Georgia State University

ScholarWorks @ Georgia State University

Psychology Theses

Department of Psychology

5-13-2020

Moderating Effect of Cardiovascular Risk Factors on the Relationships of Physical Activity with Mood and Cognitive Function in a Diverse Sample

Alexia Minto

Follow this and additional works at: https://scholarworks.gsu.edu/psych_theses

Recommended Citation

Minto, Alexia, "Moderating Effect of Cardiovascular Risk Factors on the Relationships of Physical Activity with Mood and Cognitive Function in a Diverse Sample." Thesis, Georgia State University, 2020.
doi: https://doi.org/10.57709/22411974

This Thesis is brought to you for free and open access by the Department of Psychology at ScholarWorks @ Georgia State University. It has been accepted for inclusion in Psychology Theses by an authorized administrator of ScholarWorks @ Georgia State University. For more information, please contact scholarworks@gsu.edu.

Moderating Effect of Cardiovascular Risk Factors on the Relationships of Physical Activity with Mood and Cognitive Function in a Diverse Sample

by

Lex R. Minto

Under the Direction of Vonetta M. Dotson, Ph.D.

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Arts

in the College of Arts and Sciences

Georgia State University

2024

ABSTRACT

This study investigated the effects of cardiovascular disease (CVD) risk factors on the relationships among physical activity (PA), mood and cognition in a diverse sample of middle-aged to older adults. Scores on neuropsychological tests and self-report questionnaires from 62 adults were analyzed. Multiple regression analyses were used to examine the main and interactive effects of PA and CVD risk burden on cognition and mood when controlling for age and race. CVD risk was associated with greater benefits of PA, while higher CVD risk was associated with either no benefit or lower cognitive scores. Results indicate that middle-aged to older adults with low CVD risk are more likely to benefit from PA, while higher CVD risk might limit the effectiveness of interventions for mood and cognition. Future studies are needed to further clarify individual differences that impact the relationships among PA, CVD risk, and cognitive outcomes.

INDEX WORDS: Depression, Older adults, Exercise, Cognition, Heart disease

Copyright by
Alexia Renée Minto
2021

Moderating Effect of Cardiovascular Risk Factors on the Relationships of Physical Activity with Mood and Cognitive Function in a Diverse Sample

by

Lex R. Minto

Committee Chair: Vonetta M. Dotson

Committee: Sarah J. Barber

Rebecca Ellis

Sierra Carter

Electronic Version Approved:

Office of Graduate Studies

College of Arts and Sciences

Georgia State University

May 2024

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Depression in Late Life

Depression is one of the leading mental disorders in the United States (World Health Organization, 2017). Although older adults have a lower prevalence of major depression compared to young adults, they are two to three times more likely to meet criteria for subthreshold depression (minor depression or dysthymic disorder) than they are to meet criteria for major depressive disorder (Alexopoulos, 2005). Furthermore, while middle-aged and older adults tend to have lower prevalence, they are more likely to have a poorer course of depression (Mojtabai & Olfson, 2004). Studies consistently show that there is a relationship between depressive symptoms and worse quality of life in older adults (Sivertsen et al., 2015). Indeed, older adults tend to have higher levels of disability than younger adults, and depression in the context of medical illness often leads to higher levels of morbidity and disability in this population (Fiske et al., 2009).

Research has shown that race can play a predictive role in depression prevalence, diagnosis, and prognosis (Hooker et al., 2019; Murphy et al., 2013). There is inconsistency among studies regarding the prevalence rates of late life-depression (LLD) in Black compared to White adults, with some studies finding older White adults to have higher depression prevalence rates while others found no significant differences in rates. One systematic review demonstrated that factors including sex, age, and comorbid medical conditions predicted higher prevalence of depression in Black adults, and prognosis for untreated depression in Black older adults was often worse than in untreated White older adults (Pickett et al., 2013). Similarly, Akincigil and colleagues

(2012) found that, even when diagnosed, Black older adults were less likely to be treated for their depression.

1.2 Depression and Cognition

Depression in older adults is often associated with cognitive impairment. Older adults with LLD are more likely to display cognitive changes compared to their younger counterparts (Fiske et al., 2009). Studies have shown that above the effects of age, LLD is associated with impairment in attention, verbal learning, memory, executive function and motor speed after controlling for depression severity (Brailean et al., 2016; Lockwood et al., 2000; Morimoto et al., 2015; Thomas et al., 2009). Sexton and colleagues (2012) examined the relationship between neuropsychological impairment and LLD and found that individuals with LLD performed worse across all cognitive domains. Executive function, as measured by digit span, letter fluency and Trail Making Test Part B (TMT-B), was the most frequently impaired domain (Sexton et al., 2012). Similarly, studies have shown that subthreshold depressive symptoms in older adults are associated with deficits in memory, executive functioning and processing speed, including longitudinal examinations of digit span, letter fluency and TMT-B (Brevik et al., 2013; Dotson et al., 2008).

Research also suggests that LLD is associated with dementia (Diniz et al., 2013). Although some studies failed to find evidence that links a history of depression to dementia (Ganguli et al., 2006), the results of recent meta-analyses suggest LLD does indeed increase dementia risk (Cherbuin et al., 2015; Diniz et al., 2013). Whether depression is a true risk factor for dementia instead of a prodromal syndrome is still an unanswered question; however, these hypotheses are not mutually exclusive and, overall, research supports a significant association between depressive symptoms and dementia (Butters et al., 2008; Jorm, 2001). Therefore, it is important that researchers and clinicians gain a better understanding of risk factors and potential treatments for depression and cognitive impairment, even at subclinical levels, in order to develop more effective and valid interventions for these individuals and potentially minimize the risk for dementia.

Most of the research on depression and cognitive impairment is done in samples that are predominantly or even exclusively White. However, in Black older adults, the connection between depressive symptoms and cognitive decline or impairment has also been documented in a few studies (Hamilton et al., 2014; Turner et al., 2015). For example, Turner and colleagues conducted annual evaluations on nondemented Black older adults. They found that depressive symptoms, measured by the Geriatric Depression Scale (GDS), was related to decline in semantic memory, measured by the Boston Naming, Verbal Fluency, and Wide Range Achievement Test, and working memory, measured by Digit Span forward and backward, and Digit Ordering (Turner et al., 2015).

1.3 Depression and Cardiovascular Risk Factors

In middle-aged and older adults, both clinical and subthreshold depression are associated with negative health outcomes such as cardiovascular disease (CVD) as well as risk factors for CVD such as hypertension, high cholesterol, diabetes, and obesity (Akbaraly et al., 2009; Zhang et al., 2018). Notably, this literature is primarily based on White samples, similar to the literature on depression and cognitive impairment. The “vascular depression” hypothesis suggests that CVD can predispose individuals to depressive episodes later in life, precipitate a depressive episode, or exacerbate depressive symptoms (Alexopoulos et al., 1997). Studies suggest that the link between vascular events and depressed mood may be related to subcortical and cortical ischemic lesions in brain regions involved in mood regulation, in addition to neurotransmitter changes following these lesions (Alexopoulos et al., 1997).

Since the generation of the vascular depression hypothesis, there has been extensive literature supporting this theory. Indeed, a review of the relationship between LLD, vascular dementia, and Alzheimer’s disease concluded that LLD had a stronger association with vascular dementia compared to Alzheimer’s disease, suggesting that vascular changes may play a role in the etiology of LLD (Diniz et al., 2013). Similarly, in a sample of patients in a primary care setting, individuals with significant depressive symptoms had a higher frequency of vascular disease than patients without depression (Alexopoulos et al., 1999). Mast and colleagues investigated the association between depression and CVD risk factors and observed a positive relationship between vascular burden and frequency of depression (Mast et al., 2004). However, research supports that CVD and depression may have a bidirectional relationship, such that individuals with CVD are likely to develop depression and depressed individuals are at risk for developing CVD (Aizenstein et al., 2016; Alexopoulos et al., 1997; Thomas et al., 2004), perhaps due to increased cortisol levels and increased likelihood of unhealthy lifestyle choices in depressed adults (Thomas et al., 2004).

The comorbidity of vascular disease and depression in older adults is associated with negative sequelae. One study used neuropsychological performance and white matter hyperintensities (WMH)—a neuroimaging marker reflective of vascular damage—to predict outcomes in LLD (Sheline et al., 2010). Investigators found that both higher baseline neuropsychological function and lower WMH ratings were predictive of more improvement in depressive symptom scores over a twelve-week medication intervention (Sheline et al., 2010). Similarly, other studies show that WMH disease is associated with poorer depression course (Taylor et al., 2013). Moreover, studies have shown executive dysfunction in individuals with vascular depression, and it has been suggested that worse executive dysfunction is predictive of poor antidepressant treatment response (Sneed & Culang-Reinlieb, 2011).

The relationship between LLD and CVD could be moderated by a variety of demographic, social and economic factors (Hall & Reynolds-III, 2014; Rajan et al., 2020). Findings from a recent study investigating the relationship between CVD and depression in countries with different economic levels suggest that there is a significant relationship between depression and CVD across many economic levels, but risks of mortality and CVD were more than twice as high in urban compared to rural areas (Rajan et al., 2020). Furthermore, other studies show that depressive symptoms are more strongly associated with CVD risk factors in Black compared to White adults (Boyle et al., 2007; Lewis et al., 2009), and a longitudinal study found that elevated depressive symptoms increased the risk of mortality from CVD in Black, but not White, participants (Lewis et al., 2011). Black adults have been shown to have higher incidence of risk factors related to CVD (Howard et al., 2017). This underscores the need for additional studies that include Black older adults with LLD so we can increase our understanding of factors that contribute to health disparities and find valid interventions for this population.

