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Participation in voluntary work and cognitive decline: a longitudinal analysis in the aging population

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Abstract

As the global population ages, dementia prevalence increases, posing significant challenges. While age is the primary unmodifiable risk factor for dementia, there are several modifiable risk factors associated with maintaining a social, physical and cognitive active life. Participation in voluntary work might address these aspects. Therefore, this research aims to investigate the relationship between participation in voluntary work and cognitive decline among older adults and whether this association is moderated by age, sex and education.

Longitudinal data from a subcohort of the Lifelines Dutch cohort study (DALAS), including adults aged 60-80 years, was used. The Cogstate Brief Battery (CBB) with a follow-up period of ~5 years was used to measure cognitive decline. The CBB includes the Identification task (IDN), Detection task (DET), One Card Learning task (OCL), and One Back task (ONB). Participation in voluntary work was measured using the DALAS questionnaire. Regression analysis was performed to investigate the association between voluntary work and cognitive decline, adjusted for age, sex and education.

No significant association was found between participation in voluntary work and the CBB decline measures: IDN decline -1.00 [95% CI: 17.4, 15.4], DET decline 11.66 [95% CI: -28.4, 52.2], OCL decline 0.008 [95% CI: -0.001, 0.017] , ONB decline -14.92 [95% CI: -42.7, 12.9]. The association between participation in voluntary work and OCL decline was moderated by education ($p < 0.05$), indicating that current volunteers with a high educational attainment experience less decline.

This study shows that participation in voluntary work is not associated with cognitive decline among older adults. No robust evidence was found that age, sex or educational attainment moderates this relationship. This conclusion should be interpreted with caution, as a recent study questioned the responsiveness of the CBB for longitudinal analysis. This highlights the need for alternative assessment.

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Introduction

As the population ages, the prevalence of dementia is on the rise. In 2015, around 47 million people were living with dementia and this number is expected to triple by 2050 (Livingston et al., 2017). This number particularly rises in low and middle-income countries, creating substantial challenges for individuals, their families and caregivers (Livingston et al., 2017; Livingston et al., 2020). This emphasizes the need for new health strategies and public health initiatives.

Several risk factors contribute to dementia, with age being the most significant. Dementia typically manifests at 65 or older (Livingston et al., 2017) and it is more prevalent in women than men (Livingston et al., 2020; Cao et al., 2020). Besides the non-modifiable risk factors, such as age, sex and genetic preposition, also modifiable risk factors play a role in the development of dementia. Educational attainment during early life is an important risk factor for dementia. Throughout middle age, factors such as hearing loss, traumatic brain injury, hypertension, alcohol consumption, and obesity become prominent risk factors. In late life, smoking, depression, social isolation, physical inactivity, air pollution, and diabetes are recognized as key modifiable risk factors (Livingston et al., 2017; Livingston et al., 2020).

Dementia and mild cognitive impairment involve a decline from a previously attained cognitive level that interferes with daily life and social activities (Livingston et al., 2017). There are some mechanisms that are thought to make the brain more resilient to cognitive decline, such as the concept of the cognitive brain reserve. This concept suggests that individuals with a greater reserve can tolerate more neuropathology without showing cognitive decline, compared to those who have a less reserve. Higher education is a well-known factor related to the cognitive reserve, which is thought to promote resilience at later-life (Livingston et al., 2017). As mentioned before, women are more likely to develop dementia (Cao et al., 2020), which is consistent with the concept of the cognitive brain reserve, as older women likely had less education than older men (Livingston et al., 2020).

Another hypothesis is the “use it or lose it” hypothesis. This concept suggests that improvement of cognition might be due to mental activity in general. Despite some conflicting evidence, it was found that early retirement has a significant impact on cognitive decline. Many jobs involve cognitively demanding tasks, thereby maintaining mental activity. During retirement, there is often a decrease in engagement in such tasks, which may negatively impact cognitive functioning (Livingston et al., 2020).

Cognition is expected to decline with normal cognitive aging. However, cognitive abilities are also found to be influenced by sex and education. Studies suggests that women outperform men in tasks related to (verbal) memory (Mccarrey et al., 2016; Van Exel et al., 2001; Van Hooren et al., 2007). Van Exel et al. (2001) found that older women exhibit greater resilience to age-related cognitive decline despite having lower levels of education, which contradicts the theory of the cognitive reserve. However, this theory is supported by Van Hooren et al. (2007) who revealed better cognitive performance in individuals with higher and middle education levels, compared to those with lower education levels.

Age, sex and educational attainment are all unmodifiable risk factor for older individuals. To reduce the risk of dementia it is recommended to stay socially, physically and cognitive active (Livingston et al., 2020). There is evidence suggesting that these three lifestyle components are beneficial for cognition and protect against dementia through common pathways

(Fratiglioni et al., 2004). This brings us to a promising concept that might cover all these three components: participation in voluntary work.

The International Labour Office defines participation in voluntary work as "Unpaid non-compulsory work; that is, time individuals give without pay to activities performed either through an organization or directly for others outside their own household" (International Labour Office Geneva, 2011).

The initial pathways of understanding the impact of voluntary work were described by Fried et al. (2004) and Anderson et al. (2014), where they found that participation in voluntary work leads to increased physical, cognitive and social activity, which therefore leads to improved health outcomes. Building on these models, a review of Guiney and Machado (2017) delved further into the mechanism of volunteering, suggesting that volunteering first increases social, physical and cognitive activity and through psychological and physiological mechanisms it is associated with improved health outcomes.

Research indicates that strong social networks can reduce stress, thereby providing protection against dementia. Additionally, social networks encourage healthy behaviors and improve access to healthcare resources (Kuiper et al., 2015). A longitudinal study by Tomioka et al. (2016) found that women who engage in three or more social groups, especially volunteer groups, experienced less cognitive decline.

A longitudinal study of Proulx et al. (2018) adds evidence to the potential benefits of volunteering on cognition and also shows that sex and education moderate the relationship between volunteering and cognitive functioning, with women and those with lower education benefiting the most. These findings are further supported by a review of Keefer et al. (2023). Additionally, this review also highlights existing studies do not adjust for important factors like vascular burden or hearing loss.

Despite the growing evidence supporting the positive impact of participation of voluntary work on cognition, several gaps persist. The effect of participation in voluntary work on cognition over time, specifically cognitive decline, lacks robust evidence. Furthermore, the effects of age, education and sex are thought to influence the relationship between participation in voluntary work and cognitive decline, however more evidence from longitudinal studies is needed to confirm this.

