Université de Montréal

Impact de l'activité physique auto-rapportée sur les scores au MoCA chez les personnes âgées avec et sans maladie cardiovasculaire – une étude transversale

par
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Résumé

La prévalence des maladies cardiovasculaires (MCV) augmente au cours du vieillissement. Compte tenu du vieillissement démographique accéléré au Canada, nous assistons à une explosion du nombre d'individus présentant une MCV. Les maladies cardiovasculaires ont été associées à des troubles cognitifs et à des performances cognitives diminuées. Le Montreal Cognitive Assessment (MoCA) est un outil de dépistage rapide des troubles cognitifs fréquemment utilisé dans ce contexte. Par ailleurs, de nombreuses études suggèrent que la pratique d'activité physique (AP) pourrait compenser les déficits cognitifs associés aux maladies cardiovasculaires. À ce jour, peu d'études ont examiné les associations entre la présence ou l'absence de MCV, l'AP et les performances au MoCA. **Objectif :** Examiner les associations entre l'AP et la présence ou l'absence de MCV sur le score global du MoCA et ses sous-scores chez des participants âgés de 50 ans et plus avec et sans maladies cardiovasculaires. **Méthodes :** Deux cent vingt-cinq participants dont le statut cardiovasculaire a été obtenu ont rempli un questionnaire sur l'AP et complété le MoCA. Des régressions hiérarchiques ont été effectuées avec les caractéristiques sociodémographiques (âge, sexe, éducation; étape 1) suivies des niveaux d'AP et de la présence ou l'absence de MCV (étape 2) et de l'interaction entre l'AP et les MCV (étape 3) pour prédire quels facteurs sociodémographiques et/ou de santé étaient les plus liés aux performances cognitives. **Résultats :** La présence de MCV était significativement lié au score total du MoCA et au sous-score évaluant les fonctions exécutives. Une interaction significative entre l'AP et la présence de MCV a été observée à la tâche de fluence verbale. Chez les participants sans MCV, un plus haut niveau d'AP était associé à de meilleures performances. Cette relation n'était pas observée chez les patients avec MCV. **Conclusions :** Les résultats confirment la valeur ajoutée d'intégrer le statut cardiovasculaire en tant que variable prédictive

des performances au MoCA. Nos résultats suggèrent que l'AP pourrait avoir des effets limités sur les scores au MoCA chez les patients avec une MCV.

Mots clés : maladie cardiovasculaire, Montreal Cognitive Assessment, activité physique, neuropsychologie, régression hiérarchique

Abstract

Cardiovascular disease (CVD) prevalence increases with age. Given the accelerated demographic aging in Canada, we are witnessing an explosion in the number of individuals with CVD. CVD have been associated with cognitive impairment (CI) and, lower cognitive performances. The Montreal Cognitive Assessment (MoCA) is frequently used to screen for CI in CVD patients. Strong evidence suggests that practice of physical activity (PA) could compensate these CI. However, few studies have examined the associations between presence or absence of CVD, PA, and test scores on the MoCA. **Objective:** To examine the associations between PA and presence or absence of CVD on the MoCA's total score and subscores. **Methods:** Two hundred and twenty-five participants whose CVD status was obtained, completed a self-reported questionnaire of PA, and the MoCA. Hierarchical regressions were carried out with sociodemographic characteristics (age, sex, and education; step 1) followed by PA levels and presence or absence of CVD (step 2) and the interaction between CVD and PA (step 3) to predict which sociodemographic and/or health factors were most related to cognitive performance. **Results:** CVD presence was significantly related to the MoCA's total score and the executive function subscore. A significant interaction between PA and CVD presence was observed on the verbal fluency task. In participants without CVD, high PA levels were associated with better performances. This association was not found in participants with CVD. **Conclusions:** The results confirm the added value of integrating presence or absence of CVD as a predictor of performance on the MoCA. Our results also suggest that PA may have limited effects on MoCA scores in patients with CVD.

Key words: cardiovascular disease, Montreal Cognitive Assessment, physical activity, neuropsychology, hierarchical regression

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Liste des sigles et abréviations

ALFI-MMSE: Adult Lifestyle and Function Interview-Mini Mental State Examination

CI: Cognitive Impairment

CVD: Cardiovascular Disease

GDS: Geriatric Depression Scale

MMSE: Mini Mental State Examination

MoCA: Montreal Cognitive Assessment

PA: Physical Activity

PASE: Physical Activity Scale for the Elderly

STAI: State Trait Anxiety Inventory

WHO: World Health Organisation

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Avant-propos

L'article empirique faisant l'objet de cet essai doctoral est présenté dans les prochaines pages du document. Il sera soumis à la revue **Aging, Neuropsychology, and Cognition** sous forme de **Research Article** à l'automne 2022. L'article comprend une brève mise en contexte théorique, une définition des objectifs et des hypothèses de l'étude, la description de la méthodologie employée, une présentation des résultats ainsi qu'une discussion portant sur ceux-ci. Il est présenté sous la forme qui sera soumise au journal scientifique mentionné ci-haut.

Article

Associations between cardiovascular disease status, self-reported physical activity and MoCA scores in adults aged 50 and older

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Abstract

Cardiovascular disease (CVD) prevalence increases with age. Given the accelerated demographic aging in Canada, we are witnessing an explosion in the number of individuals with CVD. CVD have been associated with cognitive impairment (CI) and, lower cognitive performances. The Montreal Cognitive Assessment (MoCA) is frequently used to screen for CI in CVD patients. Strong evidence suggests that practice of physical activity (PA) could compensate these CI. However, few studies have examined the associations between presence or absence of CVD, PA, and test scores on the MoCA. **Objective:** To examine the associations between PA and presence or absence of CVD on the MoCA's total score and subscores. **Methods:** Two hundred and twenty-five participants whose CVD status was obtained, completed a self-reported questionnaire of PA, and the MoCA. Hierarchical regressions were carried out with sociodemographic characteristics (age, sex, and education; step 1) followed by PA levels and presence or absence of CVD (step 2) and the interaction between CVD and PA (step 3) to predict which sociodemographic and/or health factors were most related to cognitive performance. **Results:** CVD presence was significantly related to the MoCA's total score and the executive functions subscore. A significant interaction between PA and CVD presence was observed on the verbal fluency task. In participants without CVD, high PA levels were associated with better performances. This association was not found in participants with CVD. **Conclusions:** The results confirm the added value of integrating presence or absence of CVD as a predictor of performance on the MoCA. Our results also suggest that PA may have limited effects on MoCA scores in patients with CVD.

Key words: cardiovascular disease, Montreal Cognitive Assessment, physical activity, neuropsychology, hierarchical regression

Introduction

Demographic aging of the population is ongoing in Canada and is mirrored in the increasing number of older adults living with chronic diseases, such as cardiovascular diseases (CVD). Recent estimates suggest that 2.4 million Canadians over the age of 20 years old have a CVD (Public Health Agency of Canada, 2018). CVD are conditions that affect the heart and/or blood vessels. Initiated by the presence of cardiovascular risk factors, they eventually pinnacle to end-stage heart disease (Chrysant, 2011; Dzau et al., 2006). This chain of pathophysiological events described as the CVD continuum (Dzau et al., 2006) has many implications for the day-to-day functioning of older adults with CVD as it negatively affects the brain structures and neurocognitive functioning (Waldstein & Elias, 2015). Accordingly, CVD have been consistently associated with the development of cognitive impairment (CI) in older adults with prevalence estimates as high as 40% (Abete et al., 2014; Cannon et al., 2017; Deckers et al., 2017; Eggermont et al., 2012; Stefanidis et al., 2018; Waldstein et al., 2010).