1.4 Cognition and Cardiovascular Risk Factors

There is extensive literature on the relationship between cognitive impairment and vascular risk factors such as hypertension, hyperlipidemia, and obesity. Jefferson and colleagues (2015) demonstrated that higher stroke risk was related to worse global cognition, working memory, processing speed, sequencing, verbal fluency, and episodic memory. They also found that higher stroke risk was predictive of cognitive decline over time (Jefferson et al., 2015). This is significant because subclinical cognitive changes, especially in older adults, may predict later cognitive impairment. The relationship between increased CVD risk factors such as hypertension and diabetes mellitus and risk for cognitive decline has also been observed in middle-aged adults (Knopman et al., 2001; Pavlik et al., 2005). Furthermore, many studies have been published linking vascular risk factors such as stroke history, hypertension, diabetes mellitus, and cigarette smoking to increased risk for dementias such as Alzheimer’s disease and vascular dementia (Jefferson et al., 2015; Kalaria et al., 2016; Lo Coco et al., 2016).

There is less literature about the association between cognition and CVD risk factors in Black middle-aged to older adults. In such a study, Williams and colleagues (2018) found mixed results. For example, they found that history of smoking and high blood pressure was associated with worse attention, executive function, and memory, but higher body mass index was associated with better attention. As mentioned earlier, the Black community is more likely to be burdened by CVD, so it is also critical to identify potential disparities in cognitive outcomes of Black adults with or at risk for CVD.

The cumulative nature of CVD risk is another important consideration. Much of the literature examining the relationship between cognitive aging and CVD risk factors typically focuses on one single risk factor at a time, instead of considering the potential burden of multiple risk factors for CVD (Jefferson et al., 2015). One study investigated the relationship between physical activity and cognitive decline in middle-aged to older women who had at least three vascular risk factors and found that regular physical activity was associated with better cognitive function (Vercambre et al., 2011). This study highlights the potential interrelationship between vascular risk factors, cognitive functioning, and physical activity.

1.5 Relationship with Physical Activity

There is a large body of evidence that supports physical activity interventions as effective in either reducing depressive symptoms or protecting against the onset of a depressive episode (Kvam et al., 2016; Mammen & Faulkner, 2013). In relationship to subthreshold symptoms, a meta-meta-analysis demonstrated that physical activity significantly reduced depressive symptoms even in non-clinical populations (Rebar et al., 2015). This is significant since, as previously mentioned, many older adults do not meet criteria for a major depressive disorder but do have subthreshold symptoms of depression. The significant relationship between physical activity and depressive symptoms in the meta-analysis implies that physical activity, regardless of clinical diagnosis of depression, may ameliorate mood. In regards to clinical depression, a review by Naismith and colleagues found that exercise treatments for LLD have been well evaluated and frequently lead to improvements in mood as well as reduced rates of relapse after the intervention (Naismith et al., 2012). However, they note that there is still a lack of studies investigating the relationship between physical activity and LLD in adults with coexisting cerebrovascular disease (Naismith et al., 2012). This is a significant gap considering the relationship between vascular changes and LLD.

In addition to mood benefits, there is also considerable evidence linking physical activity to cognitive health. A meta-analysis by Colcombe and Kramer suggests that aerobic training can increase cognitive performance in sedentary older adults and, specifically, executive function benefited the most (Colcombe & Kramer, 2003). Even in middle-aged adults, studies have shown low levels of physical activity are associated with poor cognitive performance (Singh-Manoux et al., 2005). There is also evidence that even early-life physical activity is positively associated with late-life cognitive function, as older women who were physically active at any age, particularly as teenagers, had better cognitive performance in late life than women who were inactive (Middleton et al., 2010). Yet, few studies examine the effect of physical activity on cognition in LLD. One study found that patients with LLD who engaged in progressive exercise as an adjunct to antidepressant treatment with sertraline (i.e., Zoloft) displayed greater improvements of global cognitive scores and visuospatial/executive functions compared to the non-progressive exercise group (Neviani, Belvederi Murri, Mussi, Triolo, Toni, Simoncini, Tripi, Menchetti, Ferrari, Ceresini, et al., 2017). Another study in older adults found that 150 minutes per week of moderate-to-vigorous physical activity, but not less, moderated the negative relationship between depression and cognition (Hu et al., 2019). Specifically, higher depressive symptoms were associated with worse verbal fluency in women and with slower processing speed in both men and women, but these links were attenuated or even eliminated in people who were more physically active.

Multiple neurobiological mechanisms are thought to underlie the cognitive and mood benefits of physical activity, including exercise-induced increase in brain-derived neurotrophic factor (BDNF), a protein that promotes the health and survival of neurons (Erickson et al., 2012; Szuhany et al., 2015). There is evidence that decreased BDNF expression in limbic structures, such as the hippocampus, is associated with depressed mood (Duman & Monteggia, 2006). The hippocampus has long been implicated in spatial and episodic memory (Burgess et al., 2002). Decreased BDNF expression may also contribute to hippocampal atrophy (Erickson et al., 2012), which could implicate it as a mediator in cognitive deficits in LLD. Thus, physical activity appears to directly increase BDNF, which is deficient in depression and in cognitive impairment.

Exercise also improves connectivity between brain regions implicated in mood disorders and cognitive impairment. For example, depressive symptoms are associated with reduced white matter integrity in areas such as the corpus callosum and prefrontal cortex, and within tracts that connect prefrontal regions to subcortical, temporal, parietal, and occipital regions (Gujral et al., 2017). Studies suggest that older adults with greater cardiorespiratory fitness have greater connectivity in the default mode network, a network often reduced in depression and in older adults with mild cognitive impairment (MCI) and dementia (Erickson et al., 2013). This further suggests that exercise directly targets brain abnormalities seen in depression and cognitive impairment (Hayes et al., 2014).

Physical activity may also benefit mood and cognition through improving vascular health. Several studies have shown that exercise benefits mood and cognitive functioning in populations with CVD (Frith & Loprinzi, 2017; Kruk & Nowicki, 2016;

Smith et al., 2007; Vercambre et al., 2011; Yohannes et al., 2010) and improves vascular health in people with risk factors for CVD such as hypertension, hyperlipidemia, obesity, and metabolic syndrome (Church, 2011; Dimeo et al., 2012; Kelly, 2010). Even in patients with mild-to-moderate chronic heart failure, cardiac rehabilitation has been shown to increase exercise capacity and reduce subsequent hospital admissions due to chronic heart failure (Davies et al., 2010). This suggests that physical activity is a potential alternative intervention or adjunctive intervention for various vascular conditions. Since physical activity has been shown to improve vascular health in addition to improving mood and cognitive functioning, greater physical activity may provide a triple benefit to individuals with or at risk for CVD. Additionally, since individuals with vascular disease are at higher risk for lower mood and cognitive impairment, physical activity may specifically benefit these individuals by improving mechanisms that relate CVD risk to worse health outcomes.

1.6 Present Study

In summary, many studies have demonstrated that physical activity is associated with reduced mood symptoms and better cognitive functioning. Vascular changes are an underlying etiology of both cognitive and mood deficits. Given the benefits of physical activity for vascular health and the potential of a vascular basis for cognitive and mood changes in late life, middle-aged to older adults who are at increased risk for vascular disease may experience more of the antidepressant and cognitive enhancing effect of physical activity. However, there is still a lack of studies investigating the interrelationships between these variables. There is especially a dearth of literature investigating the relationship between these factors in diverse samples, which is significant considering that Black older adults have a higher burden of risk factors for CVD (Berry et al., 2012).

To address these gaps in the literature, the current study investigated the potential moderating effects of CVD risk on the relationships of physical activity with cognitive functioning and mood in a diverse sample.

1.7 Aims of the Proposed Study

1.7.1 Specific Aim 1

The first major goal of the present study was to assess whether self-reported physical activity is associated with mood symptoms and cognitive functioning in a diverse middle-aged to older sample. *Consistent with previous findings in primarily White samples, we hypothesized that higher amounts of self-reported physical activity would be associated with better mood (**Hypothesis 1a**) and higher scores on measures of attention and working memory (**Hypothesis 1b**)*.

1.7.2 Specific Aim 2

The second aim was to assess whether CVD risk burden moderates the relationships between physical activity and health outcomes (mood and cognitive functioning) in this sample. Based on the benefits of physical activity for vascular health and the potential of a vascular basis for cognitive and mood changes, *we hypothesized that the relationships between physical activity and mood symptoms (**Hypothesis 2a**) and cognitive test scores (**Hypothesis 2b**) would be stronger in participants with higher CVD risk burden than in those with lower CVD risk burden.*

2 METHODS

Secondary data analysis was performed on data from a multidisciplinary study that involved the departments of Psychology, Social Work, Kinesiology, and Human Ecology at Louisiana State University (Gardner et al., 2006; Moore et al., 2008).

2.1 Participants

Participants were aged 45 and older and were recruited from either a Baton Rouge community center or a housing facility for seniors with low or fixed incomes for an intervention study that sought to promote healthy aging in diverse older adults. Participants were eligible if they consented to participate in a physical activity and nutrition intervention, and if they were free from neurological impairment and without contraindication for exercise. All participants provided written consent to participate in the study consistent with the guidelines of Louisiana State University's Institutional Review Board. Data from 94 participants were collected.