With this research, I aim to contribute evidence on the relationship between participating in voluntary work and cognitive decline. To make the research more robust, I will incorporate a wide range of potential covariates and confounders related to cognitive decline. However, it is also crucial to understand the demographics of volunteering. Niebuur et al. (2018) identified factors like socioeconomic status, marital status, social network size, religious service attendance, and past volunteer experiences are positively associated with participation in voluntary work. Negative associations were observed with age, functional limitations, and transitioning into parenthood (Niebuur et al., 2018).

To understand the relationship between voluntary work and cognition and the moderating role of age, sex and education, this research aims to address the following questions:

1. Is there a relationship between participation in voluntary work and cognitive decline among older adults?

2. Is this relationship moderated by age, gender and level of education?

With regard to the existing literature, I expect that older adults that participate in voluntary work show less cognitive decline compared to their peers who are not participating in voluntary work. Additionally, I expect that age, gender and education moderate this relationship, such that the benefits of participation in voluntary work are more pronounced among the oldest persons, women and those with lower level of education.

Overall, this research aims to provide additional evidence on the cognitive benefits of voluntary work for older adults and contribute insights for dementia prevention initiatives. Examining the moderating roles of age, gender, and education helps understand demographic differences in the relationship between voluntary work and cognitive decline, allowing for more targeted recommendations applicable to diverse populations.

Methods

Study design and participants

Lifelines

The Lifelines cohort study in the Netherlands involves 167,729 persons from three generations, living in the North of the Netherlands. It is a multi-disciplinary prospective population-based cohort that employs diverse methods to investigate people's health, behaviors, and genetics by examining aspects including socio-demographic background, behavior, physical health and mental health (Klijs et al., 2015). The primary goal is to understand the factors contributing to healthy ageing (Scholtens et al., 2014).

Lifelines participants were recruited between 2006 and 2013 via general practitioners across three provinces in the northern Netherlands: Groningen, Friesland and Drenthe. General practitioners (GP'S) invited all of their patients aged between 25 and 50 years old, if they met the criteria. Eventually, they were encouraged to invite their family members resulting in a total of ~64,500 participants at baseline. Additionally, around ~21,500 individuals directly registered through the website (Scholtens et al., 2014).

The baseline assessment (T1) took place from 2006 to 2012 and included physical examinations, collecting of blood and urine samples, interviews and self-report questionnaires. Follow-up assessments involve additional questionnaires every 1.5 years and physical examinations every 5 years. The Lifelines Cohort Study has been granted approval by the medical ethical committee of the University Medical Centre Groningen, the Netherlands. All participants have provided informed consent. Lifelines is accessible to all researchers, and details regarding the application and data access procedure can be found on www.lifelines.nl (Scholtens et al., 2014).

Lifelines Daily Activities and Leisure Activities add-on Study (Lifelines DALAS)

The Daily Activities and Leisure Activities Add-on Study (DALAS) was conducted as part of the Lifelines Cohort Study, in collaboration with the Department of Epidemiology at the University of Groningen. This additional digital questionnaire was send out to adult and elderly Lifelines participants aged 60-80 years. The additional criteria is that participants must have filled in either the Lifelines 2A questionnaire 1 or the 2A questionnaire 2 (Figure 1). Around ~16,000 were invited, however the response rate was ~50% (N = ~7600) (Actq [Lifelines Wiki], n.d.).

The DALAS questionnaire covers various aspects related to health, quality of life and lifestyle. This includes questions about daily activities such as employment, informal caregiving, as well as leisure activities like sports, cultural activities, traveling and social interactions (Actq [Lifelines Wiki], n.d.).

Notably, a full section of the questionnaire contains questions with regard to participation in voluntary work. These questions involve various elements such as current and past involvement, frequency, duration, intensity, types of volunteering, and underlying motivations (Actq [Lifelines Wiki], n.d.).