In fact, as early as the presence of CVD risk factors (hypertension, diabetes mellitus, dyslipidemia, and obesity), mild to moderate cognitive decrements as well as accelerated cognitive decline in processing speed, cognitive flexibility (executive function), and memory have been shown cross-sectionally and longitudinally (van den Berg et al., 2009; Yaffe et al., 2020). Further along the chain of pathophysiological events, middle-aged and elderly men presenting with sub-clinical (presence of atherosclerosis and/or arterial stiffness) or prevalent CVD (coronary heart disease, and stroke) showed lower performances in visual episodic memory and on the Mini Mental State Examination compared to their healthy counterparts (Muller et al., 2007). Interestingly, measures of atherosclerosis were related to poorer performances in executive functioning and processing speed (Muller et al., 2007). This indicates that deficits in

specific cognitive domains emerge as early as the sub-clinical stages of CVD (Muller et al., 2007). Similarly, patients with coronary heart disease, congestive heart failure, and stroke are shown to have lower performances in short term/working memory, processing speed, inhibition, cognitive flexibility, verbal fluency, and episodic memory compared to healthy-matched controls (Gayda et al., 2017; Narvaez Linares et al., 2021; Singh-Manoux et al., 2003; Singh-Manoux et al., 2008; Verhaegen et al., 2003). More importantly, longitudinal analyses of these cognitive decrements in individuals with CVD show worsened performances along with the severity of the disease and steeper decline over the years (Singh-Manoux et al., 2008; Stephan et al., 2017; Verhaegen et al., 2003). For instance, Singh-Manoux et al.'s (2008) study show that, in increments of five years after a first CVD event, men have decreasing scores in reasoning, vocabulary, semantic fluency and on a global cognition task, whereas women have lower scores in semantic fluency even after controlling for CVD medication. Thus, targeting early prevention and treatment of CVD could help alleviate these CI through pharmacological and non-pharmacological interventions. Among non-pharmacological interventions, strong evidence supports physical activity, a modifiable risk factor, to maintain and improve cognitive functioning in older adults (Bherer, 2015; Livingston et al., 2020).

Physical activity (PA) refers to any movement produced by the contraction of skeletal muscles leading to a substantial increase in energy expenditure (Caspersen et al., 1985). Higher levels of PA have been associated with reduction of atherosclerotic risk factors such as hypertension, diabetes mellitus, dyslipidemia, obesity, and incidence of CVD (Thompson et al., 2003). Furthermore, PA is a key component in CVD management in cardiac rehabilitation settings. Regarding the brain, strong evidence show that PA directly affects its aging through structural and functional changes (Badji, Sabra, et al., 2019; Hayes et al., 2014; Stillman et al.,

2016). Indeed, in healthy older adults, higher levels of PA are related to higher volume of gray matter in the frontal, temporal, occipital lobes, enthorinal cortex and hippocampus (Erickson et al., 2010; Papenberg et al., 2016), with higher brain volume, decreased brain aging (Spartano et al, 2019) and better cerebral perfusion (Zlatar et al., 2019). In patients with CVD, comparable results have been found following a 6-month cardiac PA rehabilitation program. Recovery of gray matter in regions affected by CVD was found in the superior frontal gyrus, the superior temporal gyrus, the posterior cerebellum, and the supplementary motor area (Anazodo et al., 2013).

Given the reported impacts on the brain, it is to be expected that PA will have a beneficial effect on cognitive functions. In fact, Yaffe and colleagues (2020) reported that in healthy older women whose number of steps climbed was higher, the risk of obtaining a diminished performance on the Mini Mental State Examination (MMSE) over an 8-year period was lower. In men, analogous conclusions were also found, as decreasing PA duration or intensity over a decade was associated with a diminished performance of 1.7 to 2.3 points on the overall MMSE score (van Gelder et al., 2004). These results were found even when controlling for previous MMSE performance, and various CVD risk factors (van Gelder et al., 2004). When looking at specific cognitive domains, analyses of multiple studies show that engaging in PA leads to cognitive preservation of abilities in processing speed, executive functioning, and episodic memory (Barnes et al., 2003; Zhu et al., 2017). Although not all studies show positive associations between PA, CVD populations and cognition (Gayda et al., 2017), various studies report maintenance or more efficient cognitive functioning associated with PA. In a sample of obese individuals, those with higher levels of fitness (which can be improved through higher levels of PA) had better short-term memory and executive functions performances than obese

patients with lower levels of fitness. High-fit obese individuals also had similar cognitive functioning to non-obese patients (Boidin et al., 2020). A population-based study shows that CVD patients who engage in higher levels of PA have better visuoconstructive, executive function and episodic memory performances than those reporting lower levels of PA even after taking into consideration demographic characteristics, CVD status, medication, pain, and depression (Eggermont et al., 2009). As for increased cognitive efficiency regarding PA, Talamonti and colleagues (2021) results suggest that participation in regular PA is associated with a decreased task-related cortical activation while improving performance on a working memory task in individuals with multiple CVD risk factors. In line with these results, significant improvements in processing speed, episodic memory, attention, and executive function were found in CVD patients following a 6-week cardiac rehabilitation program (Moriarty et al., 2020). Moreover, diminished oxygen demand in the prefrontal cortex was related to augmented executive function and global cognition scores suggesting improved neural efficiency following the increase of PA (Moriarty et al., 2020). Altogether, these findings highlight the beneficial effects of PA on cardiovascular health, brain health, and cognition.

As identifying CVD-related cognitive changes is becoming a priority for neuropsychologists and other health professionals (Hachinski et al., 2006), before referral to neuropsychologist for in-depth cognitive assessments, early detection of cognitive deficits can be done by many health professionals. For this purpose, usage of screening instruments and their normative data are therefore essential to rapidly characterize and adequately interpret performance changes or test scores (Bauer et al., 2011; Hachinski et al., 2006; Shirk et al., 2011). The Montreal Cognitive Assessment (MoCA; Nasreddine & Patel, 2016; Nasreddine et al., 2005) is a screening instrument that can assess several cognitive domains in a time efficient manner.

Indeed, visuospatial/visuoconstructive abilities, executive functions, episodic memory, attention/working memory, language, and orientation can be assessed (Nasreddine et al., 2005). Furthermore, the MoCA (Bauer et al., 2011; Ghafar et al., 2019; Nasreddine & Patel, 2016; Nasreddine et al., 2005) shows great sensitivity for the identification of vascular CI. However, it does not account for the presence of CVD and consideration of lifestyle habits, such as physical activity, is still lacking.