After removing individuals with missing data points, data from 62 participants were available. A sensitivity power analysis in G*Power software (Faul et al., 2007) suggested that a sample size of 62 would provide 80% power to detect medium-sized effects (f^2 = .16 with α set to .05 and two predictors) (Cohen). Participant characteristics are summarized in Table 1. The average age of the included participants is 65.9 years. The sample is 78.1% female and 68.8% Black. About 74% of the participants completed the equivalence of high school or greater.

2.2 Measures

2.2.1 Physical Activity

In the parent study, physical activity was assessed at baseline using the CHAMPS Physical Activity Questionnaire for Older Adults (Stewart et al., 2001). The CHAMPS is a self-report measure that assesses the weekly frequency and duration of lifestyle physical activities with an intraclass correlation coefficient of .66 for all activities and .67 for moderate activities and greater (Stewart et al., 2001). Various scores can be calculated from this measure, including the estimated caloric expenditure per week, weekly frequency of total physical activity, and weekly frequency of activities that are moderate intensity or greater (Stewart et al., 2001). Primary analyses for the current study used the CHAMPS total activities per week scores (total caloric expenditure per week). Based on studies that found that moderate or greater intensity physical activity had greater effects of mood and cognitive function in middle-aged and older adults (Brown et al., 2005; Hu et al., 2019), follow-up analyses used the moderate or greater intensity activities per week score, to determine if effects would differ for more intense physical activity.

Table 2.1

Sample characteristics

	Total Sample N = 62	Low-Income Housing N = 28	Community Center N = 34	Black Sample N = 44
Age (years)	65.9 ± 10.0	65.9 ± 9.5	65.9 ± 10.5	65.8 ± 10.3
Sex (% female)	50 (80.6%)	20 (71.4%)	30 (88.2%)	36 (81.8%)
Race (% Black)	44 (71.0%)	12 (42.9%)	32 (94.1%)	-
CVD risk	4.9 ± 1.3	4.6 ± 1.5	5.1 ± 1.1	5.2 ± 1.0
Education				
7th – 9th grade	8 (12.9%)	7 (25.0%)	1 (2.9%)	5 (11.4%)
10 – 11th grade	8 (12.9%)	3 (10.7%)	5 (14.7%)	6 (13.6%)
High school diploma/GED	16 (25.8%)	8 (28.6%)	8 (23.5%)	11 (25.0%)
Post high school, business, or trade school	3 (4.8%)	1 (3.6%)	2 (5.9%)	2 (4.5%)
Some college	13 (21.0%)	6 (21.4%)	7 (20.6%)	9 (20.5%)
4-year degree	5 (8.1%)	1 (3.6%)	4 (11.8%)	4 (9.1%)
Some graduate	2 (3.2%)	-	2 (5.9%)	2 (4.5%)
Graduate degree	7 (11.3%)	2 (7.1%)	5 (14.7%)	5 (11.4%)
Income (income per year)				
≤ $5,000	3 (4.8%)	3 (10.7%)	-	-
$5,001-$10,000	25 (40.3%)	19 (67.9%)	6 (17.6%)	17 (38.6%)
$10,001-$20,000	10 (16.1%)	5 (17.9%)	5 (14.7%)	5 (11.4%)
$20,001-$30,000	5 (8.1%)	-	5 (14.7%)	4 (9.1%)
$30,001-$40,000	6 (9.7%)	-	6 (17.6%)	6 (13.6%)
$40,001-$50,000	2 (3.2%)	-	2 (5.9%)	2 (4.5%)

Table 2.1 (cont'd)

	Total Sample N = 62	Low-Income Housing N = 28	Community Center N = 34	Black Sample N = 44
$70,001-$80,000	1 (1.6%)	-	1 (2.9%)	1 (2.3%)
$90,001-$100,000	1 (1.6%)	-	1 (2.9%)	1 (2.3%)
Chose not to answer	5 (8.1%)	-	5 (14.7%)	5 (11.4%)
Does not know	4 (6.5%)	1 (3.6%)	3 (8.8%)	3 (6.8%)
Mental Component Summary (MCS)	53.8 ± 11.1	52.1 ± 12.8	55.1 ± 9.6	55.1 ± 9.5
Digit Span Forward (FDS)	5.5 ± 1.2	5.3 ± 1.1	5.6 ± 1.2	5.6 ± 1.2
Digit Span Backward (BDS)	3.4 ± 1.0	3.5 ± 1.2	3.4 ± 0.8	3.2 ± 1.0
Size Judgment Span (SJS)	3.8 ± 0.9	3.5 ± 0.8	4.1 ± 0.9	4.0 ± 0.9
CHAMPS Total Activity	4843.0 ± 2811.3	4057.5 ± 2936.5	5489.9 ± 2568.9	4897.3 ± 2737.4
CHAMPS Moderate-to-Vigorous Activity	2242.4 ± 2032.0	1439.4 ± 1661.5	2903.7 ± 2092.0	2410.3 ± 2075.1

Note. CVD = cardiovascular disease. GED = Test of General Educational Development. CHAMPS = Community Healthy Activities Model Program for Seniors.

2.2.2 *Mood*

Mood was assessed using the Mental Component Summary (MCS) score from the 36-item Short Form Health Survey (SF-36) (Ware Jr, 2000). Though the SF-36 was not specifically developed to assess depression, it is often used as a screening measure for depression and anxiety (Matcham et al., 2016; Pfoh et al., 2016). In support of its use as a depression screener, Walsh and colleagues suggest that using a measure from a widely used general health survey may be a vital screening tool for depressive symptoms, especially in contexts where adults with comorbid conditions may be unduly overwhelmed by multiple health-related measures (Walsh et al., 2006). The MCS score is a composite score based on the items in the Vitality, Social Functioning, Role-Emotional, and Mental Health scales of the SF-36. Scores range from 0 to 100, with higher scores indicating better mood. A score of 42 or lower on the MCS has a specificity of depression of 80.6% and sensitivity of 73.7% for diagnosis of depression (Ware et al., 1993). Items comprising the MCS score are listed in Table 2. The internal consistency reliability coefficient of the MCS is 0.88 (Ferguson et al., 2002).

Table 2.2.2

Items in the Mental Component Summary

Vitality (VT) items
“Did you feel full of pep?”
“Did you have a lot of energy?”
“Did you feel worn out?”
“Did you feel tired?”

Social Functioning (SF) items

"…To what extent has your physical health or emotional problems interfered with social activities…"

"…How much of the time has your physical health or emotional problems interfered with your social activities…"

Role-Emotional (RE) items

"Cut down the amount of time spent on activities as a result of emotional problems"

"Accomplished less than you would like as a result of emotional problems"

"Didn't do work or other activities as carefully as usual as a result of emotional problems"

Mental Health (MH) items

"Have you been a very nervous person?"

"Have you felt down in the dumps?"

"Have you felt calm and peaceful?"

"Have you felt downhearted and blue?"

"Have you been a happy person?"

2.2.3 Cognition

Due to negative effects of mood disturbance and positive effects of physical activity on domains such as attention and working memory, analysis of cognitive functioning was focused on the Digit Span Forward (FDS; attention) and Digit Span

Backward (BDS; verbal working memory) subtests from the Wechsler Adult Intelligence Scale (Wechsler, 1955) and the Size Judgment Span (SJS; spatial working memory) (Cherry & Park, 1993) test. Separate analyses were conducted for each of these measures, rather than calculating a composite score, in order to observe the differential relationships that physical activity and cardiovascular risk burden may have on different cognitive domains.

2.2.4 Cardiovascular Risk Factors

Cardiovascular risk burden was calculated by summing self-reported diagnoses for conditions including diabetes, heart problems, high blood pressure, hyperlipidemia, obesity, stroke, and having smoked in the past six months. Cardiovascular risk was entered as a continuous measure in statistical analyses.

2.3 Data Analysis

Statistical analyses were conducted using R Version 3.6.3 (R Core Team, 2020). Multiple regression analyses were performed with CHAMPS total physical activity, the CVD risk variable, and their interaction as the independent variables and with cognitive (FDS, BDS and SJS) and mood (MCS) measures as the outcome variables. Separate models were tested for each of the four health outcomes. Race and age were entered as covariates. Education level, income, and sex were initially entered as covariates, but they were not significant in any of the models. They were removed to achieve the most parsimonious models. For each model, points with high leverage, distance, and influence were assessed to determine whether they should be removed. Two points of which the absolute values for leverage and distance were greater than .5 or 2.5, respectively, were removed. An alpha ≤ 0.05 was be considered significant.

Main effects were analyzed to determine if there is a relationship between physical activity and health outcomes (Aim 1). Interaction effects between the CHAMPS total physical activity score and CVD risk were analyzed to determine if burden of CVD risk moderates relationships between physical activity and health outcomes (Aim 2).

Three sets of planned follow-up analyses were conducted. The first used the CHAMPS total moderate-to-vigorous intensity activity score to determine whether more intense physical activity is associated with stronger effects. Second, the primary analyses were repeated in only the Black participants, who comprised nearly three-fourths of the sample, to examine the relationships specific to this population given the dearth of physical activity literature in Black individuals. The third set stratified the data by recruitment location (community center and a low-income housing facility) to address the possibility of confounds due to factors, such as disability, that might systematically differ between settings.

3 RESULTS

Intercorrelations of variables in the models are presented in Table 3. Results are summarized in Tables 4-8 and Figure 1.

3.1 Results for Specific Aim 1

There were no significant main effects of physical activity on mood symptoms, attention, or working memory in the total sample.