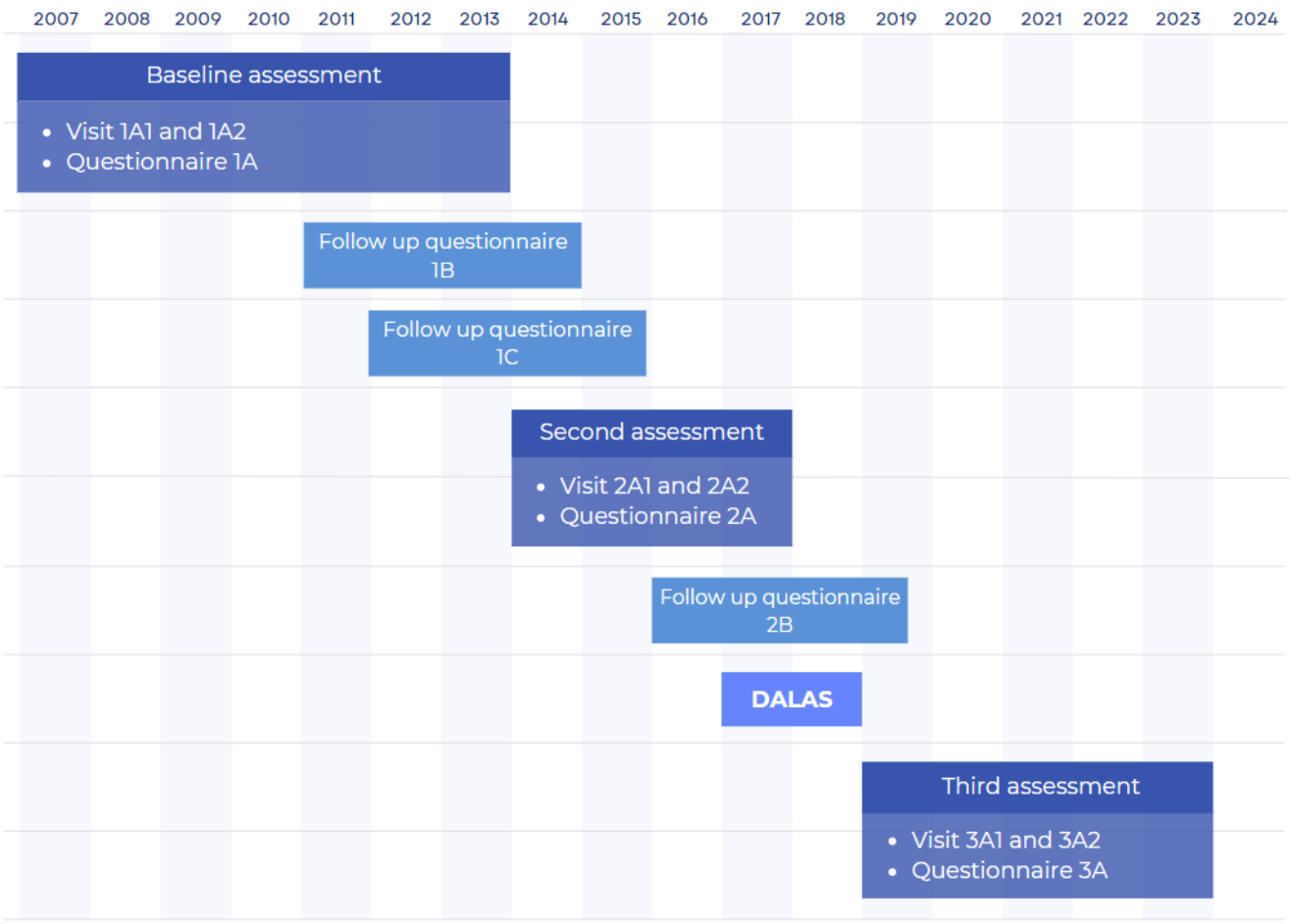

Figure 1 Lifelines assessments timeline (General_Assessments [Lifelines Wiki], n.d.)

Study population

For this research I focused on individuals between 60-80 years of age who completed the DALAS questionnaire (N = ~7600). Additionally, participants must have completed all four Cogstate Brief Battery (CBB) tests during both 2A and 3A Lifelines assessments (Figure 1).

Participants with missing data on any of the CBB tests were excluded from the analysis. Additionally, those with incomplete data for any of the assessments or for several covariates were excluded.

Variables

In the current study, variables were extracted from different Lifelines waves, including 1A, 2A, 3A and the Lifelines DALAS questionnaire (Figure 1).

Dependent variable – cognitive decline
Cognitive decline is the outcome variable of this study, measured by the Cogstate Brief Battery (CBB). These scores were obtained from the Lifelines 2A and 3A wave, with a 5-year follow up period in between.

The CBB includes four computerized tests, each assessing different cognitive domains (Cogstate [Lifelines Wiki], n.d.).

The Identification task (IDN) measures visual attention. The primary outcome is reaction time (in milliseconds), which has been normalized using log10 transformation. Lower scores indicate better performance.

The Detection task (DET) measures psychomotor function and speed processing. The primary outcome is speed measure (in milliseconds), which has been normalized using log10 transformation. Lower scores indicate better performance.

The Once Card Learning task (OCL) measures visual learning and memory. The primary outcome is the proportion of correct answers (hitrate), which has been normalized using arcsine transformation. Higher scores indicate better performance.

The One Back task (ONB) measures attention and working memory. The primary outcome is reaction time (in milliseconds), normalized using log10 transformation and the proportion of correct answers (hitrate), which has been normalized using arcsine transformation. For longitudinal analysis they recommend using speed measure (personal contact with Cogstate). Therefore, for this analysis I focused on the speed measure of the ONB test. Lower scores indicate better performance.

Cognitive decline was assessed through longitudinal changes in CBB test performance. As the primary outcomes are either normalized by log10 or have been subjected to an arcsine transformation, I focused on the non-normalized scores. (Cogstate [Lifelines Wiki], n.d.; Kuiper et al., 2017)

Cognitive decline was assessed by computing the change scores on the four CBB tests. It is expected that reaction time will increase and hitrate will decrease over time among older adults. For the IDN, DET and ONB tasks, cognitive decline is determined by subtracting the 2A scores from the 3A scores, with higher positive values indicating greater decline. Conversely, for the OCL task, decline is calculated by subtracting the 3A scores from the 2A scores, with higher positive values also indicating increased cognitive decline.

Independent variable - participation in voluntary work
Participation in voluntary work, as defined in the introduction, was measured using the Lifelines DALAS questionnaire. Volunteering can be categorized into formal (within an organizational context) and informal (outside an organizational context) activities. Both types are considered as ‘voluntary work’ in this research.

For determining individuals’ volunteer status two specific questions from the DALAS questionnaire have been used: “Have you ever done any volunteer work?” (yes / no) and “Do you currently still do volunteer work?” (yes / no). Those who answered ‘no’ to the first question were classified as never volunteers. Those who answered ‘yes’ on the first question but ‘no’ to the second question were classified as past volunteers. Those who answered ‘yes’

to both questions were classified as current volunteers. For the analysis, two dummies were created, using never volunteers as the reference category. In **Figure 2** the operationalization can be visualized.

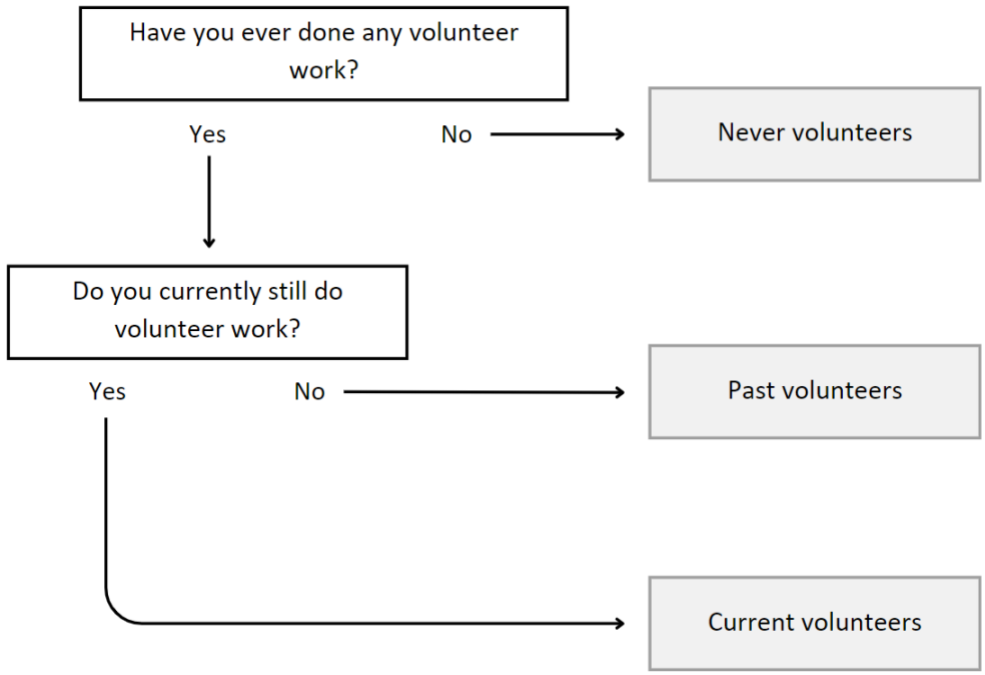

Figure 2 Operationalization of volunteer status

Potential covariates and confounding variables
Below is a brief overview of all the included variables and how they were used in the analysis. In **Table 1** an overview of the variables and their data collection waves is shown. Some of them have been further explained in **Supplement A, Table 1.**

