ORIGINAL RESEARCH

The effect of clinical, demographic and lifestyle factors on executive functions in middle aged and older women

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Abstract

Objective: Global population ageing has contributed to an increased prevalence of cognitive dysfunction. The current study investigated the psychological, health, lifestyle and demographic factors later in life that are associated with executive function.

Methods: The data for this project were collected as part of the Longitudinal Assessment of Women (LAW) study. A neuropsychological test battery was administered to 376 women and this was augmented by self-report data from a postal questionnaire covering psychological, lifestyle and sociodemographic factors.

Results: Investigation of variables influencing a composite measure of executive functioning demonstrated that increasing age and higher self-reported depression had a negative relationship with executive abilities while higher levels of education, mild alcohol consumption and higher BMI had a positive relationship with executive functioning.

Conclusion: These findings suggest that treating depression, and encouraging a healthy diet, which may include mild alcohol consumption, may positively affect executive performance in older adults.

Keywords: Executive functioning, Depression, Anxiety, Diabetes, Obesity, Alcohol.

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Introduction

Globally, the number of people aged 65 years and over is expected to double over the next two decades [1]. Population ageing will contribute to an increased prevalence of cognitive impairment and neurodegenerative disorders, with predicted negative impacts on communities in terms of economic and personal costs [2]. Cognitive decline in later life encompasses a spectrum of severity, from age-associated memory impairment through mild cognitive impairment (MCI) to dementia.

Deficits in executive functioning are commonly associated with age related cognitive decline and contribute to difficulties in daily functioning. Executive functioning is especially important to consider given that research suggests that the frontal lobes are the most susceptible to changes in structural integrity during the normal aging process, compared with other brain regions [3]. This is supported by literature showing greater volumetric loss of grey and white matter, increased white matter hyperintensities (WMHs) and greater dopaminergic changes in the frontal regions of the brain [3, 4, 5, 6]. Therefore it is important to increase understanding of psychological, health, demographic and lifestyle factors associated with executive abilities in order to help prevent or slow the onset of executive dysfunction with advancing age.

Depression and anxiety

Research has indicated that depression disrupts fronto-subcortical circuits and the frontal cortex [7, 8]. In line with these neurobiological changes are deficits in cognition including executive functioning evidenced by poorer performance on a number of measures including the Trail Making Test, Stroop Test, Rule Shift Cards task, Hayling sentence completion, verbal fluency and the Wisconsin Card Sorting Test (WCST) [7, 9-15]. Executive functioning deficits have been observed to occur independent of age as well [7, 13].

Research also has identified abnormalities in fronto-striatal circuits in a number of anxiety disorders [16, 17]. As a result of these findings, researchers have suspected executive functioning deficits; however, the few available studies for the most part employ relatively narrow measures of executive functioning. From the available evidence, memory difficulties appear to be the most frequently reported cognitive deficit [18-20]. A recent study suggests that older adults with generalized anxiety disorder may show selective deficits in cognitive flexibility (as demonstrated by poorer performance on Trail Making Test B) compared with age-matched controls [20].

Type 1 and type 2 diabetes

In a meta analysis of 33 articles, Brands and colleagues [21] investigated the magnitude of neuropsychological deficits associated with a diagnosis of type 1 diabetes. Significant mild deficits were identified for processing speed and cog-

nitive flexibility compared with controls. Cognitive flexibility was reported to represent executive processes including the ability to shift cognitive set and problem solve. Deficits in executive functioning have also been observed in Type 2 diabetes [22, 23]. Research also indicates that executive dysfunction does not differ significantly between those with Type 1 and Type 2 diabetes [24].

Obesity and body mass index

Of the available cognitive studies investigating executive functioning and Body Mass Index (BMI), results have been mixed. Higher BMI scores have been linked to reduced executive functioning abilities (Stroop test, Austin Maze & WCST [25, 26]). In contrast Sweat and colleagues [27] found no significant differences in cognitive performance (including performance on a measure of executive functioning, the Tower of London test) between a sample of normal weight and obese adults. Elias and colleagues [28] found significant negative effects of BMI for cognition in males only, with BMI not predicting performance on a broad range of cognitive measures (including Verbal Fluency) for women.

Hypertension

In a systematic review of 24 studies by van den Berg and colleagues [29], deficits in memory were most frequently observed (42% of the studies analysed) followed by deficits in processing speed (29% of studies analysed) and executive functioning (25% of these studies) among participants with hypertension. Effect sizes for executive functioning were small in comparison to the other cognitive domains. Van den Berg and colleagues [29] also note that studies that did not find an association between hypertension and cognitive functioning were generally conducted in samples over the age of 65.

Smoking

Smoking is associated with reduced cortical and subcortical volumes (including prefrontal cortex), increases in WMHs and increases in cerebral infarcts compared with people with no lifetime use of nicotine [30]. Of the limited studies investigating a broad range of executive functioning measures in older adults, Schinka and colleagues [31] found no significant differences in performance on executive tests between smokers and non-smokers.