3.2 Results for Specific Aim 2

Analyses revealed significant CVD risk by physical activity interactions for attention ($\beta = -.0001$, $p < .01$) and verbal working memory ($\beta = -.0001$, $p < .01$). In individuals with low CVD risk, higher physical activity was associated with better attention and verbal working memory. However, in individuals with high CVD risk, higher physical activity was associated with worse attention and verbal working memory. There were no significant interaction effects of physical activity and CVD risk on mood symptoms or visual working memory, although the interaction approached significance for visual working memory ($p = .06$).

3.3 Results for Follow-Up Analyses

There were no significant effects in the analysis of moderate-to-vigorous physical activity.

When the sample was limited to only Black adults, higher self-reported physical activity was associated with worse attention ($\beta = -.0002$, $p < .05$). There was also a significant CVD risk by physical activity interaction on visual working memory ($\beta = -.0001$, $p < .05$). The direction of this relationship was similar to that observed for attention and verbal working memory in the total sample, such that in individuals with low CVD risk, but not those with high CVD risk, higher physical activity was associated with better visual working memory. There were no other significant interaction effects of physical activity and CVD risk on mood symptoms or cognitive function.

In the analyses stratified by recruitment setting, the results for participants living in the low-income housing facility mirrored the results in the total sample (CVD risk by physical activity interaction for attention (β = -.0002, *p* < .01) and an interaction approaching significance for verbal working memory (β = -.0001, *p* = .05)). In community center participants, there was a significant negative relationship between physical activity and attention (β = -.0002, *p* < .05), such that more physical activity was associated with worse attention. However, higher physical activity was associated with better mood (β = .002, *p* < .05). There were no significant interaction effects of physical activity and CVD risk on mood symptoms or cognitive functioning in this subsample.

Table 3.1

Correlations between Age, CVD Risk and Study Measures

	Age	Total PA	MVPA	MCS	FDS	BDS	SJS	CVD
Age	1	–	–	–	–	–	–	–
Total PA	-0.117	1	–	–	–	–	–	–
MVPA	-0.207	.796**	1	–	–	–	–	–
MCS	0.113	0.198	0.156	1	–	–	–	–
FDS	0.040	-0.153	-0.204	0.041	1	–	–	–
BDS	0.156	-0.137	-0.183	0.098	.472**	1	–	–
SJS	-0.174	0.102	0.042	0.164	.447**	.305*	1	–
CVD	-0.183	-0.146	0.076	0.150	-0.022	-0.212	-0.025	1

Note. PA = physical activity. MVPA = moderate-to-vigorous physical activity. MCS = Mental Component Summary. FDS = Forward Digit Span. BDS = Backward Digit Span. SJS = Size Judgment Span. CVD = risk for cardiovascular disease. PA = physical activity. * Pearson correlation significant at the .05 level. ** Pearson correlation significant at the .01 level.

Table 3.2

Results of Regression Analyses of Total PA for the Total Sample

	MCS		**FDS**		**BDS**		**SJS**	
	B	***SE***	***B***	***SE***	***B***	***SE***	***β***	***SE***
Age	0.194	-0.145	0.003	-0.015	0.014	-0.012	-0.016	-0.011
Race	-2.896	-3.279	-0.345	-0.330	0.634*	-0.277	-0.512	-0.260
PA	0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
CVD	1.432	-1.226	0.012	-0.123	-0.009	-0.104	-0.049	-0.097
PA × CVD	0.000	0.000	0.000**	0.000	0.000**	0.000	0.000	0.000
Constant	54.637**	-1.696	5.547**	-0.171	3.206**	-0.143	3.960**	-0.135

Note: MCS = Mental Component Summary, FDS = Digit Span Forward, BDS = Digit Span Backward, SJS = Size Judgment Span, PA = physical activity, CVD = risk for cardiovascular disease, ****p*** < 0.05; ******p*** < 0.01

Table 3.3

Results of Regression Analyses of MVPA for the Total Sample

	MCS		FDS		BDS		SJS	
	B	***SE***	***B***	***SE***	***B***	***SE***	***β***	***SE***
Age	0.192	-0.148	-0.001	-0.015	0.012	-0.013	-0.018	-0.012
Race	-2.965	-3.345	-0.378	-0.346	0.634*	-0.291	-0.527	-0.267
MVPA	0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
CVD	1.1	-1.182	-0.071	-0.122	-0.089	-0.103	-0.117	-0.094
MVPA × CVD	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
Constant	54.603**	-1.713	5.625**	-0.177	3.269**	-0.149	4.001**	-0.137

Note: MCS = Mental Component Summary, FDS = Digit Span Forward, BDS = Digit Span Backward, SJS = Size Judgment Span, MVPA = moderate-to-vigorous physical activity, CVD = risk for cardiovascular disease, ****p*** < 0.05; ******p*** < 0.01

Table 3.4

Results of Regression Analyses for the Black Sample

	MCS		FDS		BDS		SJS	
	B	***SE***	***B***	***SE***	***B***	***SE***	***β***	***SE***
Age	0.216	-0.155	0.001	-0.018	0.018	-0.016	-0.011	-0.014
PA	0.001	-0.001	0.000*	0.000	0.000	0.000	0.000	0.000
CVD	0.339	-1.589	0.189	-0.183	0.127	-0.160	0.061	-0.145
PA × CVD	0.000	-0.001	0.000	0.000	0.000	0.000	0.000*	0.000
Constant	55.026**	-1.434	5.576**	-0.165	3.197**	-0.145	3.923**	-0.131

Note: MCS = Mental Component Summary, FDS = Digit Span Forward, BDS = Digit Span Backward, SJS = Size Judgment Span, *PA* = physical activity, CVD = risk for cardiovascular disease, $^{*}\boldsymbol{p} < 0.05$; $^{**}\boldsymbol{p} < 0.01$

Table 3.5

Results of Regression Analyses for the Housing Facility Sample

	MCS		FDS		BDS		SJS	
	B	***SE***	***B***	***SE***	***B***	***SE***	***β***	***SE***
Age	0.203	0.269	0.009	0.019	0.024	0.023	-0.008	0.016
Race	-4.690	5.445	-0.440	0.385	0.897	0.460	-0.302	0.330
PA	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
CVD	1.927	1.972	-0.083	0.139	-0.022	0.166	-0.026	0.119
PA × CVD	0.000	0.001	0.000**	0.000	0.000	0.000	0.000	0.000
Constant	55.246**	4.070	5.393**	0.288	2.907**	0.343	3.595**	0.247

Note: MCS = Mental Component Summary, FDS = Digit Span Forward, BDS = Digit Span Backward, SJS = Size Judgment Span, PA = physical activity, CVD = risk for cardiovascular disease, $^{**}\boldsymbol{p} < 0.01$

Table 3.6

Results of Regression Analyses for the Community Center Sample

	MCS		FDS		BDS		SJS	
	B	***SE***	***B***	***SE***	***B***	***SE***	***β***	***SE***
Age	0.265	-0.182	-0.013	-0.021	0.009	-0.015	-0.019	-0.017
Race	4.652	-7.285	0.147	-0.836	0.813	-0.606	0.743	-0.664
PA	0.002*	-0.001	0.000*	0.000	0.000	0.000	0.000	0.000
CVD	1.259	-1.761	0.053	-0.202	0.034	-0.147	-0.095	-0.161
PA × CVD	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
Constant	54.551**	-1.719	5.655**	-0.197	3.270**	-0.143	4.069**	-0.157

Note: MCS = Mental Component Summary, FDS = Digit Span Forward, BDS = Digit Span Backward, SJS = Size Judgment Span, PA = physical activity, CVD = risk for cardiovascular disease, $^{*}p < 0.05$; $^{**}p < 0.01$

4 DISCUSSION

The present study investigated whether physical activity was related to mood and cognitive functioning, and whether risk for CVD moderated these relationships in a diverse sample of middle-aged and older adults. We also investigated these relationships in Black adults and stratified by participants' recruitment location, which were subsets of the total sample of diverse adults living in New Orleans, Louisiana.

4.1 Effects of Physical Activity on Mood and Cognitive Functioning

Contrary to our first hypothesis, there were no main effects of physical activity on mood or cognitive functioning in the total sample. This finding is not consistent with the majority of previous literature indicating that physical activity is associated with better mood and cognitive functioning (Barnes et al., 2003; Mammen & Faulkner, 2013). However, findings in the literature are mixed, and there are other studies that have not found such a relationship in middle-aged to older adult populations (Fukukawa et al., 2004; Wassink-Vossen et al., 2014).

A large study of 1,151 community-dwelling adults in Japan by Fukukawa and colleagues (2004) found that physical activity, as measured by pedometer, was associated with decreased depressive symptoms at two-year follow-up in older (age 65 to 79) but not middle-aged (age 40-64) adults. In the Lifestyle Interventions and Independence for Elders Pilot study (Matthews et al., 2011), a 12-month physical activity intervention did not reduce depressive symptoms in adults aged 70 to 89. However, a follow-up study in the same sample showed benefits in a subset of participants (Dotson et al., 2016). Men, but not women, showed decreases in somatic symptoms of depression, but not total depressive symptoms, after the intervention.

These previous null results suggest the possibility that the present results might have differed by age, sex, or type of depressive symptoms; however, the sample size did not allow for an exploration of this possibility.