Potential demographic covariates/confounders are:

- Age (continuous)
- Sex (0 = male, 1 = female)
- Paid work (0 = no, 1 = yes).
- Living arrangement, based on cohabiting with a partner (0 = no, 1 = yes) (Supplement A, Table 1).
- Educational attainment has been divided into three categories (1 = low, 2 = middle, 3 = high). Dummy variables have been used for the analysis, with the low category as the reference category (Supplement A, Table 1).
- Income was transformed into equivalized household income, calculated by dividing the midpoint of each participants' net household income by the square root of their household size (OECD, 2018) (Supplement A, Table 1). Missing data were imputed with the mean. A dichotomous variable was created to indicate whether participants had missing data on income (0 = yes, 1 = no).

Potential covariates/confounders related to modifiable risk factors for dementia are:

- Self-reported health is divided into four categories: 1 = excellent, 2 = very good, 3 = good, 4 = moderate/poor (combined due to small sample sizes). Dummy variables were used for analysis, with the excellent category the reference category.
- Variables related to cardiovascular health:

    - The presence of coronary heart disease (CHD) risk (0 = no, 1 = yes) (Supplementary A, Table 1).
    - The presence of high cholesterol (0 = no, 1 = yes)
    - The presence of hypertension (0 = no, 1 = yes).
- The presence of hearing problems (0 = no, 1 = yes).
- Physical inactivity, based on meeting the national health guidelines (0 = yes, 1 = no) (Ministerie van Volksgezondheid, Welzijn en Sport, 2021) (Supplement A, Table 1).
- Obesity, measured by height and weight (0 = no, 1 = yes) (Voedingscentrum, n.d.).
- Depressive symptoms, measured by The Emotional Distress-Depression short form 4a (0 = no, 1 = yes) (Supplement A, Table 1).
- Small social network size, based on whether participants discussed personal matters with <5 individuals over a two-week period (0 = no, 1 = yes).
- Loneliness, measured using the De Jong Gierveld Loneliness short scale (0 = no, 1 = yes) (Supplement A, Table 1).
- Low social participation measured by the Ability to Participate in Social Roles and Activities short form 4a (0 = no, 1 = yes) (Supplement A, Table 1).

Other relevant potential covariates/confounders:

- Taking care of grandchildren (0 = no, 1 = yes).
- Informal caregiving (0 = no, 1 = yes).
- Church attendance, based on attending a religious gathering once a month or more (0 = no, 1 = yes) (Supplement A, Table 1).
- Cogstate Brief Battery (CBB) baseline scores (2A assessment).

Table 1 Summary of transformed variables and their data collection waves

Baseline assessment 1A	**Second assessment 2A**	**DALAS questionnaire**	**Third assessment 3A**
Educational attainment	Cogstate Brief Battery • Baseline score	Voluntary work	Cogstate Brief Battery
Equivalized household income	Obesity	Age	
Missing data income		Sex	
CHD risk presence		Paid work	
High cholesterol		Cohabiting	
Hypertension		Self-reported health	
		Hearing problems	
		Physical inactivity	
		Depressive symptoms	
		Small social network size	
		Loneliness	
		Low social participation	
		Taking care of grandchildren	
		Informal caregiving	
		Church attendance	

Statistical analysis

Statistical analyses were conducted according to the a-priori written Statistical Analyses Plan (Supplement B).

Briefly, descriptive statistics were used to visualize data distribution, identify outliers and detect missing values. Outliers due to measurement errors or participant errors were removed, while those not influencing the data distribution were retained. Dummy variables were created for voluntary work, educational attainment, self-reported health.

Both univariable and multivariable regression analysis were performed. The regression models used cognitive decline as the dependent variable. Independent variables included the dummies for voluntary work and other relevant covariates/confounders. Statistical significance was set at $p < 0.05$.

The CBB baseline score for each associated decline measure was included in the regression models to control for initial cognitive difference, improving the accuracy and reliability of the analysis. By including the baseline scores, the true effects of participation in voluntary work on cognitive decline can be better identified.

In Model 0, a univariable linear regression analysis was performed to examine the relationship between participation in voluntary work and cognitive decline, as well as between the other potential covariates/confounders and cognitive decline.

In Model 1, multivariable linear regression analysis was performed, so the selected independent variables (potential covariates/confounders) were added jointly to the model.

In Model 2, the two-way interaction terms between the voluntary work dummies and potential moderators (age groups, sex and education) were added to the multivariable linear regression model (Model 1). The dichotomous variable age-groups was used for moderation analysis. Only if an interaction term is significant ($p < 0.05$), it was added to the second model and presented in the result section.

IBM SPSS Statistics software version 25 is used for all analysis.

Results

Sample characteristics

Out of the ~16,000 participants invited to take part in the Lifelines DALAS questionnaire, around ~7600 participants completed it. From this initial sample, 5978 participants had complete CBB scores for the 2A assessment. Further selection for complete CBB scores on the 3A assessment reduced the sample to 4111 participants.

During the 3A measurements of Lifelines, the CBB received a software update. Because of this, participants measured after this software update were measured using different variables than before the update. This led to many participants not having comparable variables for the 2A and 3A assessment, which reduced the sample size to N = 1316.

Subsequently, due to outliers and missing data on the 1A assessment, 12 participants were removed from the sample. This resulted in a final sample size of 1304 participants, with some variables still containing missing data (Supplement A, Table 2).

The flowchart of the study population selection is shown in **Figure 3**.