To our knowledge, two independent research groups have separately studied the associations between CVD or PA with the MoCA scores. Gagnon and colleagues (2022; 2021) have conducted two studies using the MoCA. Along the CVD continuum, Gagnon, and colleagues (2021) found that coronary heart disease and heart failure are related to impairments in executive function (verbal fluency), episodic memory, and orientation performances on the MoCA. Furthermore, in their videoconference-based normative data for the MoCA, Gagnon et al. (2022) found that lower age, and higher level of education but not CVD and sex, were related to the global score. Both previous studies were conducted without any regards to PA. Whereas, Innocenti and colleagues (2017) have identified that self-reported PA predicts the MoCA global score, executive, language, visuospatial/visuoconstructive and attention/working memory subscores in men without CVD.

The aim of this study was to determine if and to which extent the presence of both CVD, and self-reported PA are associated with global score and subscores on the MoCA in secondary analyses of previous work from our group (Gagnon et al., 2022). We hypothesize that both the presence of CVD and PA will predict the global MoCA score and the executive function, episodic memory, and attention/working memory subscores in a sample of older adults with and without CVD. We expect that PA will also have a predictive power and potentially interact with

CVD to predict MoCA scores. As this study was conducted during the COVID-19 pandemic, measures of PA and CVD status were self-reported.

Materials and methods

Participants

The sample included adults aged 50 years and over taking part in two registered clinical trials. Their goals were to investigate the benefits of home-based physical exercise and cognitive training in two different populations during the COVID-19 pandemic with remote assessments and trainings: the COVEPIC trial [NCT04635462] (Dupuy et al., 2021; participants with low or high cardiovascular risk) and the COVEPICARDIO trial [NCT04661189] (Besnier et al., 2021; participants with stable CVD). Both trials were approved by the Montreal Heart Institute's ethics board. Study participants provided consent prior to the start of the study.

Inclusion criteria for our sample were as follows: 1) adults over the age of 50 years old; 2) access to Internet and to a tablet or computer; 3) no contraindication to exercise training; 4) CVD participants had to have: stable coronary heart disease, stable chronic heart failure, corrected valvular disease or atrial fibrillation with a low risk profile. Participants were excluded if they had: 1) significant cognitive impairment operationalized by a score $\leq$ 19/23 on a modified home-based version of the ALFI-MMSE (Roccaforte et al., 1992); 2) severe respiratory disease (e.g., severe asthma, COPD, COVID-19); 3) non-cardiopulmonary limitation to exercise training (e.g., severe arthritis) or severe exercise intolerance.

The original sample contained 250 participants. Twenty participants were excluded due to missing data (e.g., MoCA scores or predictors: age, sex, number of years of education, PA) and five due to extreme data ($\pm$3.29 standard deviation for the variables of interest; Tabachnick et Fidell, 2019). The final sample for this study was composed of 225 participants.

Procedures and materials

Following a pre-screening of inclusion and exclusion criteria, participants were contacted by research assistants during a preliminary phone call to review the consent form, provide oral consent and were administered a modified home-based version of the ALFI-MMSE (Gagnon et al., 2022; Roccaforte et al., 1992). Participants were invited to subsequently give their written consent by email. On a following appointment, general cognitive functioning was assessed remotely with the French 7.1 version of the MoCA (Nasreddine et al., 2005). Participants also had to fill self-reported questionnaires on their medical history, current mood, anxiety, and PA levels through online forms.

MoCA

Slights adaptations (reported elsewhere; Gagnon et al., 2022) were made to the original version of the MoCA because of its remote administration. Calculation of the MoCA subscores differed from the original version. Items were grouped according to the cognitive domains they represented (Lezak et al., 2004). Thus, calculation of the visuospatial/visuoconstructive abilities, executive functions, and language subscore were modified. The visuospatial/visuoconstructive abilities were assessed by the copy of a 3-dimensional cube (1 point) and the drawing of a clock (3 points). Executive functions were assessed by an oral recitation of the short trail B (1 point), a phonemic fluency task (1 point) and a verbal abstraction exercise (2 points). Language was assessed by the repetition of two syntactically complex sentences (2 points) and the naming of three animals (3 points). Memory abilities were assessed through immediate and delayed recall of a short list of words (5 points). Attention, concentration and working memory were assessed by a target detection exercise (1 point), a subtraction task (3 points) and a forward and backward digit span exercise (2 points). Finally, orientation in time and space was evaluated for a total of 6 points for a total MoCA score on 30 points (Nasreddine et al., 2005). The 1-point correction for

school attendance under 12 years was not applied since number of years of education was a predictive variable.

Mood and anxiety

Mood and anxiety were assessed with the Geriatric Depression Scale for the elderly (GDS; Yesavage, 1988) and the State Trait Anxiety Inventory (STAI; Spielberger et al., 1971). Since participants were recruited from May 2020 to August 2022, we wanted to document the psychological functioning of our sample during the COVID-19 pandemic.

Physical activity

The Physical Activity Scale for the Elderly (PASE; Washburn et al., 1993) was administered to participants through online forms to measure their level of PA over the last 7-days. The PASE is a validated questionnaire comprising 10 items and designed specifically for a population over the age of 65. The questionnaire assesses PA levels according to different types of PA such as walking, leisure activities, moderate-intensity exercise, vigorous-intensity exercise, muscular endurance, domestic activities, taking care of a loved one and professional activities. The total score varies between 0 and 793; higher scores indicating higher PA levels. The individual total PASE score was calculated by multiplying the amount of time spent in each activity by the item weights and summing over all activities.

Statistical analyses

No imputations were done as participants with missing data were excluded from the sample. Descriptive statistics were performed using means, standard deviations, and frequencies. After examination of assumptions (normality, skewness, kurtosis, multicollinearity, and singularity), a three-stage hierarchical regression was carried out with sociodemographic characteristics (age, sex, and education) entered first, followed by PA levels and CVD status

(presence or absence) in a second step as independent variables, and in a third step, the interaction between PA levels and CVD status (see Figure 1). Following inspection of residuals, assumptions of homodasticity, and normality were met for the regressions that were statistically significant. Moreover, one-way ANOVAs were performed on the sociodemographic characteristics (age and number of years of education), PASE score, MoCA total scores and subscores and the components of the executive functions subscore to examine differences between CVD and non-CVD participants.

Results

As shown in Table 1, 225 participants were included in the statistical analyses, 110 of whom had a CVD. The whole sample had a mean age of 66.19 years old and 16.58 years of education, near equivalent to a university degree in Quebec, Canada. Participants had a mean MoCA score of 26.44 (range: 19 to 30), non-CVD participants had a higher total score (see Supplementary Table 1). The mean PASE score was 147.71 (range: 27.20 to 344.27), with CVD participants having greater PA levels than non-CVD participants (see Supplementary Table 1). Self-reported medical and psychological characteristics can be found in Table 1. No significant correlation was found between psychological symptoms and cognitive performance (state anxiety: r= -0.092, p=0.175; trait anxiety: r= -0.110, p= 0.105; depressive symptoms: r= -0.110, p=103). Hypertension and dyslipidemia were the most prevalent CVD risk factors reported in all participants (CVD and non-CVD participants). In the CVD group, cerebral, peripheral, or coronary atherosclerosis (17.3%) and atrial fibrillation (14.5%) were the most frequent diseases reported.