These three studies also all looked at walking as a measure of physical activity, and their respective authors suggested that more intense physical activity may have been required to impact depressive symptoms. Other studies have suggested that the benefits of physical activity on mood and cognitive functioning may be "dose-dependent," indicating that significant or stronger effects may only be observed at more intense levels of physical activity (Hu et al., 2019; Kirk-Sanchez & McGough, 2014; Vidoni et al., 2015). Therefore, exploratory analyses of the potential effects of moderate-to-vigorous physical activity on mood and cognitive functioning were conducted in the present stud. Contrary to our predictions, moderate-to-vigorous physical activity was not significantly associated with mood, attention, or working memory in this sample. This contrasts with previous work suggesting that moderate-to-vigorous physical activity, but not less, was associated with improvements in cognitive domains (Fernandes et al., 2018; Hu et al., 2019; Olson et al., 2016). The more restricted range of scores for moderate-to-physical activity in our sample might explain the lack of significant effects despite the effects found for total activity.

When analyses were limited to Black participants (71% of the total sample), the only significant effect was a negative association between physical activity and attention. However, visual inspection of graphs in the Black sample revealed the same pattern of relationships between physical activity, mood, and working memory measures as in the total sample. This suggests the lack of findings was related to statistical power.

The finding that higher self-reported physical activity was related to worse attention in Black participants was unexpected. This opposes existing research that suggests a positive relationship between physical activity and cognition in Black adults (Pugh et al., 2003). As mentioned earlier, while this may not align with our current understanding of the benefits of physical activity, longitudinal studies with an exercise intervention component may help illuminate the true nature of this relationship.

We conducted analyses stratified by recruitment setting since confounds such as physical disability might differ between participants recruited from the community center versus the low-income housing facility. Indeed, Wassink-Vossen and colleagues (2014) suggest that functional disability may play a role in the difference in physical activity between depressed and non-depressed individuals. Results in the low-income housing facility mirrored the results in the total sample—there were no main effects of physical activity on any of our outcomes. In contrast, partially consistent with our first hypothesis, physical activity was significantly associated with better mood in the community center sample. Considering that this subsample was generally more educated and had higher SES than the low-income housing facility, this finding highlights potential individual differences that can moderate the benefits of physical activity. Physical activity was significantly associated with worse attention in the community center sample, similar to what we found in Black participants. The latter finding is not surprising since 94.1% of the community center sample was Black.

In addition to possible impacts from education and socioeconomic status, the general pattern we found of no relationships among physical activity, mood and cognitive functioning may be in part due to the restricted range in mood and cognitive scores in this sample. Overall, participants were not clinically depressed and were not cognitively impaired. These relationships may be stronger in individuals with more impairment in mood and cognition, as literature suggests that physical activity can be beneficial for those with more severe mood and cognitive symptoms (Baker et al., 2010; Neviani, Belvederi Murri, Mussi, Triolo, Toni, Simoncini, Tripi, Menchetti, Ferrari, & Ceresini, 2017; Wassink-Vossen et al., 2014). However, results from this cross-sectional study do not contradict the possibility that increasing physical activity in individuals would lead to better health outcomes. It is still possible that an exercise intervention with this population would have positive effects on mood and cognitive functioning over time. Future longitudinal research with a larger sample size that includes a range of individuals with more varied mood and cognitive scores may give more insight on the true nature of this relationship.

4.2 Moderating Effect of Cardiovascular Risk Factors

In partial support of our second hypothesis, cardiovascular risk burden significantly moderated the relationship between physical activity and cognitive function in the domains of attention and verbal working memory. Yet, contrary our hypothesis, the benefits of physical activity were only apparent in people at lower risk for CVD, while higher CVD risk was associated with no benefit or even a negative effect. Additionally, we did not find a significant interaction of risk for CVD and physical activity on mood or visual working memory. There is little research examining the effects of cumulative vascular risk burden on the relationship between physical activity and health outcomes. However, there is evidence to suggest that physical activity is associated with preservation of cognitive functioning in individuals with or at risk for CVD (Vercambre et al., 2011). Contrary to the present study, the longitudinal study by Vercambre and colleagues (2011) that found such an association involved analyses with thousands of participants. Sample size and the cross-sectional nature of the current study may have contributed to the lack of other significant interaction effects.

The interaction effects for attention and verbal working memory in the total sample were not statistically significant in the Black sample, but again, visual inspection of graphs showed the same pattern of effects, suggesting a power issue. We also found a similar pattern that was statistically significant for visual working memory in Black participants. The low-incoming housing subsample again had results parallel to the total sample (i.e., physical activity was associated with better attention and verbal working memory but only in those with low CVD risk). There were no significant interaction effects in the community center sample.

Overall, results did not confirm our hypothesis that people who are most at risk for CVD would benefit more from physical activity due to their vulnerability to vascular-related mood and cognitive disruption. Rather, our results are consistent with an alternative hypothesis, that the protective effects of vascular health allow older adults to benefit from physical activity, while CVD risk factors limit potential benefits. In line with this hypothesis, studies suggest that active older adults with low health risk are more likely to have better cognitive functioning (Ávila-Funes et al., 2011). In an investigation of factors related to cognitive improvement following antidepressant treatment in LLD, Barch and colleagues (2012) found that higher vascular risk significantly predicted less improvement in working memory and executive function. This suggests that in some individuals, having a higher risk for CVD may prevent them from experiencing positive effects of interventions for mood and cognitive functioning.

Since some studies suggests that people with vascular burden benefit from physical activity (Alosco et al., 2014), it is unclear why this was not the case in the current study. There is evidence that strenuous physical activity can actually exacerbate CVD (Armstrong et al., 2015; Williams & Thompson, 2014). However, the level of physical activity in the current sample was not particularly high, so this would not fully explain our results. Furthermore, co-morbid conditions in individuals at higher health risk may limit their ability to obtain the benefits from physical activity compared to those at lower health risk. Treatments that involve physical activity interventions as a way to improve mood or cognitive functioning may need to involve approaches that aim to reduce functional and medical barriers that may prevent individuals from benefiting from exercise. Additional research investigating the optimal amount and intensity of physical activity in population at risk for CVD with depression and cognitive concerns is also necessary to avoid potential iatrogenic effects of exercise.

4.3 Limitations

There are several limitations to this study. As mentioned previously, the sample size is small. Additionally, physical activity and risk factors for CVD were obtained through self-report. Self-report data is more likely to be unreliable and inaccurate compared to objective data. Future studies would benefit from using more objective measures of these variables such as through accelerometer data and a thorough, standardized health questionnaire. Research has shown that objective measures of physical activity are more reliable and more closely correlated to caloric expenditure and cardiorespiratory fitness (Bassett Jr, 2000; Loprinzi, 2013). This study is also cross-sectional, which does not allow us to make causal inferences regarding the effects of physical activity and risk for CVD on mood and cognitive function. A longitudinal study that includes an exercise intervention would provide more information on the potential effects of physical activity and its relationship with cardiovascular risk factors on various health outcomes.

In this study, we used the MCS from the SF-36 to assess mood. While this measure may be a helpful screening tool to capture mood symptoms in middle-aged to older adults, it does not include all the symptoms traditionally associated with clinical depression. It may be beneficial to use other traditional measures of depressive symptoms to examine potential relationships between physical activity, risk for CVD and health outcomes. Additionally, exclusion criteria for the study included individuals with cognitive impairment and those contraindicated for exercise. Since individuals with certain cardiovascular conditions or common comorbidities may be contraindicated for exercise (Hansen et al., 2018), the range of possible vascular risk factors may have been limited for the study. Similarly, the range of scores for cognitive measures may have been restricted, reducing our ability to detect a potential relationship over a wide range of scores. It would also be valuable for future studies to include additional measures of cognitive functioning so that we may gain a more comprehensive understanding of the relationship of risk factors for CVD and physical activity on different cognitive domains.

Finally, this study included a high number of participants considered to be of lower socioeconomic status. These individuals may have had limited means to access resources for engaging in physical activity. Murray and colleagues (2012) found that individuals with higher socioeconomic status reported more exercise and stronger intentions to exercise, which may be explained by reduced barriers to exercise. Factors such as socioeconomic status and potential disability in older adults, and especially in Black older adults, likely play a role in physical activity levels. Future studies in larger samples should systematically examine potential moderating roles of socioeconomic status, disability and other individual differences on physical activity levels and the benefits of physical activity.

4.4 Conclusion

Overall, this study provides further evidence of the benefits of physical activity on mood and cognitive functioning. The study extends previous research by demonstrating that CVD risk can moderate the effects, with lower CVD risk being associated with greater benefits. Given the differences in findings between the total sample and subsamples based on race and recruitment setting, study findings highlight the potential impacts of demographic factors on the relationships among physical activity, CVD risk, and health outcomes. Further studies are needed to fully examine the relationships between physical activity and risk for CVD on various health outcomes in a diverse group of older adults.

REFERENCES

Aizenstein, H. J., Baskys, A., Boldrini, M., Butters, M. A., Diniz, B. S., Jaiswal, M. K., Jellinger, K. A., Kruglov, L. S., Meshandin, I. A., & Mijajlovic, M. D. (2016). Vascular depression consensus report–A critical update. *BMC medicine, 14*(1), 161.

Akbaraly, T. N., Kivimäki, M., Brunner, E. J., Chandola, T., Marmot, M. G., Singh-Manoux, A., & Ferrie, J. E. (2009). Association between metabolic syndrome and depressive symptoms in middle-aged adults: results from the Whitehall II study. *Diabetes care, 32*(3), 499-504.

