants (3.3%) reported Least Active patterns of low physical activity and high television viewing time. In adjusted models, participants with Least Active patterns of physical activity and television viewing were more likely to have poor cognitive performance on both the DSST and Stroop test (DSST: OR=1.95, 95% CI 1.19-3.22; Stroop: OR=2.20, 95% CI 1.36-3.56, Figure 1) compared with those who reported Most Active patterns. The association with hte RAVLT was elevated but not significant (OR=1.39, 95% CI 0.87-2.22). Participants reporting Intermediate patterns also had elevated odds of poor cognitive performance on DSST (DSST: OR=1.57, 95% CI 1.23-2.00).

DISCUSSION

In this biracial cohort followed for 25 years, we found that low levels of physical activity and high levels of television viewing time during young to mid adulthood were associated with worse cognitive performance in mid-life. In particular, these behaviors were associated with slower processing speed and worse executive function but not with verbal memory. Participants with the least active patterns of behavior (ie, both low physical activity and television viewing time) were the most likely to have poor cognitive function.

Previous longitudinal investigations of physical activity in midlife and late life support our findings.[13,32,33] These earlier studies indicated that low physical activity levels are associated with poor cognitive performance and cognitive decline in older adults. Results from the slightly older British 1946 birth cohort suggest that greater leisure-time physical activity in adults during their mid-30's contributes to less cognitive decline during middle age (43-53 years).[34] A few other studies have also investigated the effects of physical activity participation at earlier ages, but these relied on retrospective measures.[11,12] In one investigation, regular early life physical activity was associated with better information processing speed in men but not women,[11] and in the second study, older women who reported more physical activity during adolescence were also less likely to develop cognitive impairment based on a global test of cognition.[12] Similar results were reported in a small, retrospective study of postmenopausal women in whom long-term moderate physical activity beginning in early adulthood was associated with better cognitive function in late life.[35] In CARDIA, change in cardiorespiratory fitness in young adulthood was also associated with psychomotor speed at mid-life, [13] and a more recent prospective study examined the association between leisure time physical activity throughout life and mid-life cognitive function.[36] Although the measure of leisure time activity was not standardized and patterns of activity over time were not assessed, the study found that participation in leisure time physical activity (defined as participation in sports as a child or adolescent and regular sport or exercise as an adult) for ≥4 days each week was associated with better memory and executive function compared with no leisure time physical activity.

Studies of physical activity and cognitive function among adolescents and young adults have focused mainly on the acute benefits for cognitive function.[37] In small trials, that have been limited to short time periods, physical activity among young adults improved visuospatial memory, executive function, and processing speed.[38-40] In cross-sectional, observational studies, regular physical activity was also associated with better cognitive function in young adults,[41,4243] but the long-term effects of physical activity on cognitive function during this life stage are unclear.[37]

Physical activity during young adulthood may preserve cognitive function and contribute to cognitive reserve by increasing neurogenesis as well as synaptic plasticity, particularly in regions associated with executive function and processing speed, but physical activity may also affect other risk factors for cognitive impairment, including cardiovascular risk factors, inflammatory factors and depressive symptoms.[44,45] Observational studies in middle and late age have also reported correlations between physical activity and higher measures of total brain and gray matter volume as well as lower β-amyloid levels in the brain.[46-49] Although some studies have reported differences in the association of physical activity with Alzheimers disease risk and amyloid deposition by APOE status,[50] we did not find an interaction between physical activity patterns and APOE phenotype. It is possible that physical activity affects cognition through non-APOE associated pathways or there may be differences in this association by age.

To our knowledge, this study is also one of the first to report an adverse association between increased television viewing time in early adulthood and mid-life cognitive performance. Increasing evidence suggests that sedentary behavior, such as television viewing, is associated with cardiovascular disease, obesity, and mortality in adults,[51,52] and television viewing in young adulthood has also been associated with worse cardiometabolic risk factors in middle age.[53] In addition, television viewing in middle-aged and older adults has been identified as a risk factor for cognitive impairment,[54-56] but the content and degree of cognitive engagement may be an important aspect of this behavior to consider.[18,57]

The effects of television watching on cognitive function may involve several complex pathways. Physiologic studies suggest that sedentary behaviors like television watching adversely affect metabolic function by increasing blood pressure as well as lipid and glucose levels.[58-60] Television viewing may also be associated with different cognitive and social patterns, depression, and poor dietary patterns.[61-63] The association of physical activity and sedentary behaviors with cognitive function may also be bi-directional,[64] and reverse causation could contribute to the observed associations.[65] Even though we did not have baseline cognitive testing, given the young age of the participants at study enrollment and the fact that they remained in the study for 25 years, it is unlikely that they had clinically significant cognitive deficits.

The CARDIA study is a well-characterized large and diverse cohort with follow-up data from over twenty years and repeated measures of physical activity. This is one of the first studies to examine the longitudinal association between physical activity and sedentary behaviors and cognitive function in a younger cohort with carefully repeated measures. However, there are a few limitations to consider. Although the retention of CARDIA participants was high over the 25 years of the study, it is possible that there was some selection bias due to loss to follow up. Both physical activity and television viewing were self-reported. In addition, we were limited to examining the effects of television viewing and were unable to consider cognitively stimulating sedentary activities such as video games. Although we assessed the domains of executive function, processing speed, and verbal memory, not all cognitive domains were evaluated.