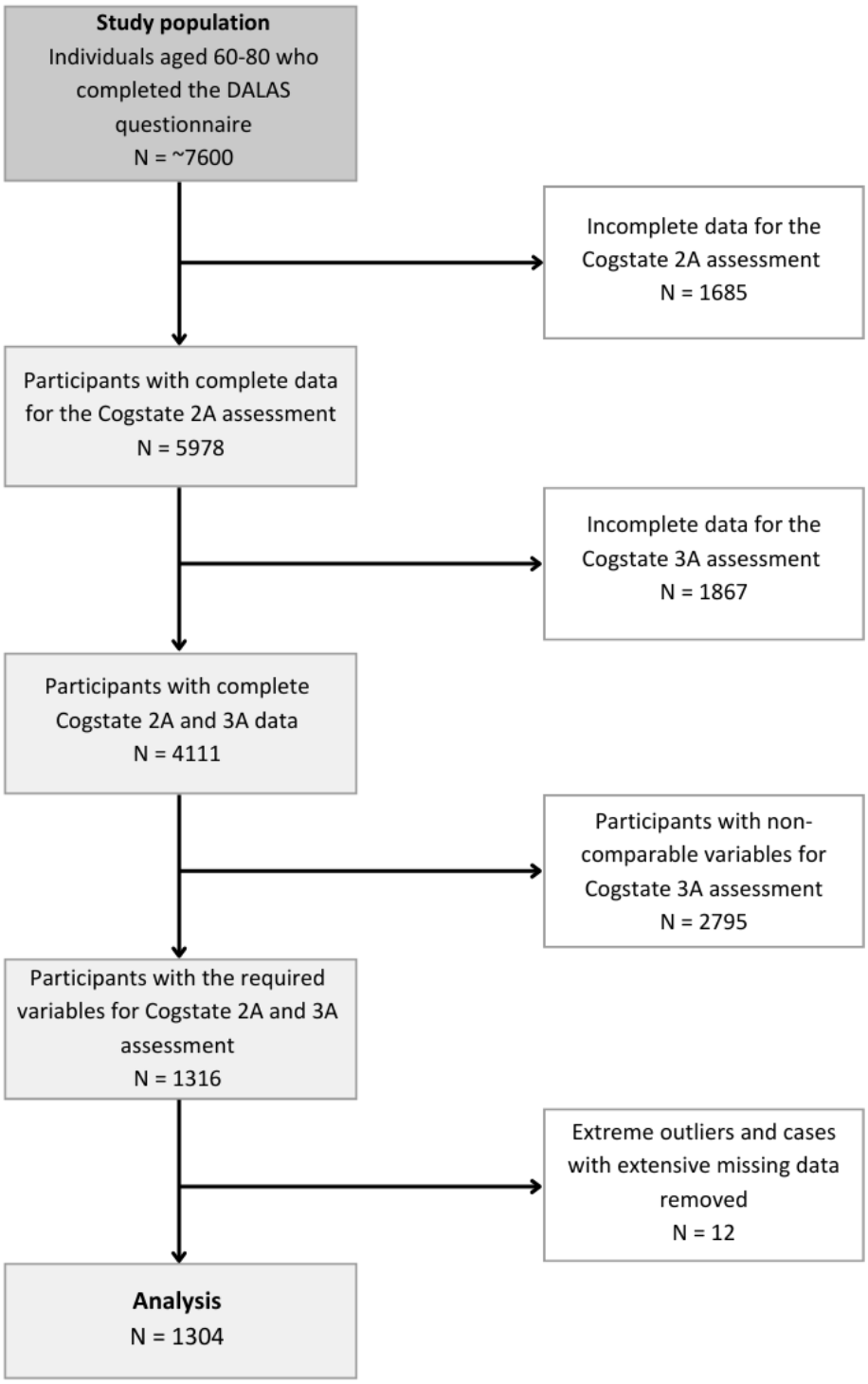

Figure 3 Flow chart study population

Among the 1304 participants included in the analysis, volunteer status was provided by 1302 participants. Background characteristics for the full sample as well as the never volunteers, past volunteers, and current volunteers, are shown in **Table 2**.

The full sample consists of 1304 participants, with an average age of 66.02 years (SD = 4.66). The distribution of sex is relatively equal (45.5% male, 54.6% female). Most participants do not engage in paid work and the majority report to be cohabiting with a partner.

Current volunteers (M = 66.51, SD = 4.72) are relatively older than never volunteers (M = 65.46, SD = 4.41), with also a higher proportion of participants in the 70-80 age range. High educational attainment is more prevalent among current volunteers, while low educational attainment is more prevalent among never volunteers.

Current volunteers are less likely to engage in paid work and tend to have a higher equivalized income, compared to never volunteers. In general, current volunteers perceive their health more positively, tend to have a larger social network size, experience lower levels of loneliness, are better able to participate socially, are more likely to take care of grandchildren and provide informal care and attend religious meetings more frequently, compared to never volunteers.

This suggests that current volunteers in this research possess a better socio-economic status, but also maintain a healthier, more social and active lifestyle.

Tabel 2 Descriptives of the full sample (N = 1304), the never volunteers (N = 269) the past volunteers **(** N = 236) and current volunteers (N = 797)

Variables	**Full sample N = 1304**	**Never volunteers N = 269**	**Past volunteers N = 236**	**Current volunteers N = 797**	**P-value[2]**
Age, M (SD)[1]	66.02 (4.66)	65.46 (4.41)	64.94 (4.50)	66.51 (4.72)	<0.001
Age groups					0.002
• 60 – 69	1007 (77.2%)	217 (80.7%)	198 (83.9%)	591 (74.2%)	
• 70 - 80	297 (22.9%)	52 (19.3%)	38 (16.1%)	206 (25.8%)	
Sex (Female), (N%)[3]	712 (54.6%)	140 (52.0%)	143 (60.6%)	427 (53.6%)	0.107
Educational attainment, (N%)	419 (32.7%)	124 (46.6%)	67 (29.1%)	228 (29.1%)	<0.001
• *Low*	405 (31.6%)	85 (32%)	73 (31.7%)	246 (31.4%)	
• *Middle*	458 (35.7%)	57 (21.4%)	90 (39.1%)	310 (39.5%)	
• *High*					
Paid work, N (%)	514 (39.5%)	123 (45.7%)	109 (46.2%)	282 (35.5%)	<0.001
Equivalized household income, M (SD)	1816.01 (491.16)	1743.22 (457.24)	1773.83 (494.29)	1852.30 (498.43)	0.002
Missing data income[4] (No), N (%)	1155 (88.6%)	235 (84.7%)	208 (88.1%)	710 (89.1%)	0.726
Cohabiting, N (%)	1116 (88.2%)	219 (85.5%)	197 (85.7%)	698 (89.7%)	0.088

1. Mean and standard deviation
2. Obtained using Chi-Square tests (categorical variables) or One-Way ANOVA (continuous variables)
3. All percentages are valid percentages (excluding missing cases)
4. Missing data for equivalized income has been imputed, this dichotomous variable indicates whether participants had missing data on the income variables.