Akincigil, A., Olfson, M., Siegel, M., Zurlo, K. A., Walkup, J. T., & Crystal, S. (2012). Racial and ethnic disparities in depression care in community-dwelling elderly in the United States. *American journal of public health, 102*(2), 319-328.

Alexopoulos, G. S. (2005). Depression in the elderly. *The lancet, 365*(9475), 1961-1970.

Alexopoulos, G. S., Bruce, M. L., Silbersweig, D., Kalayam, B., & Stern, E. (1999). Vascular depression: A new view of late-onset depression. *Dialogues in clinical neuroscience, 1*(2), 68.

Alexopoulos, G. S., Meyers, B. S., Young, R. C., Campbell, S., Silbersweig, D., & Charlson, M. (1997). 'Vascular depression'hypothesis. *Archives of general psychiatry, 54*(10), 915-922.

Alosco, M. L., Spitznagel, M. B., Cohen, R., Raz, N., Sweet, L. H., Josephson, R., Hughes, J., Rosneck, J., & Gunstad, J. (2014). Decreased physical activity predicts cognitive dysfunction and reduced cerebral blood flow in heart failure. *Journal of the neurological sciences, 339*(1-2), 169-175.

Armstrong, M. E., Green, J., Reeves, G. K., Beral, V., & Cairns, B. J. (2015). Frequent physical activity may not reduce vascular disease risk as much as moderate activity: large prospective study of women in the United Kingdom. *Circulation, 131*(8), 721-729.

Ávila-Funes, J. A., Pina-Escudero, S., Aguilar-Navarro, S., Gutierrez-Robledo, L., Ruiz-Arregui, L., & Amieva, H. (2011). Cognitive impairment and low physical activity are the components of frailty more strongly associated with disability. *The journal of nutrition, health & aging, 15*(8), 683-689.

Baker, L. D., Frank, L. L., Foster-Schubert, K., Green, P. S., Wilkinson, C. W., McTiernan, A., Plymate, S. R., Fishel, M. A., Watson, G. S., Cholerton, B. A., Duncan, G. E., Mehta, P. D., & Craft, S. (2010). Effects of Aerobic Exercise on Mild Cognitive Impairment: A Controlled Trial. *Archives of Neurology, 67*(1), 71-79.

Barch, D. M., D'Angelo, G., Pieper, C., Wilkins, C. H., Welsh-Bohmer, K., Taylor, W., Garcia, K. S., Gersing, K., Doraiswamy, P. M., & Sheline, Y. I. (2012). Cognitive improvement following treatment in late-life depression: Relationship to vascular risk and age of onset. *The American Journal of geriatric psychiatry, 20*(8), 682-690.

Barnes, D. E., Yaffe, K., Satariano, W. A., & Tager, I. B. (2003). A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. *Journal of the American Geriatrics Society, 51*(4), 459-465.

Bassett Jr, D. R. (2000). Validity and reliability issues in objective monitoring of physical activity. *Research quarterly for exercise and sport, 71*(sup2), 30-36.

Berry, J. D., Dyer, A., Cai, X., Garside, D. B., Ning, H., Thomas, A., Greenland, P., Van Horn, L., Tracy, R. P., & Lloyd-Jones, D. M. (2012). Lifetime Risks of Cardiovascular Disease. *New England Journal of Medicine, 366*(4), 321-329.

Boyle, S. H., Surwit, R. S., Georgiades, A., Brummett, B. H., Helms, M. J., Williams, R. B., & Barefoot, J. C. (2007). Depressive symptoms, race, and glucose concentrations: The role of cortisol as mediator. *Diabetes care, 30*(10), 2484-2488.

Brailean, A., Comijs, H. C., Aartsen, M. J., Prince, M., Prina, A. M., Beekman, A., & Huisman, M. (2016). Late-life depression symptom dimensions and cognitive functioning in the Longitudinal Aging Study Amsterdam (LASA). *Journal of affective disorders, 201*, 171-178.

Brevik, E. J., Eikeland, R. A., & Lundervold, A. J. (2013). Subthreshold depressive symptoms have a negative impact on cognitive functioning in middle-aged and older males. *Frontiers in psychology, 4*, 309.

Brown, W. J., Ford, J. H., Burton, N. W., Marshall, A. L., & Dobson, A. J. (2005). Prospective study of physical activity and depressive symptoms in middle-aged women. *American Journal of Preventive Medicine, 29*(4), 265-272.

Burgess, N., Maguire, E. A., & O'Keefe, J. (2002). The human hippocampus and spatial and episodic memory. *Neuron, 35*(4), 625-641.

Butters, M. A., Young, J. B., Lopez, O., Aizenstein, H. J., Mulsant, B. H., Reynolds III, C. F., DeKosky, S. T., & Becker, J. T. (2008). Pathways linking late-life depression to persistent cognitive impairment and dementia. *Dialogues in clinical neuroscience, 10*(3), 345.

Cherbuin, N., Kim, S., & Anstey, K. J. (2015). Dementia risk estimates associated with measures of depression: A systematic review and meta-analysis. *BMJ open, 5*(12).

Cherry, K. E., & Park, D. C. (1993). Individual difference and contextual variables influence spatial memory in younger and older adults. *Psychology and Aging, 8*(4), 517.

Church, T. (2011, 2011/05/01/). Exercise in Obesity, Metabolic Syndrome, and Diabetes. *Progress in Cardiovascular Diseases, 53*(6), 412-418.

Cohen, J. *Statistical Power Analysis for the Behavioral Sciences. Hillsdale, New Jersey, 1988*. Lawrence Erlbaum Associates: Routledge.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14*(2), 125-130.

Davies, E. J., Moxham, T., Rees, K., Singh, S., Coats, A. J., Ebrahim, S., Lough, F., & Taylor, R. S. (2010). Exercise based rehabilitation for heart failure. *Cochrane database of systematic reviews*(4).

Dimeo, F., Pagonas, N., Seibert, F., Arndt, R., Zidek, W., & Westhoff, T. H. (2012). Aerobic exercise reduces blood pressure in resistant hypertension. *Hypertension, 60*(3), 653-658.

Diniz, B. S., Butters, M. A., Albert, S. M., Dew, M. A., & Reynolds, C. F., 3rd. (2013). Late-life depression and risk of vascular dementia and Alzheimer's disease: Systematic review and meta-analysis of community-based cohort studies. *The British journal of psychiatry : the journal of mental science, 202*(5), 329-335.

Dotson, V. M., Hsu, F.-C., Langaee, T. Y., McDonough, C. W., King, A. C., Cohen, R. A., Newman, A. B., Kritchevsky, S. B., Myers, V., & Manini, T. M. (2016). Genetic moderators of the impact of physical activity on depressive symptoms. *The Journal of frailty & aging, 5*(1), 6.

Dotson, V. M., Resnick, S. M., & Zonderman, A. B. (2008). Differential association of concurrent, baseline, and average depressive symptoms with cognitive decline in older adults. *The American Journal of geriatric psychiatry, 16*(4), 318-330.

Duman, R. S., & Monteggia, L. M. (2006, 2006/06/15/). A Neurotrophic Model for Stress-Related Mood Disorders. *Biological Psychiatry, 59*(12), 1116-1127.

Erickson, K. I., Gildengers, A. G., & Butters, M. A. (2013). Physical activity and brain plasticity in late adulthood. *Dialogues in clinical neuroscience, 15*(1), 99-108.

Erickson, K. I., Miller, D. L., & Roecklein, K. A. (2012). The aging hippocampus: Interactions between exercise, depression, and BDNF. *The Neuroscientist, 18*(1), 82-97.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods, 39*(2), 175-191.

Ferguson, R. J., Robinson, A. B., & Splaine, M. (2002). Use of the reliable change index to evaluate clinical significance in SF-36 outcomes. *Quality of Life Research, 11*(6), 509-516.

Fernandes, R. M., Correa, M. G., dos Santos, M. A., Almeida, A. P., Fagundes, N. C., Maia, L. C., & Lima, R. R. (2018). The effects of moderate physical exercise on adult cognition: a systematic review. *Frontiers in physiology, 9*, 667.

Fiske, A., Wetherell, J. L., & Gatz, M. (2009). Depression in older adults. *Annual review of clinical psychology, 5*, 363-389.

Frith, E., & Loprinzi, P. D. (2017). Physical activity and cognitive function among older adults with hypertension. *Journal of hypertension, 35*(6), 1271-1275.

Fukukawa, Y., Nakashima, C., Tsuboi, S., Kozakai, R., Doyo, W., Niino, N., Ando, F., & Shimokata, H. (2004). Age differences in the effect of physical activity on depressive symptoms. *Psychology and Aging, 19*(2), 346.

Ganguli, M., Du, Y., Dodge, H. H., Ratcliff, G. G., & Chang, C.-C. H. (2006). Depressive symptoms and cognitive decline in late life: A prospective epidemiological study. *Archives of general psychiatry, 63*(2), 153-160.

Gardner, R. E., Allen, P. D., Cherry, K. E., Monroe, P. A., O'Neil, C. E., & Wood, R. H. (2006). Baseline Results of an Interdisciplinary Effort to Promote Healthy Aging among Culturally Diverse Adults. *Medicine & Science in Sports & Exercise, 38*(5), S305.

Gujral, S., Aizenstein, H., Reynolds, C. F., 3rd, Butters, M. A., & Erickson, K. I. (2017). Exercise effects on depression: Possible neural mechanisms. *General hospital psychiatry, 49*, 2-10.

Hall, C. A., & Reynolds-III, C. F. (2014). Late-life depression in the primary care setting: Challenges, collaborative care, and prevention. *Maturitas, 79*(2), 147-152.