Alcohol

Data collected in multiple longitudinal studies has indicated that those with light to moderate alcohol use outperform abstainers on measures of memory, attention, processing speed and executive abilities [32-34]. Research does not indicate that increasing alcohol use results in increased cognitive benefit, rather that abstainers and high-level users perform at similar levels, such that a U shape distribution is often observed [35, 36].

Education

Superior executive functioning performance has been observed for those with higher education attainment including performance on the Stroop test [37, 38], WCST [39, 40] Verbal Fluency and a modified version of the Trail Making Test [41]. An individual's measured intelligence has been found not to interact with cognitive test scores in several studies [39, 41].

Social support

In a longitudinal study of older adults living at home, free from dementia and MMSE scores >23 at baseline, Fratiglioni and colleagues [42] found that decreasing social networks were associated with increasing risk of dementia. Protective benefits for larger social networks on global cognitive functioning have been repeatedly replicated (e.g. [43]). Despite this, there are currently no published results specifically investigating the relationship between social networks and executive functioning performance.

The present study

Gaps remain in the extant literature on the relationship between psychological, lifestyle and demographic factors contributing to executive dysfunction in later life. Few (e.g. anxiety and smoking) or no (social networks) published studies and variability in outcomes (obesity) make it difficult to establish a firm relationship between these factors and executive abilities. Moreover, most of the cited literature contains analyses that investigated a narrow range of executive functioning measures on which to base their conclusions, failing to account for the multidimensional nature of the domain. Finally, executive tests designed for older adults have often not been included in the neuropsychological test batteries of prior investigations. Such measures should be included to increase the validity of the assessment process and conclusions drawn from the dataset.

Methods

Ethical approval for this study was obtained from the Royal Brisbane and Women's Hospital and The University of Queensland human ethics committees.

Participants

The sample for the current research project was part of the Longitudinal Assessment of Women (LAW) study at the Royal Brisbane and Women's Hospital, Australia, which has been described previously [44]. In 2001, a random sample of women aged 40–80 years residing in the Northern suburbs of Brisbane, Australia, was identified from the electoral roll. Voter registration is compulsory in Australia. From an initial cohort of 511 women, 376 (73%) were still participating in the study in 2008. Data for the current analysis are based on a total sample of 376 women. A sample of 359 participants (aged 48–86 years) was retained for the current analysis. Participants were excluded from

the total sample if they reported a history of stroke (n=12), brain tumor (n=1) and midline congenital malformation (n=1). Refusal to complete cognitive assessment measures/poor test taking effort (n=2) and difficulty with the English alphabet (n=1) were other reasons for exclusion from the final sample used for analyses.

Procedure

Data for the LAW study 2008 were collected via face-to-face interviews and mailed questionnaires. The cognitive assessment and physical measures (weight, height, BMI, waist, hip and waist/hip ratio) were obtained during one 3-hour interview at a research clinic. Type 2 Diabetes as the reason for visiting a doctor was recorded as yes or no. Lifetime nicotine use was assessed via one item with three levels, with participants required to rate either 1=no history of smoking, 2=smoked in the past but not currently and 3=currently smoke. For the purposes of the current study education in the sample was divided into 1=no formal education, 2 =school based education, 3=trade/apprenticeship and 4=university qualification to facilitate adequate cell sizes. Formal measures administered are described below.

Materials

ENRICHD Social Support Instrument

The ENRICHD Social Support Instrument (ESSI) is a self-report measure of perceived social support [45]. It contains 6 items—answered on a 5-point Likert scale—assessing structural, instrumental and emotional support. Higher scores indicate better social support and scores less than 18 indicate poor social support [46].

Geriatric Anxiety Inventory

The Geriatric Anxiety Inventory (GAI) is 20-item self-report measure of generalized anxiety, specifically designed for older adults [47]. Participants are required to respond either agree or disagree (coded 0 and 1 respectively) with scores being summed and range from 0 to 20. Higher scores indicate greater self assessed anxiety, with scores above 8 being considered clinically significant [47].

Geriatric Depression Scale

The Geriatric Depression Scale (GDS) is a measure of self-rated depression designed for older adults [48]. The current study employed the 15-item version of the scale. Scores range from 1–15, with higher scores indicating worse depression. A cut off score of 6/7 has demonstrated sensitivity of 85% and specificity of 74% using ICD-10 criteria for a major depressive episode [49].

Alcohol Use Disorders Identification Test

The Alcohol Use Disorders Identification Test (AUDIT) is a 10-item questionnaire assessing excessive alcohol consumption [50]. It is designed as a screening tool to identify hazardous and harmful alcohol use along with alcohol

dependence. Scores range from 0–40, with scores greater than 8 being sensitive to alcohol related problems [50].