Tabel 2 continued

Variables	Full sample N = 1304	Never volunteers N = 269	Past volunteers N = 236	Current volunteers N = 797	P-value
Self-Reported Health, N (%)					0.031
• *Excellent*	227 (17.4%)	52 (19.3%)	41 (17.4%)	134 (16.8%)	
• *Very good*	479 (36.7)	86 (32.0%)	70 (29.7%)	322 (40.4%)	
• *Good*	533 (40.9%)	117 (43.5%)	109 (46.2%)	306 (38.4%)	
• *Mediocre/poor*	65 (5.0%)	14 (5.2%)	16 (6.8%)	35 (4.4%)	
CHD risk presence, N (%)	45 (3.5%)	<10 (<10%)	<10 (<10%)	30 (3.9%)	0.455
High Cholesterol, N (%)	326 (25.1%)	54 (20.1%)	61 (26.0%)	211 (26.6%)	0.102
Hypertension, N (%)	464 (35.7%)	87 (32.5%)	89 (37.7%)	287 (36.2%)	0.419
Hearing problems, N (%)	346 (26.5%)	67 (24.9%)	63 (26.7%)	216 (27.1%)	0.779
Physical inactivity, N (%)	420 (32.3%)	87 (32.3%)	83 (35.2%)	249 (31.2%)	0.524
Obesity, N (%)	189 (14.5%)	36 (13.4%)	41 (17.4%)	112 (14.1%)	0.374
Depressive symptoms, N (%)	153 (11.7%)	30 (11.2%)	38 (16.1%)	85 (10.7%)	0.071
Small social network size, N (%)	629 (48.3%)	160 (59.5%)	124 (52.5%)	344 (43.3%)	<0.001
Loneliness, N (%)	266 (20.4%)	62 (23.0%)	60 (25.4%)	144 (18.1%)	0.024
Low social participation, N (%)	92 (7.1%)	20 (7.4%)	28 (11.9%)	44 (5.5%)	0.040
Taking care of grandchildren, (N%)	835 (64.1%)	160 (59.5%)	140 (59.3%)	534 (67.1%)	0.019
Informal caregiving, N (%)	412 (31.7%)	51 (19.0%)	68 (28.9%)	293 (37.0%)	<0.001
Attending church more than once a month, N (%)	327 (25.1%)	17 (6.3%)	33 (14.0%)	277 (34.8%)	<0.001
Baseline score IDN test, M (SD)	2.72 (0.09)	2.72 (0.10)	2.72 (0.09)	2.72 (0.09)	0.710
Baseline score DET test, M (SD)	2.64 (0.19)	2.63 (0.19)	2.64 (0.19)	2.64 (0.19)	0.906
Baseline score OCL test, M (SD)	0.94 (0.12)	0.93 (0.12)	0.94 (0.12)	0.95 (0.12)	0.477
Baseline score ONB test, M (SD)	2.94 (0.10)	2.95 (0.10)	2.93 (0.09)	2.94 (0.10)	0.075

In **Table 3** the decline measures of all CBB subtests are presented. Higher outcomes indicate more decline, negative outcomes indicate improvement. While there are some variations in the decline measures between the three groups, these differences are not statistically significant. Moreover, IDN decline and ONB decline only have mean outcomes that show decline.

Table 3 Descriptives of the decline measures of all CBB tests for the full sample, the never volunteers, past volunteers and current volunteers.

Decline measures	Full sample N = 1304	Never volunteers N = 269	Past volunteers N = 236	Current volunteers N = 797	P-value[2]
IDN decline, M (SD)[1]	8.62 (124.72)	6.83 (146.10)	2.85 (109.96)	11.17 (121.002)	0.576
DET decline, M (SD)	-9.54 (317.24)	-8.02 (308.28)	-19.96 (268.23)	-6.49 (333.74)	0.874
OCL decline, M (SD)	-0.17 (0.09)	-0.18 (0.10)	-0.17 (0.10)	-0.17 (0.10)	0.232
ONB decline, M (SD)	4.37 (199.24)	9.09 (206.01)	-2.09 (176.47)	4.43 (203.567)	0.820

1. Mean and standard deviation.
2. Obtained using One-Way ANOVA or Kruskal-Wallis test (IDN decline)

Results of univariable and multivariable linear regression

The results of univariable linear regression analysis are shown in **Supplement A, Table 3.** To gain a more comprehensive understanding of the relationship between participation in voluntary work, multivariable linear regression was performed. In **Table 4** the results of multivariable linear regression analysis are presented for every cognitive decline measure separately. As mentioned before, an increase in the outcome indicates more cognitive decline.

The multivariable models, adjusted for all potential covariates/confounders, show that current volunteering is not associated with any of the decline measures. Additionally, no significant association was found between past volunteers and any of the decline measures.

Among the four cognitive decline measures examined, only the interaction term between current volunteering and high educational attainment is significant for OCL decline attainment -0.016 [95% CI: -0.030, -0.002] is significant (p = 0.02). This indicates that current volunteers with high educational attainment experience less cognitive decline compared to those who never volunteered, or current volunteers with low educational attainment. The multivariable model for OCL decline, incorporating these interaction terms, is presented in **Table 4**. The multivariable model without interaction terms is provided in **Supplement A, Table 4.**

Overall, the multivariable models for IDN decline, DET decline, OCL decline and ONB decline yielded significant R-squared values, indicating that a substantial amount of the variance in cognitive decline is explained by the predictors. For OCL decline a large part of the variance is explained by the predictors, especially the CBB baseline score (R^2 = 86%).