Global score

As seen in Table 2, sociodemographic characteristics (age, sex, and number of years of education) were significant predictors of the global MoCA score, R^2= 0.179, F (3,221) = 16.109, p < 0.001. All sociodemographic variables contributed to the variance. Introducing CVD status and PA levels in step 2 resulted in a significant increment in R^2, R^2= 0.226, F (5,219) = 12.767, p <0.001. Age, number of years of education, and CVD status were significant predictors. The unstandardized beta for CVD status indicated that the variable was associated with a decrement of 1.15 points on the total score. Addition of the interaction between CVD status and PA levels in step 3 did not significantly increase the prediction of the MoCA global score as R^2 remained stable, R^2= 0.227, F (6,218) = 10.693, p< 0.001.

Subscores

When looking at the six MoCA subscores (see Table 3 to Table 8), only two models reached significance, namely visuospatial/visuoconstructive abilities, F (6, 218) = 3.678, p=0.002, and executive functions, F (6,218) = 6.248, p<0.001. Memory, F (6,218) = 1.293, p =0.261; attention/working memory, F (6,218) = 1.187, p =0.314; language, F (6,218) = 0.967, p =0.448; , and orientation, F (6,218) = 1.041, p =0.399 subscores were not predicted by any of the sociodemographic characteristics nor by CVD status or PA levels, or interaction between CVD status and PA levels.

For the visuospatial/visuoconstructive abilities subscore (see Table 3), the model with sociodemographic characteristics reached significance in step 1, R^2= 0.090, F (3,221) = 7.291, p<0.001. Age and number of years of education contributed to the variance. The second step model with CVD status and PA was significant, R^2= 0.091, F (5,219) = 4.376, p<0.001. However, addition of CVD status and PA levels did not reliably change R^2. In step 3, although

the model reached significance, adding the interaction of CVD status and PA levels to the prediction of the subscore by age and number of years of education did not significantly change R^2, R^2= 0.092, F (6,218) = 3.678, p= 0.002.

For the executive functions subscore (see Table 4), entry of sociodemographic characteristics reached significance in step 1, R^2= 0.080, F (3,221) = 6.385, p<0.001. Sex and number of years of education contributed to the variance. In step 2, introduction of CVD status and PA levels resulted in a significant increment of R^2 in predicting the subscore, R^2= 0.143, F (5,219) = 7.286, p < 0.001. Number of years of education and CVD status were significant predictors. In the third step model, addition of the interaction between CVD status and PA levels to the prediction of the subscore by number of years of education and CVD status was significant R^2= 0.147, F (6,218) = 6.248, p< 0.001. Yet, adding the interaction term did not significantly change R^2.

Constituents of the executive functions subscore: abstraction, short trail B and verbal fluency tasks

Because the executive functions subscore was significantly predicted by CVD status and various studies have identified distinctive constituents of executive functions as related to CVD, additional statistical analyses were run. Three steps (step 1: age, sex, and number of years of education; step 2: CVD status and PA levels; step 3: interaction between CVD status and PA levels hierarchical regressions were done on the three constituents (tasks) that make up the executive functions subscore (see Table 9 to Table 11).

For the short trail B task (see Table 9), contribution of sociodemographic characteristics was significant in step 1, R^2= 0.068, F (3,221) = 5.349, p < 0.001. In fact, only the number of years of education was a major contributor to the variance. In step 2, introduction of CVD status

and PA levels resulted in a significant increment of R^2, R^2= 0.141, F (5,219) = 7.180, p<0.001. Number of years of education and CVD status were significant predictors. Although, the third model containing the interaction between CVD status and PA levels was significant, R^2= 0.141, F (6,218) = 5.958, p<0.001, it did not reliably improve R^2.

For the number of words provided on the verbal fluency task (see Table 10), the model containing sociodemographic characteristics was unsignificant, R^2= 0.023, F (3,221) = 1.742, p = 0.159. None of the sociodemographic variables predicted the number of words evoked during the task. In step 2, introduction of CVD status and PA levels significantly improved R^2, $R^{2=}$0.050, F (5,219) = 2.291, p = 0.047. CVD status was a significant contributor. On the third step, adding the interaction of CVD status and PA levels to the prediction of number of words evoked reached significance and reliably improved R^2, R^2= 0.071, F (6,218) = 2.784, p= 0.013. More precisely, in participants without CVD, higher levels of PA were associated with more words evoked during the verbal fluency task. The inverse relation was observed in participants with CVD (see Figure 2).

Finally, for the abstraction task (see Table 11), the first model containing sociodemographic characteristics reached significance, R^2= 0.065, F (3,221) = 5.113, p < 0.002. Number of years of education was the only significant contributor. In step 2, adding CVD status and PA levels to the prediction did not reliably improve R^2 although the model was significant, R^2= 0.078, F (5,219) = 3.723, p<0.003. When the interaction between CVD status and PA levels was added to the prediction of the abstraction task score in step 3, R^2 improved, R^2= 0.082, F (6,218) = 3.223, p= 0.005. Even so, adding the interaction between CVD status and PA levels did not improve R^2 in a significant manner.

Discussion

The aim of our study was to determine if and to which extent the presence of CVD and self-reported PA levels were associated with MoCA scores. Our findings suggest that CVD status, but not PA, is significantly related to the MoCA total score and the executive functions subscore. More precisely, we observed that CVD was associated with lower global MoCA scores, lower number of words generated during the verbal fluency task, as well as a diminished score on the short trail task (see Supplementary Table 1). More importantly, we have showed that in CVD patients, high PA levels were associated with worse performance during the verbal fluency task. In non-CVD participants, the opposite relationship was found. Finally, neither CVD status nor PA levels were related to the visuospatial/visuoconstructive abilities, language, attention/working memory, orientation, and episodic memory subscores.

Our results are in line with previous studies reporting lower cognitive performances in patients with CVD, in measures of global cognition (Gagnon et al., 2021; Muller et al., 2007; Singh-Manoux et al., 2008) and executive functions (Gayda et al., 2017; Narvaez Linares et al., 2021; Singh-Manoux et al., 2008; van den Berg et al., 2009; Verhaegen et al., 2003). When looking at the predictive ability of CVD status on the total MoCA score, our data suggests that if an individual has a CVD it is associated with a diminished performance of 1.15 points on the overall MoCA score when age and number of years of education are considered. Although this difference might not be clinically significant, it highlights the importance of considering CVD status when interpreting screening instruments' scores. Moreover, our results confirm the sensitivity of the MoCA in detecting global cognition and executive functions decrements in a sample of adults aged 50 and over with cardiovascular risk factors and CVD.

Clinicians' knowledge and identification of these CVD-related scores is of importance as deficits in global cognition and executive functions can affect self-care management in CVD populations (Riley & Arslanian-Engoren, 2013). In fact, disease management can become a challenge with poorer organisational skills, planning, and self-regulation abilities, as well as less efficient memory retrieval strategies (Riley & Arslanian-Engoren, 2013). All these higher order executive functions (organisation, planning, self-regulation, and information retrieval strategies; Lezak et al., 2004) tap into cognitive processes that have been highlighted to be sensitive to CVD presence (executive control abilities and cognitive flexibility) and which we have also found to be related to CVD.

Underlying the associations between CVD and lower cognitive performances are mechanisms involved in the heart-brain continuum hypothesis (Abete et al., 2014). For instance, cerebral hypoperfusion through reduced cerebral blood flow (de la Torre, 2012) as well as white and gray matter degradation (Badji, Noriega de la Colina, et al., 2019; Badji, Sabra, et al., 2019; Moroni et al., 2018) have been identified and correlated with lower cognitive functioning in older adults (Badji, Noriega de la Colina, et al., 2019).