Hamilton, J. L., Brickman, A. M., Lang, R., Byrd, G. S., Haines, J. L., Pericak-Vance, M. A., & Manly, J. J. (2014). Relationship between depressive symptoms and cognition in older, non-demented African Americans. *Journal of the International Neuropsychological Society: JINS, 20*(7), 756.

Hansen, D., Niebauer, J., Cornelissen, V., Barna, O., Neunhäuserer, D., Stettler, C., Tonoli, C., Greco, E., Fagard, R., & Coninx, K. (2018). Exercise prescription in patients with different combinations of cardiovascular disease risk factors: a consensus statement from the EXPERT working group. *Sports medicine, 48*(8), 1781-1797.

Hayes, S. M., Alosco, M. L., & Forman, D. E. (2014). The effects of aerobic exercise on cognitive and neural decline in aging and cardiovascular disease. *Current geriatrics reports, 3*(4), 282-290.

Hooker, K., Phibbs, S., Irvin, V. L., Mendez-Luck, C. A., Doan, L. N., Li, T., Turner, S., & Choun, S. (2019). Depression among older adults in the United States by disaggregated race and ethnicity. *The Gerontologist, 59*(5), 886-891.

Howard, G., Safford, M. M., Moy, C. S., Howard, V. J., Kleindorfer, D. O., Unverzagt, F. W., Soliman, E. Z., Flaherty, M. L., McClure, L. A., & Lackland, D. T. (2017). Racial differences in the incidence of cardiovascular risk factors in older black and white adults. *Journal of the American Geriatrics Society, 65*(1), 83-90.

Hu, L., Smith, L., Imm, K. R., Jackson, S. E., & Yang, L. (2019). Physical activity modifies the association between depression and cognitive function in older adults. *Journal of affective disorders, 246*, 800-805.

Jefferson, A. L., Hohman, T. J., Liu, D., Haj-Hassan, S., Gifford, K. A., Benson, E. M., Skinner, J. S., Lu, Z., Sparling, J., Sumner, E. C., Bell, S., & Ruberg, F. L. (2015). Adverse vascular risk is related to cognitive decline in older adults. *Journal of Alzheimer's disease : JAD, 44*(4), 1361-1373.

Jorm, A. F. (2001). History of depression as a risk factor for dementia: An updated review. *Australian & New Zealand Journal of Psychiatry, 35*(6), 776-781.

Kalaria, R. N., Akinyemi, R., & Ihara, M. (2016, 2016/05/01/). Stroke injury, cognitive impairment and vascular dementia. *Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease, 1862*(5), 915-925.

Kelly, R. B. (2010). Diet and exercise in the management of hyperlipidemia. *American family physician, 81*(9), 1097-1102.

Kirk-Sanchez, N. J., & McGough, E. L. (2014). Physical exercise and cognitive performance in the elderly: current perspectives. *Clinical interventions in aging, 9*, 51.

Knopman, D., Boland, L., Mosley, T., Howard, G., Liao, D., Szklo, M., McGovern, P., & Folsom, A. (2001). Cardiovascular risk factors and cognitive decline in middle-aged adults. *Neurology, 56*(1), 42-48.

Kruk, P., & Nowicki, M. (2016). Effects of regular physical activity on pain, anxiety, and depression in patients with treatment-resistant arterial hypertension. *Family Medicine & Primary Care Review*(3), 268-273.

Kvam, S., Kleppe, C. L., Nordhus, I. H., & Hovland, A. (2016). Exercise as a treatment for depression: A meta-analysis. *Journal of affective disorders, 202*, 67-86.

Lewis, T. T., Everson-Rose, S. A., Colvin, A., Matthews, K., Bromberger, J. T., & Sutton-Tyrrell, K. (2009). The interactive effects of race and depressive symptoms on calcification in African-American and white women. *Psychosomatic medicine, 71*(2), 163.

Lewis, T. T., Guo, H., Lunos, S., Mendes de Leon, C. F., Skarupski, K. A., Evans, D. A., & Everson-Rose, S. A. (2011). Depressive symptoms and cardiovascular mortality in older black and white adults: Evidence for a differential association by race. *Circulation: Cardiovascular Quality and Outcomes, 4*(3), 293-299.

Lo Coco, D., Lopez, G., & Corrao, S. (2016). Cognitive impairment and stroke in elderly patients. *Vascular health and risk management, 12*, 105-116.

Lockwood, K. A., Alexopoulos, G. S., Kakuma, T., & Van Gorp, W. G. (2000). Subtypes of cognitive impairment in depressed older adults. *The American Journal of geriatric psychiatry, 8*(3), 201-208.

Loprinzi, P. D. (2013). Objectively measured light and moderate-to-vigorous physical activity is associated with lower depression levels among older US adults. *Aging & mental health, 17*(7), 801-805.

Mammen, G., & Faulkner, G. (2013). Physical activity and the prevention of depression: A systematic review of prospective studies. *American Journal of Preventive Medicine, 45*(5), 649-657.

Mast, B. T., MacNeill, S. E., & Lichtenberg, P. A. (2004). Post-stroke and clinically-defined vascular depression in geriatric rehabilitation patients. *The American Journal of geriatric psychiatry, 12*(1), 84-92.

Matcham, F., Norton, S., Steer, S., & Hotopf, M. (2016). Usefulness of the SF-36 Health Survey in screening for depressive and anxiety disorders in rheumatoid arthritis. *BMC musculoskeletal disorders, 17*(1), 224.

Matthews, M. M., Hsu, F. C., Walkup, M. P., Barry, L. C., Patel, K. V., & Blair, S. N. (2011). Depressive symptoms and physical performance in the lifestyle interventions and independence for elders pilot study. *Journal of the American Geriatrics Society, 59*(3), 495-500.

Middleton, L. E., Barnes, D. E., Lui, L. Y., & Yaffe, K. (2010). Physical activity over the life course and its association with cognitive performance and impairment in old age. *Journal of the American Geriatrics Society, 58*(7), 1322-1326.

Mojtabai, R., & Olfson, M. (2004). Major depression in community-dwelling middle-aged and older adults: prevalence and 2-and 4-year follow-up symptoms. *Psychological Medicine, 34*(4), 623.

Moore, D. S., Ellis, R., Allen, P. D., Monroe, P. A., Cherry, K. E., O'Neil, C. E., & Wood, R. H. (2008). Construct validation of physical activity surveys in culturally diverse older adults: A comparison of four commonly used questionnaires. *Research quarterly for exercise and sport, 79*(1), 42-50.

Morimoto, S. S., Kanellopoulos, D., Manning, K. J., & Alexopoulos, G. S. (2015). Diagnosis and treatment of depression and cognitive impairment in late life. *Annals of the New York Academy of Sciences, 1345*(1), 36-46.

Murphy, E., Hou, L., Maher, B. S., Woldehawariat, G., Kassem, L., Akula, N., Laje, G., & McMahon, F. J. (2013). Race, genetic ancestry and response to antidepressant treatment for major depression. *Neuropsychopharmacology, 38*(13), 2598-2606.

Murray, T. C., Rodgers, W. M., & Fraser, S. N. (2012). Exploring the relationship between socioeconomic status, control beliefs and exercise behavior: a multiple mediator model. *Journal of behavioral medicine, 35*(1), 63-73.

Naismith, S. L., Norrie, L. M., Mowszowski, L., & Hickie, I. B. (2012). The neurobiology of depression in later-life: Clinical, neuropsychological, neuroimaging and pathophysiological features. *Progress in neurobiology, 98*(1), 99-143.

Neviani, F., Belvederi Murri, M., Mussi, C., Triolo, F., Toni, G., Simoncini, E., Tripi, F., Menchetti, M., Ferrari, S., & Ceresini, G. (2017). Physical exercise for late life depression: Effects on cognition and disability. *International Psychogeriatrics, 29*(7), 1105-1112.

Olson, R. L., Chang, Y.-K., Brush, C. J., Kwok, A. N., Gordon, V. X., & Alderman, B. L. (2016). Neurophysiological and behavioral correlates of cognitive control during low and moderate intensity exercise. *NeuroImage, 131*, 171-180.

Pavlik, V. N., Hyman, D. J., & Doody, R. (2005). Cardiovascular risk factors and cognitive function in adults 30–59 years of age (NHANES III). *Neuroepidemiology, 24*(1-2), 42-50.

Pfoh, E. R., Chan, K. S., Dinglas, V. D., Cuthbertson, B. H., Elliott, D., Porter, R., Bienvenu, O. J., Hopkins, R. O., & Needham, D. M. (2016). The SF-36 offers a strong measure of mental health symptoms in survivors of acute respiratory failure. A tri-national analysis. *Annals of the American Thoracic Society, 13*(8), 1343-1350.

Pickett, Y. R., Bazelais, K. N., & Bruce, M. L. (2013). Late-life depression in older African Americans: A comprehensive review of epidemiological and clinical data. *International journal of geriatric psychiatry, 28*(9), 903-913.

Pugh, K. G., Kiely, D. K., Milberg, W. P., & Lipsitz, L. A. (2003). Selective impairment of frontal-executive cognitive function in African Americans with cardiovascular risk factors. *Journal of the American Geriatrics Society, 51*(10), 1439-1444.

R Core Team. (2020). *R: A language and environment for statistical computing.* In R Foundation for Statistical Computing.