Tabel 4 Multivariable linear regression for IDN decline, DET decline , OCL decline and ONB decline (N = 1200)

	IDN decline		DET decline		OCL decline[2]		ONB decline	
Variables	**B (95% C.I.)[1]**	**p-value**	**B (95% C.I.)**	**p-value**	**B (95%C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**
Intercept	1876.28 [1670.50, 2082. 95]	<0.001	2067.59 [1731.7, 2403.5]	<0.001	-0.956 [-1.003, -0.908]	<0.001	2401.11 [2051.2, 2751.0]	<0.001
Voluntary workers								
• *Never volunteers*	*Ref.*		*Ref.*		*Ref.*		*Ref.*	
• *Past volunteers*	-5.87 [-25.4, 13.6]	0.56	4.84 [-43.5, 53.2]	0.84	0.005 [-0.006, 0.017]	0.37	-23.45 [-56.5, 9.6]	0.17
• *Current volunteers*	-1.00 [-17.4, 15.4]	0.91	11.66 [-28.4, 52.2]	0.57	0.008 [-0.001, 0.017]	0.07	-14.92 [-42.7, 12.9]	0.29
Covariates								
Age	**3.66 [2.0, 5.3]**	**<0.001**	**8.87 [4.7, 13.0]**	**<0.001**	**0.001 [0.000, 0.001]**	**0.01**	**7.66 [4.8, 10.5]**	**<0.001**
Female	9.08 [-4.1, 22.2]	0.18	-4.12 [-36.6, 28.4]	0.80	-0.002 [-0.007, 0.003]	0.43	**34.67 [12.3, 57.1]**	**0.002**
Educational attainment								
• *Low*	*Ref.*		*Ref.*		*Ref.*		*Ref.*	
• *Middle*	-4.83 [-20.2, 10.5]	0.54	11.45 [-26.6, 49.9]	0.56	0.003 [-0.008, 0.014]	0.55	-9.35 [-35.4, 16.6]	0.48
• *High*	-7.95 [-24.0, 8.2]	0.33	-32.93 [-72.7, 6.9]	0.11	0.002 [-0.010, 0.015]	0.71	-13.88 [-41.0, 13.3]	0.32
Paid work	-5.03 [-19.9, 9.8]	0.51	23.59 [-13.2, 60.4]	0.21	0.004 [-0.001, 0.009]	0.13	4.19 [-21.1, 29.4]	0.75
Cohabiting	-4.75 [-14.5, 24.0]	0.63	-24.70 [-72.3, 22.9]	0.31	0.003 [-0.004, 0.010]	0.45	2.58 [-30.0, 35.1]	0.88
Equivalized household income	-0.01 [-0.02, 0.01]	0.42	-0.01 [-0.04, 0.02]	0.57	-0.000 [0.00, 0.00]	0.14	0.01 [-0.02, 0.03]	0.67
Missing data income	-1.78 [-21.9, 18.3]	0.86	-20.18 [-70.0, 29.6]	0.43	-0.003 [-0.010, 0.004]	0.42	-7.24 [-41.3, 26.8]	0.68

1. Unstandardized beta and 95% confidence interval
2. OCL decline is the only decline measure measured in hitrate instead of speed measure

Tabel 4 Continued

	IDN decline		DET decline		OCL decline		ONB decline	
Variables	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**
Self-reported health								
• *Excellent*	*Ref.*		*Ref.*		*Ref.*		*Ref.*	
• *Very good*	9.19 [-8.3, 26.7]	0.30	27.85 [-15.6, 71.3]	0.21	-0.005 [-0.011, 0.002]	0.14	7.49 [-22.2, 37.2]	0.62
• *Good*	8.25 [-9.7, 26.2]	0.37	21.84 [-22.7, 66.3]	0.34	-0.004 [-0.011, 0.002]	0.21	4.10 [-26.4, 34.6]	0.79
• *Mediocre / poor*	-13.89 [-48.6, 20.8]	0.43	39.55 [-46.3, 125.4]	0.37	-0.006 [-0.019, 0.006]	0.32	17.04 [-41.7, 75.8]	0.57
CHD risk presence	-17.12 [-49.7, 15.5]	0.30	-42.32 [-123.0, 38.4]	0.30	0.010 [-0.002, 0.021]	0.10	-29.94 [-85.2, 25.3]	0.29
High cholesterol	14.19 [-0.3, 28.7]	0.06	0.31 [-35.5, 36.1]	0.99	0.000 [-0.005, 0.006]	0.90	5.33 [-19.2, 29.8]	0.67
Hypertension	-0.50 [-13.4, 12.4]	0.94	**48.20 [16.2, 80.2]**	**0.003**	**0.006 [0.001, 0.011]**	**0.01**	-1.17 [-23.1, 20.7]	0.92
Hearing problems	-0.25 [-14.2, 13.7]	0.97	6.40 [-28.1, 40.9]	0.72	-0.001 [-0.006, 0.004]	0.61	10.15 [-13.5, 33.8]	0.40
Physical inactivity	2.68 [-10.5, 15.9]	0.69	10.31 [-22.4, 43.0]	0.54	0.001 [-0.004, 0.006]	0.62	-13.43 [-35.8, 8.9]	0.24
Obesity	2.69 [-14.9, 20.2]	0.76	18.81 [-24.6, 62.2]	0.40	0.000 [-0.006, 0.007]	0.90	11.47 [-18.3, 41.2]	0.45
Depressive symptoms	-10.03 [-30.3, 10.2]	0.33	29.34 [-20.8, 79.5]	0.25	0.003 [-0.004, 0.011]	0.38	10.17 [-24.2, 44.5]	0.56
Small social network size	3.73 [-8.7, 16.1]	0.56	-8.97 [-39.7, 21.8]	0.57	0.002 [-0.003, 0.006]	0.39	2.14 [-18.9, 23.2]	0.84
Loneliness	-0.99 [-17.2, 15.2]	0.91	1.54 [-38.7, 41.7]	0.94	0.002 [-0.004, 0.008]	0.57	-12.93 [-40.4, 14.6]	0.36
Low social participation	21.60 [-5.8, 49.1]	0.12	-46.41 [-114.4, 21.6]	0.18	0.004 [-0.006, 0.014]	0.40	23.48 [-23.1, 70.0]	0.32
Taking care of grandchildren	-8.10 [-20.9, 4.7]	0.22	-2.94 [-34.6, 28.8]	0.86	-0.001 [-0.005, 0.004]	0.82	-8.41 [-30.1, 13.3]	0.45
Informal caregiving	0.57 [-12.7, 13.8]	0.93	-8.34 [-41.1, 24.4]	0.62	-0.001 [-0.006, 0.004]	0.75	-7.49 [-29.9, 14.9]	0.51
Attending church more than once a month	5.32 [-9.4, 20.1]	0.48	-12.60 [-49.1, 23.9]	0.50	-0.002 [-0.007, 0.003]	0.44	14.16 [-10.9, 39.2]	0.27
Baseline score[3]	**-774.80 [-844.6, -705.0]**	**<0.001**	**-1002.29 [1082.3, -922.3]**	**<0.001**	**0.780 [0.762, 0.799]**	**0.00**	**-988.83 [-1101.4, -876.2]**	**<0.001**

3. The CBB baseline score of the associated CBB decline measure

Tabel 4 Continued

	IDN decline		DET decline		OCL decline		ONB decline	
Variables	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**	**B (95% C.I.)**	**p-value**
Interaction terms								
Past volunteers * middle educational attainment					-0.003 [-0.019, 0.014]	0.76		
Past volunteers * high educational attainment					-0.017 [-0.034, 0.001]	0.06		
Current volunteers * middle educational attainment					-0.010 [-0.023, 0.003]	0.13		
Current volunteers * high educational attainment					**-0.016 [-0.030, -0.002]**	**0.02**		
R^2	0.298		0.357		0.861		0.213	

Conclusion and discussion

The primary aim of this research was to investigate if there is an association between participation in voluntary work and cognitive decline. By using the CBB change scores within an longitudinal assessment in the investigated population, no association was found between participation in voluntary work and cognitive decline among older adults.