Contrary to our hypotheses, CVD status was not related to the episodic memory subscore. A good proportion of studies or reviews reporting lower performances in this cognitive domain tend to do so in heart failure participants (Bauer et al., 2011; Vogels et al., 2007). In our sample, only 9 participants (4%) reported having an implantable defibrillator or permanent pacemaker, indicating greater severity of CVD. Therefore, it could be that the participants clinically impaired enough to influence these MoCA subscores were not numerous enough in our sample.

Given the large amount of evidence in the existing literature, we expected that PA would predict cognitive performance on the MoCA. Surprisingly and in contrast to various study

findings, PA was not associated with the total score or any of the screening instrument's subscores. Only one of our results was associated with the PASE score. Our data showed that higher levels of PA was associated with higher number of words evoked during the verbal fluency task in non-CVD participants. To our surprise, the opposite relationship was found for CVD participants (fewer words evoked with higher PA levels). Similarly, in coronary heart disease stable patients engaging in regular PA, no beneficial effect of PA was found on cognitive performances (Gayda et al., 2017). Gayda, and colleagues (2017) have highlighted that irreversible changes in the cerebral vasculature could have occurred with the increased severity of the disease resulting in diminished cognitive performances that PA cannot counteract. Moreover, the same authors have argued that optimal pharmacologic therapy could boost vascular function to a maximum, without any room for PA to exert its beneficial effects on cognition. Gayda et al. (2017) findings could explain the results we have obtained. Neither pharmacological treatments nor severity of CVD were considered in the present analyses, thus warranting further examination in other samples of older adults with and without CVD.

Another possible explanation for our lack of findings could reside in participant characteristics. Compared to other studies using the PASE as a measure of PA (Eggermont et al., 2009; Ottenbacher et al., 2014), our participants had greater PA levels (mean PASE score of 147.71) and were younger (mean age of 66 years old). In the MOBILIZE Boston Study (Eggermont et al., 2009), authors have found significant associations between the highest quartile of PASE scores (score over 137) and executive functioning in older adults with a mean age of 78 years old. Ottenbacher and its colleagues (2014) reported that older adults (mean age of 74 years old) who had PASE scores in the third and fourth quartiles (scores over 85 and 132) showed slower general cognitive decline over 14 years using the MMSE. In line with these

results is the moderator model (Stones et Kozma, 1988), where benefits of PA on cognition could be more apparent in oldest-old adults (Boucard et al., 2012). Thus, our non-significant findings could be partly explained by our sample's age and greater PA levels.

At last, it is worth mentioning that the PASE measures PA over a period of 7 days. Even though self-reported lifetime questionnaires of PA pave way for challenges such as recall errors (Sallis & Saelens, 2000), and social desirability (Adams et al., 2005; Brenner & DeLamater, 2013), they could better reflect PA's long term beneficial effects on cognition in a sample of older adults with and without CVD.

Study limitations

It is important to note that the findings of our study are limited by its cross-sectional design, therefore, we cannot interpret them as causal. Moreover, since our study was based on an analysis of secondary data, it may not have been able to detect all the hypothesized effects. As previously stated, another limit of this study is that we did not consider pharmacological treatment or CVD severity as a moderator in the relationships that we studied. Nonetheless, the strength of this study resides in the added value of considering CVD status in the interpretation of cognitive screening instruments scores. Further studies in clinical populations should examine the contribution of health-related factors on neuropsychological test scores.

Conclusion

In this study, we demonstrated that the presence of CVD is a significant contributor of performance on the MoCA. More specifically, having a CVD was associated with decreased performance on the MoCA total score and executive functions subscore. We have also showed that higher PA was associated with greater scores at the executive component of the MoCA in non-CVD participants but not in those with CVD. The demand for early detection of cognitive

difficulties will significantly intensify following the accelerated aging of the population, and in parallel, the augmented prevalence of CVD. Knowledge of the extent to which the presence of CVD affects screening tests scores, and which cognitive domains are most sensitive to CVD is of interest for neuropsychologists working with cardio-geriatrics populations.

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Declaration of interest

The authors report no conflict of interest.

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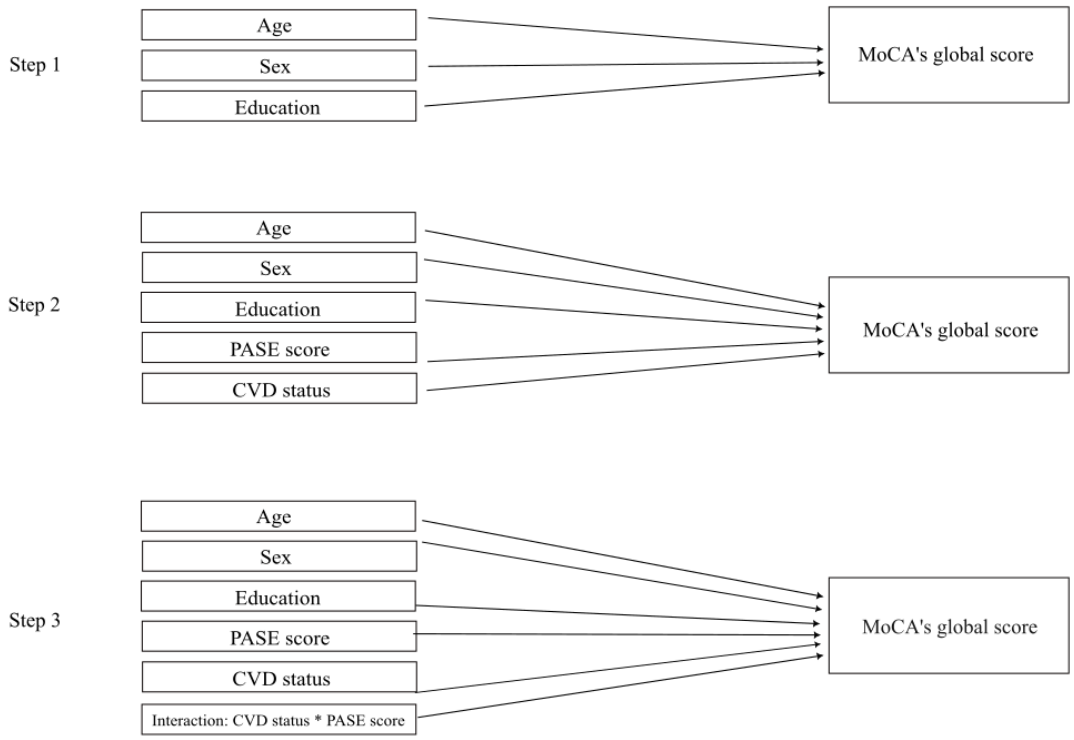
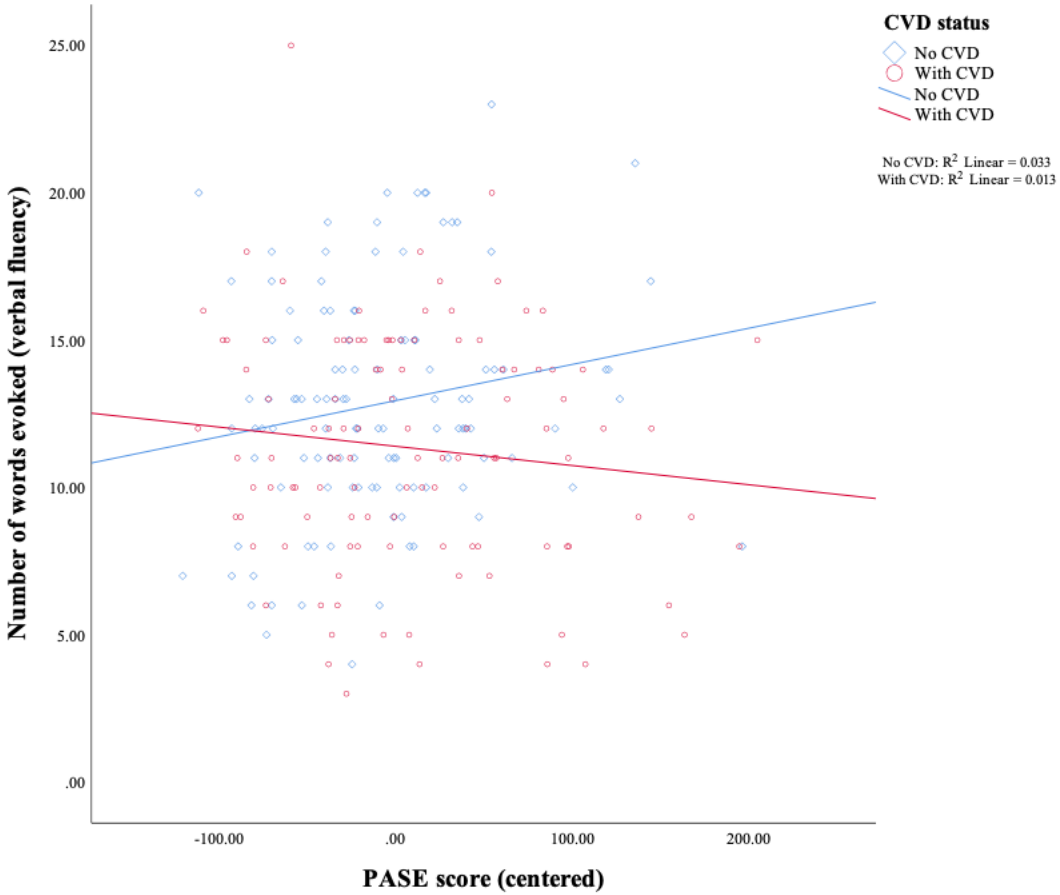
Figure 1. *Hierarchical entry of predictors on the MoCA's global score*