Rajan, S., McKee, M., Rangarajan, S., Bangdiwala, S., Rosengren, A., Gupta, R., Kutty, V. R., Wielgosz, A., Lear, S., & AlHabib, K. F. (2020). Association of Symptoms of Depression With Cardiovascular Disease and Mortality in Low-, Middle-, and High-Income Countries. *JAMA Psychiatry*.

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015, 2015/08/07). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychology Review, 9*(3), 366-378.

Sexton, C., McDermott, L., Kalu, U., Herrmann, L., Bradley, K., Allan, C., Le Masurier, M., Mackay, C., & Ebmeier, K. (2012). Exploring the pattern and neural correlates of neuropsychological impairment in late-life depression. *Psychological Medicine, 42*(6), 1195.

Sheline, Y. I., Pieper, C. F., Barch, D. M., Welsh-Boehmer, K., McKinstry, R. C., MacFall, J. R., D'Angelo, G., Garcia, K. S., Gersing, K., & Wilkins, C. (2010). Support for the vascular depression hypothesis in late-life depression: Results of a 2-site, prospective, antidepressant treatment trial. *Archives of general psychiatry, 67*(3), 277-285.

Singh-Manoux, A., Hillsdon, M., Brunner, E., & Marmot, M. (2005). Effects of physical activity on cognitive functioning in middle age: evidence from the Whitehall II prospective cohort study. *American journal of public health, 95*(12), 2252-2258.

Sivertsen, H., Bjørkløf, G. H., Engedal, K., Selbæk, G., & Helvik, A.-S. (2015). Depression and quality of life in older persons: A review. *Dementia and geriatric cognitive disorders, 40*(5-6), 311-339.

Smith, P. J., Blumenthal, J. A., Babyak, M. A., Georgiades, A., Hinderliter, A., & Sherwood, A. (2007). Effects of exercise and weight loss on depressive symptoms among men and women with hypertension. *Journal of Psychosomatic Research, 63*(5), 463-469.

Sneed, J. R., & Culang-Reinlieb, M. E. (2011). The vascular depression hypothesis: An update. *The American Journal of geriatric psychiatry, 19*(2), 99-103.

Stewart, A. L., MILLS, K. M., King, A. C., Haskell, W. L., Gillis, D., & Ritter, P. L. (2001). CHAMPS physical activity questionnaire for older adults: Outcomes for interventions. *Medicine & Science in Sports & Exercise, 33*(7), 1126-1141.

Szuhany, K. L., Bugatti, M., & Otto, M. W. (2015). A meta-analytic review of the effects of exercise on brain-derived neurotrophic factor. *Journal of psychiatric research, 60*, 56-64.

Taylor, W. D., Aizenstein, H. J., & Alexopoulos, G. S. (2013). The vascular depression hypothesis: mechanisms linking vascular disease with depression. *Molecular psychiatry, 18*(9), 963-974.

Thomas, A., Gallagher, P., Robinson, L., Porter, R., Young, A., Ferrier, I., & O'Brien, J. (2009). A comparison of neurocognitive impairment in younger and older adults with major depression. *Psychological Medicine, 39*(5), 725-733.

Thomas, A. J., Kalaria, R. N., & T O'Brien, J. (2004). Depression and vascular disease: What is the relationship? *Journal of affective disorders, 79*(1-3), 81-95.

Turner, A. D., Capuano, A. W., Wilson, R. S., & Barnes, L. L. (2015). Depressive symptoms and cognitive decline in older african americans: Two scales and their factors. *The American Journal of geriatric psychiatry, 23*(6), 568-578.

Vercambre, M.-N., Grodstein, F., Manson, J. E., Stampfer, M. J., & Kang, J. H. (2011). Physical activity and cognition in women with vascular conditions. *Archives of internal medicine, 171*(14), 1244-1250.

Vidoni, E. D., Johnson, D. K., Morris, J. K., Van Sciver, A., Greer, C. S., Billinger, S. A., Donnelly, J. E., & Burns, J. M. (2015). Dose-response of aerobic exercise on cognition: a community-based, pilot randomized controlled trial. *PloS one, 10*(7), e0131647.

Walsh, T. L., Homa, K., Hanscom, B., Lurie, J., Sepulveda, M. G., & Abdu, W. (2006). Screening for depressive symptoms in patients with chronic spinal pain using the SF-36 Health Survey. *The Spine Journal, 6*(3), 316-320.

Ware, J. E., Snow, K. K., Kosinski, M., & Gandek, B. (1993). *SF-36 health survey : manual and interpretation guide*. Health Institute, New England Medical Center.

Ware Jr, J. E. (2000). SF-36 health survey update. *Spine, 25*(24), 3130-3139.

Wassink-Vossen, S., Collard, R. M., Voshaar, R. C. O., Comijs, H. C., de Vocht, H. M., & Naarding, P. (2014). Physical (in) activity and depression in older people. *Journal of affective disorders, 161*, 65-72.

Wechsler, D. (1955). Wechsler adult intelligence scale (WAIS). *Journal of Consulting Psychology, 19*(4), 319-320.

Williams, I. C., Park, M. H., Tsang, S., Sperling, S. A., & Manning, C. (2018). Cognitive function and vascular risk factors among older African American adults. *Journal of immigrant and minority health, 20*(3), 612-618.

Williams, P. T., & Thompson, P. D. (2014). Increased cardiovascular disease mortality associated with excessive exercise in heart attack survivors. Mayo Clinic Proceedings,

World Health Organization. (2017). Depression and other common mental disorders: Global health estimates. *Geneva: World Health Organization*, 1-24.

Yohannes, A. M., Doherty, P., Bundy, C., & Yalfani, A. (2010). The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. *Journal of clinical nursing, 19*(19-20), 2806-2813.

Zhang, Y., Chen, Y., & Ma, L. (2018). Depression and cardiovascular disease in elderly: Current understanding. *Journal of Clinical Neuroscience, 47*, 1-5.

APPENDIX

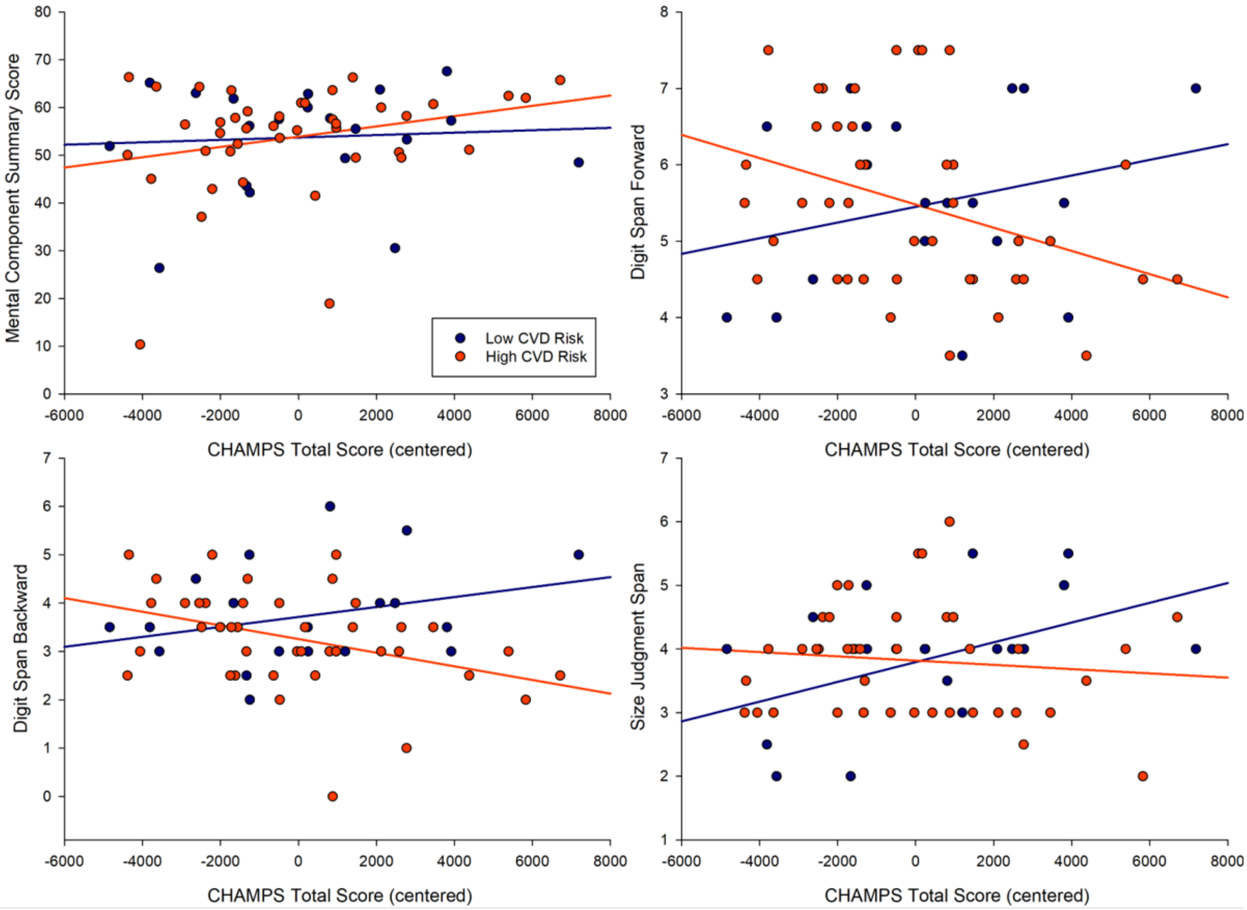

Figure 1. Aim 2 Regression Analyses