The findings in this study suggest the need for additional investigation in several areas. In particular, early adulthood may be a critical period to promote physical activity for healthy cognitive aging especially as physical activity levels during this life stage track with activity levels in later life.[10,66] More research is also needed to understand the association between screen-based sedentary behaviors and cognitive function, especially clarification of the mechanisms of this association, exploration of the full range of sedentary behaviors, and possible effects independent of physical activity. Regarding population-based health, the effect of sedentary behavior may be especially consequential because the use of screen-based technologies for work and leisure has increased in the past several decades.[4,14]

CONCLUSIONS

Our results indicate that the lifestyle behaviors in early adulthood that were evaluated in this study could have an effect on the risk of cognitive impairment and support a potential role for both physical activity and sedentary behavior as modifiable risk factors for prevention. Individuals with both low physical activity and high sedentary behavior may represent a critical target group.

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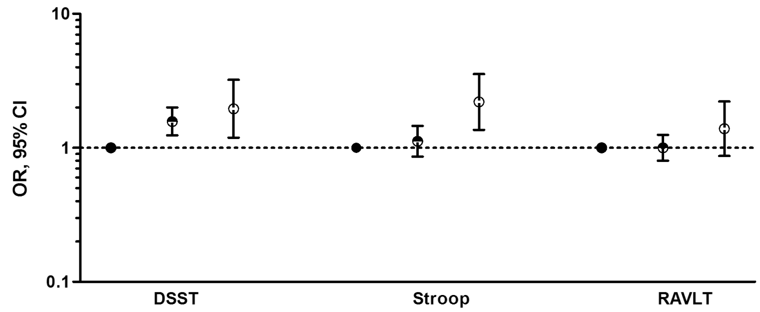

Figure 1.

Combined Pattern of Physical Activity and Television Viewing Time and Poor Cognitive Performance[a]

[a]Models adjusted for age, race, sex, education, smoking, alcohol use, BMI, and hypertension.

● Most Active (Reference): Long-term Pattern of High Physical Activity and Low Television Viewing Time

◓ Intermediate: Long-term Pattern of High Physical Activity and High Television Viewing Time or Long-term Pattern of Low Physical Activity and Low Television Viewing Time

○ Least Active: Long-term Pattern of Low Physical Activity and High Television Viewing Time

Table 1

Baseline Characteristics of CARDIA Participants by Long-Term Pattern of Physical Activity (n=3,247)

Characteristic Mean, SD or n (%)	Moderate-High (n=2,719)	Low (n=528)	p
Age (mean ± SD)	25.1 ± 3.6	25.2 ± 3.7	0.53
Female (n, %)	1557 (57.3)	279 (52.8)	0.06
Black (n, %)	1162 (42.7)	314 (59.5)	<0.001
Education (years, mean ± SD)	14.2 ± 2.2	13.7 ± 2.2	<0.001
Body Mass Index (mean ± SD)	24.4 ± 4.7	25.0 ± 5.7	0.13
Smoking (current, n, %)	688 (25.5)	150 (28.6)	0.14
Alcohol (ml/day, mean ± SD)	11.5 ± 18.9	10.7 ± 21.8	0.001
Hypertension (n, %)	52 (1.9)	25 (4.7)	<0.001
Diabetes (n, %)	9 (0.3)	4 (0.7)	0.25
APO e4[a] n(%)	705 (29.0)	154 (33.1)	0.08

[a]350 missing

Table 2

Long-Term Patterns of Physical Activity and Poor Cognitive Performance at Mid-Life

Physical Activity Pattern by Cognitive Evaluation	Poor Cognitive Performance, n(%)	*Unadjusted OR (95%CI)*	*Adjusted* [a] *OR (95%CI)*
Digit Symbol Substitution Test			
Low	113 (21.6)	1.62 (1.28-2.04)	1.47 (1.14-1.90)
Moderate-High	394 (14.5)	1.00 (Reference)	1.00 (Reference)
Stroop			
Low	84 (16.2)	1.37 (1.06-1.78)	1.20 (0.91-1.58)
Moderate-High	332 (12.3)	1.00 (Reference)	1.00 (Reference)
Rey Auditory Verbal Learning Test – Delayed			
Low	116 (22.1)	1.17 (0.93-1.47)	1.05 (0.83-1.33)
Moderate-High	527 (19.5)	1.00 (Reference)	1.00 (Reference)

[a] Adjusted for age, race, sex, education, smoking, BMI, alcohol use, and hypertension

Table 3

Long-Term Pattern of Television Viewing Time and Poor Cognitive Performance at Mid-Life

Television Viewing Pattern by Cognitive Evaluation	**Poor Cognitive Performance, n(%)**	***Unadjusted OR (95%CI)***	**Adjusted[a] OR (95%CI)**
Digit Symbol Substitution Test			
Low-Moderate	412 (14.3)	1.00 (Reference)	1.00 (Reference)
High	95 (27.4)	2.26 (1.75-2.93)	1.64 (1.21-2.23)
Stroop			
Low-Moderate	342 (12.0)	1.00 (Reference)	1.00 (Reference)
High	74 (21.4)	2.01 (1.52-2.66)	1.56 (1.13-2.14)
Rey Auditory Verbal Learning Test – Delayed			
Low-Moderate	548 (19.1)	1.00 (Reference)	1.00 (Reference)
High	95 (27.1)	1.58 (1.23-2.04)	1.14 (0.86-1.53)

[a] Adjusted for age, race, sex, education, smoking, alcohol use, BMI, and hypertension