Note. Step 1, Step 2, and Step 3 were applied as the regression model for the global score and 6 subscores of the MoCA: executive functions, visuospatial/visuoconstructive, memory, language, attention/working memory, and orientation. CVD = cardiovascular disease; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly.

Figure 2. *Interaction between PA levels and CVD status on the number of words evoked during the verbal fluency task*



Note. CVD = cardiovascular disease; PASE = Physical Activity Scale for the Elderly; PASE score (centered) = values are centered to the mean of the PASE score.

Table 1

Characteristics of 225 participants included in study

Characteristics	Full sample (N=225) M (SD) or N (%)	Healthy participants (N=115) M (SD) or N (%)	CVD participants (N=110) M (SD) or N (%)
Age (years)	66.19 (8.00)	65.07 (7.98)	67.36 (7.90)
Women	120 (53.30%)	89 (77.40%)	31 (28.20%)
Education (years)	16.58 (3.19)	16.99 (2.75)	16.15 (3.55)
PASE score	147.71 (64.11)	138.73 (56.94)	157.11 (69.87)
GDS score	6.80 (5.94)	6.94 (5.28)	6.65 (6.61)
STAI-Trait	32.83 (9.72)	32.95 (9.02)	32.69 (10.48)
STAI-State	30.77 (8.98)	31.09 (7.94)	30.43 (10.02)
MoCA	26.44 (2.35)	27.25 (2.05)	25.60 (2.39)
Medical history			
Height (cm)	168.54 (28.17)	163.15 (13.22)	174.18 (37.21)
Weight (kg)	79.22 (18.28)	74.13 (16.09)	84.53 (18.98)
Neurological disorder	20 (8.8)	12 (10.3)	8 (7.3)
Polyneuropathy	4 (1.8)	3 (2.6)	1 (0.9)
Epilepsy	1 (0.4)	1 (0.9)	
Parkinson's disease			
Stroke, or transient cerebral ischemia	13 (5.8)	4 (3.4)	9 (8.2)
Hypertension	95 (42.0)	38 (32.8)	57 (51.8)
Hypertension medication	97 (42.9)	38 (32.8)	59 (53.6)
Systolic Blood Pressure[a] (mmHG)	125.15 (15.68)	127.10 (16.29)	123.37 (14.98)
Diastolic Blood Pressure[a] (mmHG)	75.56 (8.80)	76.38 (7.91)	74.81 (9.53)
Diabetes	40 (17.7)	16 (13.8)	24 (21.8)
Dyslipidemia	94 (41.6)	36 (31.0)	58 (52.7)
Cerebral, peripheral, or coronary atherosclerosis	19 (8.4)		19 (17.3)
Symptomatic aortic stenosis	3 (1.3)		3 (2.7)
Atrial fibrillation	16 (7.1)		16 (14.5)
Exertional arrythmia	4 (1.8)		4 (3.6)
Implantable defibrillator/ permanent pacemaker	9 (4.0)		9 (8.2)
Drug use	2 (0.9)	2 (1.7)	
Tobacco use	4 (1.8)	2 (1.7)	2 (1.8)
# of alcoholic drinks/week	4.21 (5.15)	4.39 (4.81)	4.01 (5.52)

Note. Adj = Adjusted; CVD = cardiovascular disease; GDS = Geriatric Depression Scale; MMSE = Mini Mental State Examination; mmHg = millimetre of mercury; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error; STAI = State Trait Anxiety Inventory.
[a] Means and standard deviations are reported for 149 participants.