My hypothesis was that individuals who participate in voluntary work would have less cognitive decline compared to those who do not participate in voluntary work, as previous research has often found that volunteering is associated with better cognitive functioning, compared to non-volunteers (Tomioka et al., 2016; Proulx et al., 2018; Keefer et al., 2023). However, no significant association was found between either current volunteers or past volunteers and cognitive decline.

In addition to the lack of significant associations between participation in voluntary work and cognitive decline, hardly any associations were found between other covariates, except for age, hypertension and sex. These results should be interpreted with caution due to some limitations of this research.

Firstly, the use of the Cogstate Brief Battery (CBB) to measure cognitive decline. As the decline measures are based on change in milliseconds and change hitrate, there is a possibility that these change scores may not adequately capture cognitive decline. This raises questions about the responsiveness of the CBB, the ability of the CBB to detect changes over time. The responsiveness of the CBB has already been questioned in a study of Banh et al. (2021), where they found very weak to no associations between longitudinal changes in CBB and participant characteristics. This suggests that the CBB has limited utility in identifying cognitive decline in older adults (Banh et al., 2021).

Secondly, the ability to measure cognitive decline over a 5-year follow-up period is debatable. Given that the change scores between the 2A and 3A assessments are minimal, a 5-year period may not be sufficient to capture significant cognitive decline in older adults. Although previous studies have successfully detected cognitive decline in older adults over shorter follow-up periods using different cognitive tests (Tomioka et al., 2016; Proulx et al., 2018), the CBB may not be suitable for capturing decline over this relatively short follow-up period. Furthermore, the study may be underpowered due to the relatively small sample size, which could limit the ability to detect significant associations.

Thirdly, baseline cognitive scores predominantly predict cognitive decline. For IDN decline, DET decline, and ONB decline, measured in milliseconds, higher baseline scores are negatively associated with cognitive decline. For OCL decline, measured in hitrate, higher baseline scores are positively associated with cognitive decline. For all CBB tests this indicates that better performance at baseline is associated with more cognitive decline. This suggests a potential ceiling effect where high baseline scores can inflate the apparent decline, limiting the sensitivity of the CBB in detecting true cognitive changes over time. Ceiling effects can be addressed by using relative decline measures. This approach normalizes changes in cognitive scores based on initial performance, providing a more accurate assessment of cognitive changes across different baseline levels.

Lastly, the CBB may not effectively detect cognitive changes over time due to potential learning effects. Despite no evidence of learning effects being found in previous research

(Faletti et al., 2006), participants may have become more accustomed to the CBB during the 3A assessment, potentially influencing the results.

The second aim was to investigate whether this relationship is moderated by age, sex or educational attainment. No robust evidence was found that age, sex or education moderate this relationship. My hypothesis was that age, sex, and educational attainment would moderate the relationship between participation in voluntary work and cognitive decline, as previous research (Tomioka et al., 2016; Guiney and Machado, 2017; Proulx et al., 2018; Keefer et al., 2023) suggested that the benefits of volunteering might be particularly pronounced in women and those with lower education.

In this research, no significant interactions were found for age and sex. Only one significant interaction was found between volunteering and a high educational attainment for OCL decline. Contrary to the expectations, the findings suggests that current volunteers with a high educational attainment experience less cognitive decline compared to those with low educational attainment. However, this association was only found in one decline measure (OCL decline), so no definitive conclusions can be drawn about whether educational attainment moderates the association between participation in voluntary work and cognitive decline. Moreover, it is possible that the significant interaction is due to random chance.

In addition to the challenges of this research mentioned above, there are some additional limitations that require careful considerations.

Firstly, the loss of participants due to incomplete CBB scores raises concerns about the validity of the study findings. Excluding individuals with incomplete data may introduce attrition bias, compromising the outcome of this research. Many participants were lost because of the variables of the CBB 3A assessment were not comparable, resulting in a relatively small sample size. This, combined with the responsiveness issues of the CBB, the sample size might be too small to detect subtle effects or changes in cognitive decline.

Secondly, the measurement of cardiovascular risk factors, including hypertension, high cholesterol and coronary heart disease, presents another limitation. These variables were assessed during the 1A wave, whereas baseline cognition was measured during the 2A wave. The time lag between these measurements could affect the accuracy and relevance of the associations observed. Additionally, these risk factors were self-reported through questions, rather than being confirmed through the blood tests or clinical evaluations. Despite these limitations, significant positive associations were found between hypertension and DET and OCL decline, suggesting that managing hypertension might be important in reducing cognitive decline.

Lastly, for the measurement of volunteer status, no consideration has been given to whether it is formal or informal volunteering, the type of volunteering or the amount of volunteering. There might be differences in the degree of social, physical and cognitive activity between different types of volunteering. These might be important factors emphasized in prior studies (Guiney and Machado, 2017; Proulx et al., 2018; Keefer et al., 2023), that could impact the association with cognition. For future research this can be done using the additional questions related to volunteering from the DALAS questionnaire, where participants are asked to give a more detailed description about their voluntary work.

For future research, a more detailed assessment of volunteer status is needed. Moreover, utilizing more sensitive assessments for longitudinal cognitive measurement, implementing longer follow-up periods and increasing sample sizes will provide a more comprehensive understanding of the effects of volunteering on cognition in older adults.

In conclusion, no association was found between participation in voluntary work and cognitive decline among older adults, contrary to previous research. Although no association was found, the results highlight important aspects for future research and practical implications. Addressing these challenges will enable more accurate and effective research, leading to the development of tailored recommendations suitable for diverse demographic groups. This, in turn, will improve cognitive health interventions for the aging population.

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