Table 2

Hierarchical regression analysis predicting MoCA global score with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.179; 0.168	0.179***
Constant	27.016***	24.032	30.001	1.515			
Age	-0.060**	-0.097	-0.023	0.019	-0.205		
Sex	1.022***	0.428	1.615	0.301	0.217		
Education	0.173***	0.084	0.262	0.045	0.234		
Step 2						0.226; 0.208	0.046**
Constant	28.593***	25.114	32.072	1.765			
Age	-0.063**	-0.102	-0.025	0.019	-0.216		
Sex	0.423	-0.251	1.097	0.342	0.090		
Education	0.151***	0.063	0.239	0.045	0.205		
PASE score	-0.001	-1.794	-0.518	0.002	-0.246		
CVD status	-1.156***	-0.006	0.004	0.324	-0.023		
Step 3						0.227; 0.206	0.002
Constant	28.344***	24.790	31.899	1.803			
Age	-0.063**	-0.102	-0.025	0.019	-0.216		
Sex	0.445	-0.232	1.123	0.344	0.095		
Education	0.150***	0.062	0.238	0.045	0.204		
PASE score	0.001	-0.006	0.008	0.004	0.027		
CVD status	-1.151***	-1.790	-0.512	0.324	-0.245		
PASE score * CVD status	-0.003	-0.012	0.006	0.005	-0.065		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 3

Hierarchical regression analysis predicting MoCA's visuospatial/visuoconstructive subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.090; 0.078	0.090***
Constant	4.328***	3.170	5.486	0.588			
Age	-0.027***	-0.042	-0.013	0.007	-0.254		
Sex	-0.072	-0.302	0.158	0.117	-0.042		
Education	0.046**	0.011	0.080	0.017	0.168		
Step 2						0.091; 0.070	0.001
Constant	4.495***	3.106	5.884	0.705			
Age	-0.029***	-0.044	-0.013	0.008	-0.264		
Sex	-0.093	-0.362	0.176	0.137	-0.053		
Education	0.045*	0.009	0.080	0.018	0.164		
PASE score	0.000	-0.269	0.240	0.129	-0.008		
CVD status	-0.014	-0.002	0.001	0.001	-0.029		
Step 3						0.092; 0.067	0.001
Constant	4.421	3.001	5.841	0.720			
Age	-0.029***	-0.044	-0.013	0.008	-0.264		
Sex	-0.086	-0.357	0.185	0.137	-0.050		
Education	0.044*	0.009	0.079	0.018	0.163		
PASE score	0.000	-0.003	0.003	0.001	0.012		
CVD status	-0.013	-0.268	0.243	0.129	-0.007		
PASE score * CVD status	-0.001	-0.004	0.003	0.002	-0.052		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 4

Hierarchical regression analysis predicting MoCA's executive functions subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.080; 0.067	0.080***
Constant	2.239***	1.054	3.424	0.601			
Age	-0.004	-0.019	0.011	0.007	-0.035		
Sex	0.179***	-0.057	0.415	0.120	0.102		
Education	0.069***	0.034	0.105	0.018	0.251		
Step 2						0.143; 0.123	0.063***
Constant	2.409***	1.037	3.782	0.696	-0.014		
Age	-0.002	-0.017	0.014	0.008	-0.020		
Sex	-0.035	-0.301	0.231	0.135	0.228		
Education	0.063***	0.028	0.098	0.018	-0.285		
PASE score	0.001	-0.001	0.003	0.001	0.068		
CVD status	-0.502***	-0.753	-0.250	0.128	0.073		
Step 3						0.147; 0.123	0.004
Constant	2.264**	0.864	3.665	0.711			
Age	-0.002	-0.017	0.014	0.008	-0.014		
Sex	-0.022	-0.289	0.245	0.135	-0.012		
Education	0.062***	0.028	0.097	0.018	0.226		
PASE score	0.002	-0.001	0.005	0.001	0.148		
CVD status	-0.498***	-0.750	-0.247	0.128	-0.283		
PASE score * CVD status	-0.002	-0.005	0.002	0.002	-0.101		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 5

Hierarchical regression analysis predicting MoCA's memory subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
	Step 1						
Constant	3.614***	2.032	5.196	0.803		0.028; 0.014	0.028
Age	-6.206e-6	-0.020	0.020	0.010	0.000		
Sex	0.363	0.049	0.678	0.160	0.159		
Education	0.015	-0.032	0.062	0.024	0.041		
Step 2							
Constant	4.027***	2.132		0.961		0.031; 0.009	0.004
Age	-0.002	-0.023		0.011	0.074		
Sex	0.280	-0.087		0.186	0.081		
Education	0.011	-0.037		0.024	0.068		
PASE score	-0.001	-0.003		0.001	0.072		
CVD status	-0.116	-0.464		0.176	0.077		
Step 3						0.034; 0.008	0.003
Constant	4.194***	2.259	6.129	0.982			
Age	-0.002	-0.023	0.019	0.011	-0.014		
Sex	0.265	-0.103	0.634	0.187	0.116		
Education	0.012	-0.036	0.060	0.024	0.033		
PASE score	-0.002	-0.006	0.002	0.002	-0.111		
CVD status	-0.120	-0.468	0.228	0.176	-0.053		
PASE score * CVD status	0.002	-0.003	0.007	0.002	0.090		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 6

Hierarchical regression analysis predicting MoCA's attention/working memory subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.016; 0.003	0.016
Constant	6.486***	5.570	7.403	0.465			
Age	-0.011	-0.022	0.001	0.006	-0.130		
Sex	-0.084	-0.266	0.098	0.092	-0.064		
Education	-0.005	-0.032	0.022	0.014	-0.024		
Step 2						0.021; -0.001	0.004
Constant	6.735***	5.639	7.832	0.556			
Age	-0.012	-0.024	0.000	0.006	-0.145		
Sex	-0.139	-0.351	0.074	0.108	-0.105		
Education	-0.007	-0.035	0.020	0.014	-0.036		
PASE score	0.000	-0.002	0.001	0.001	-0.040		
CVD status	-0.082	-0.283	0.119	0.102	-0.062		
Step 3						0.032; 0.005	0.011
Constant	6.561***	5.445	7.676				
Age	-0.012	-0.024	0.000	0.074	-0.146		
Sex	-0.123	-0.336	0.089	0.108	-0.093		
Education	-0.008	-0.036	0.019	0.014	-0.040		
PASE score	0.001	-0.001	0.003	0.001	0.086		
CVD status	-0.078	-0.278	0.123	-0.059	0.077		
PASE score * CVD status	-0.002	-0.005	0.001	0.105	-0.163		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 7

Hierarchical regression analysis predicting MoCA's language subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.020; 0.006	0.020
Constant	4.867***	3.981	5.754	0.450			
Age	-0.008	-0.019	0.003	0.006	-0.098		
Sex	-0.010	-0.186	0.166	0.089	-0.008		
Education	0.020	-0.006	0.046	0.013	0.099		
Step 2						0.025; 0.002	0.005
Constant	4.637***	3.577	5.698	0.538			
Age	-0.006	-0.018	0.006	0.006	-0.073		
Sex	-0.007	-0.212	0.199	0.104	-0.005		
Education	0.021	-0.006	0.048	0.014	0.104		
PASE score	0.001	-0.001	0.002	0.001	-0.035		
CVD status	-0.045	-0.239	0.150	0.099	0.072		
Step 3						0.026; -0.001	0.001
Constant	4.579***	3.495	5.663				
Age	-0.006	-0.018	0.006	0.075	-0.074		
Sex	-0.002	-0.208	0.205	0.082	-0.001		
Education	0.021	-0.006	0.047	0.068	0.103		
PASE score	0.001	-0.001	0.003	0.109	0.115		
CVD status	-0.043	-0.238	0.152	0.078	-0.034		
PASE score * CVD status	-0.001	-0.003	0.002	0.106	-0.056		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 8

Hierarchical regression analysis predicting MoCA's orientation subscore with sociodemographic characteristics (Step 1), physical activity and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Step 1						0.015; 0.001	0.015
Constant	5.956***	5.655	6.257	0.153			
Age	-0.002	-0.005	0.002	0.002	-0.058		
Sex	0.024	-0.036	0.084	0.030	0.056		
Education	0.005	-0.004	0.014	0.005	0.076		
Step 2						0.024; 0.002	0.009
Constant	6.007***	5.648	6.367	0.182			
Age	-0.002	-0.006	0.002	0.002	-0.081		
Sex	0.034	-0.035	0.104	0.035	0.079		
Education	0.005	-0.004	0.014	0.005	0.077		
PASE score	0.000	-0.001	0.000	0.000	0.087		
CVD status	0.037	-0.029	0.103	0.033	-0.070		
Step 3						0.028; 0.001	0.004
Constant	6.042***	5.675	6.408	0.186			
Age	-0.002	-0.006	0.002	0.002	-0.081		
Sex	0.031	-0.039	0.101	0.035	0.072		
Education	0.005	-0.004	0.014	0.005	0.079		
PASE score	0.000	-0.001	0.000	0.000	-0.146		
CVD status	0.037	-0.029	0.102	0.033	0.085		
PASE score * CVD status	0.000	0.000	0.001	0.000	0.097		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 9

Hierarchical regression predicting the short trail B score with sociodemographic characteristics (Step 1), PA and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Short trail B							
Step 1						0.068; 0.055	0.068**
Constant	0.818**	0.321	1.315	0.252			
Age	-0.005	-0.012	0.001	0.003	-0.118		
Sex	0.078	-0.021	0.177	0.050	0.106		
Education	0.021**	0.006	0.035	0.007	0.178		
Step 2						0.141; 0.121	0.073***
Constant	1.001***	0.428	1.574	0.291			
Age	-0.005	-0.011	0.001	0.003	-0.112		
Sex	-0.030	-0.140	0.081	0.056	-0.040		
Education	0.017*	0.003	0.031	0.007	0.147		
PASE score	0.000	-0.001	0.001	0.000	0.029		
CVD status	-0.230***	-0.335	-0.125	0.053	-0.314		
Step 3						0.141; 0.117	0.000
Constant	0.996***	0.410	1.582	0.297			
Age	-0.005	-0.011	0.001	0.003	-0.112		
Sex	-0.029	-0.141	0.083	0.057	-0.040		
Education	0.017*	0.002	0.031	0.007	0.147		
PASE score	0.000	-0.001	0.001	0.001	0.036		
CVD status	-0.230***	-0.335	-0.125	0.053	-0.313		
PASE score * CVD status	-6.876e-5	-0.002	0.001	0.001			

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 10

Hierarchical regression predicting the number of words (verbal fluency task) with sociodemographic characteristics (Step 1), PA and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Verbal fluency (# of words)							
Step 1						0.023; 0.010	0.023
Constant	14.073***	8.563	19.583	2.796			
Age	-0.054	-0.123	0.014	0.035	-0.110		
Sex	0.381	-0.714	1.476	0.556	0.048		
Education	0.086	-0.077	0.250	0.083	0.069		
Step 2						0.050; 0.028	0.027*
Constant	16.017***	9.496	22.538	3.309			
Age	-0.058	-0.130	0.014	0.036	-0.116		
Sex	-0.382	-1.645	0.882	0.641	-0.048		
Education	0.059	-0.106	0.223	0.084	0.047		
PASE score	-0.001	-0.010	0.008	0.004	-0.014		
CVD status	-1.488*	-2.684	-0.292	0.607	-0.187		
Step 3						0.071; 0.046	0.021*
Constant	14.520***	7.926	21.114	3.346			
Age	-0.058	-0.130	0.013	0.036	-0.118		
Sex	-0.248	-1.505	1.009	0.638	-0.031		
Education	0.052	-0.111	0.216	0.083	0.042		
PASE score	0.010	-0.003	0.023	0.007	0.165		
CVD status	-1.454*	-2.640	-0.269	0.601	-0.183		
PASE score * CVD status	-0.019*	-0.035	-0.002	0.008	-0.231		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Table 11

Hierarchical regression predicting the abstraction score with sociodemographic characteristics (Step 1), PA and CVD status (Step 2), and interaction between CVD status and PA (Step 3)

	B	95% CI for B		SE B	β	R^2; R^2_{Adj}	ΔR^2
		LL	UL				
Abstraction							
Step 1						0.065; 0.052	0.065**
Constant	0.758*	0.037	1.479	0.366			
Age	0.004	-0.005	0.013	0.005	0.058		
Sex	0.0053	-0.091	0.196	0.073	0.049		
Education	0.041***	0.020	0.063	0.011	0.246		
Step 2						0.078; 0.057	0.013
Constant	0.711	-0.147	1.570	0.436			
Age	0.005	-0.004	0.015	0.005	0.076		
Sex	0.005	-0.161	0.171	0.084	0.005		
Education	0.040***	0.018	0.062	0.011	0.240		
PASE score	0.000	-0.001	0.002	0.001	0.058		
CVD status	-0.130	-0.288	0.027	0.080	-0.123		
Step 3						0.082; 0.056	0.003
Constant	0.633	-0.244	1.510	0.445			
Age	0.005	-0.004	0.015	0.005	0.076		
Sex	0.012	-0.155	0.179	0.085	0.011		
Education	0.040***	0.018	0.061	0.011	0.238		
PASE score	0.001	-0.001	0.003	0.001	0.128		
CVD status	-0.129	-0.286	0.029	0.080	-0.121		
PASE score * CVD status	-0.001	-0.003	0.001	0.001	-0.090		

Note. Adj = Adjusted; CVD = cardiovascular disease; CI = confidence interval; LL = lower limit; UL = upper limit; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation; SE = standard error.
*p< .05. ** p<.01. ***p<0.001.

Supplementary Table 1

Differences between non-CVD and CVD participants on the sociodemographic (age and years of education), PASE score, MoCA global score and subscores and components of the executive functions subscore (one-way ANOVA)

	Healthy participants (N=115) M (SD)	**CVD participants (N=110)** M (SD)	**F (1, 223)**	**p**
Age (years)	65.07 (7.98)	67.36 (7.90)	4.689	0.031
Education (years)	16.99 (2.75)	16.15 (3.55)	3.927	0.049
PASE score	138.73 (56.94)	157.11 (69.87)	4.695	0.031
MoCA				
Global score	27.25 (2.05)	25.60 (2.39)	31.569	< 0.001
Visuospatial/visuoconstructive subscore	3.27 (0.81)	3.19 (0.92)	0.463	0.497
Executive functions subscore	3.49 (0.68)	2.96 (0.98)	21.651	< 0.001
Memory subscore	4.19 (1.04)	3.91 (1.23)	3.457	0.064
Attention/working memory subscore	5.67 (0.66)	5.63 (0.66)	0.477	0.490
Language subscore	4.70 (0.58)	4.64 (0.69)	0.054	0.816
Orientation subscore	5.95 (0.22)	5.95 (0.20)		
Components of the EF subscore				
Trail task	0.96 (0.20)	0.72 (0.45)	26.333	< 0.001
Verbal fluency	12.83 (3.85)	11.33 (3.98)	8.240	0.004
Abstraction	1.79 (0.45)	1.64 (0.59)	4.290	0.039

Note. CVD = cardiovascular disease; EF= executive functions; MoCA = Montreal Cognitive Assessment; PASE = Physical Activity Scale for the Elderly; SD = standard deviation.