Body Mass Index
BMI is an estimated measure of a person's body fat. According to the World Health Organization a BMI less than 18.5 is considered underweight, BMI 18.5 – 24.9 is considered normal weight, BMI 25.0 – 29.9 is considered overweight and BMI greater than 30 is considered obese [51].

Diastolic blood pressure
Diastolic blood pressure is a measure of an individual's minimum blood pressure. High diastolic blood pressure is defined as per Australian guidelines as exceeding 90mm of mercury at rest [52].

Executive functioning measures
Four measures were used to gauge executive functioning: the California Older Adult Stroop Test (COAST) [53], a purpose-designed variant of the Stroop test for older adults; and three tests from the Delis-Kaplan Executive Function System (D-KEFS) [54] the Trail Making Test [55]; the Verbal Fluency Test [55]; and the Tower Test [55].

Results

Table 1 displays basic sociodemographic and clinical characteristics of the sample.

In order to generate a measure of executive functioning that best represents the multivariate nature of the domain, a principal components analysis (PCA) was performed to determine if test scores could be reduced to a single component. The primary measures for each of the executive tests were included in the analysis: colour word test time (in seconds) from the COAST; number-letter switching completion time (in seconds) on the Trail Making Test; total achievement score on the Tower Test; and the total correct responses score from all three conditions of the Verbal Fluency test. The PCA revealed the presence of a single factor explaining 59.73% of the variance. A single factor solution was confirmed by examination of the scree plot and parallel analysis [56]. Inspection of the component matrix revealed high loadings for each variable on this factor and the communalities suggest the factor accounted for a substantial proportion of variance of each measure. As this component extraction appeared meaningful (i.e. reflecting a range of executive abilities) factor saved scores were then added to the data set to be used as the dependent variable in a series of regression analyses.

Regression Analyses

Putative explanatory health and lifestyle variables were entered simultaneously into a standard regression model, allowing for the evaluation of each variable's independent contribution to the prediction of executive functioning. A significant model was produced R^2=0.43, $F_{(12, 271)}$=16.99, p<0.001. Inspection of the standardised coefficients revealed that age had a significant effect (β=0.40, p=0.001), as did school education (β=-0.21, p=0.003), university education (β=-0.38, p=0.001), GDS score (β=0.20, p=0.001) and AUDIT score (β=-0.12, p=0.02). A trend was also observed for BMI (β=-0.09, p=0.067). Age accounted for the greatest amount of unique variance (11.2%) to the model. Inspection of the β values indicated that poorer executive ability was associated with older age and higher GDS score while higher AUDIT score associated with better executive ability. Those with university education and those with a school based qualification also demonstrated better executive ability compared with people without a formal education history. University education however resulted in greater change in the dependent variable compared with school education.

To further investigate the results obtained, heteroscedasticity-consistent standard error (HCSE [57]) estimators were used in a subsequent regression analysis. This approach was undertaken as post-estimation procedures in-

Table 1. Sociodemographic and clinical characteristics.

Variable	Mean	Standard deviation (SD)	Frequency	Percentage
Age	65.2	10.2	-	-
Education				
No Formal Education	-	-	42	12.0
School Education Only	-	-	173	49.6
Trade Qualification	-	-	7	2.0
University Education	-	-	123	35.2
Saw Doctor because of Diabetes				
Yes	-	-	21	6.0
No	-	-	328	94.0
Diastolic Blood Pressure	73.7	10.5	-	-
GAI Total Score	2.2	3.7	-	-
GDS Total Score	1.7	1.9	-	-
BMI	27.8	5.4	-	-

GAI = Geriatic Anxiety Inventory; GDS = Geriatric Depression Scale; BMI = Body Mass Index.

dicated minor violations of normality (positive skew) in a number of independent variables (including AUDIT score and ESSI variables). The use of HCSE provides a more robust estimate of the standard error when heteroscedasticity is observed, compared with standard regression models that assume homoscedasticity [57]. The HCSE regression model was significant $R^2 = 0.43$, F (12, 271)=15.19, p<0.001 (**Table 2**). All variables that were significant predictors from the standard regression model were confirmed in the HCSE regression. However, BMI (which was approaching significance in the first regression model) was significant when homoscedasticity was not assumed. The results from this regression analysis suggest that the significant predictors identified in the first regression analysis were not the result of heteroscedasticity and represent factors that uniquely contribute to executive ability.

In order to generate a more parsimonious model, we removed non-significant predictors from the HCSE regression and retained a significant model R^2=0.41, F (6, 277)=27.82, p<0.001, which is summarized in **Table 3**. Age, education, BMI, GDS and AUDIT score all remained significant predictors of executive functioning.

Discussion

The aim of the current study was to investigate the relationship between executive functioning and a set of psychological, health, demographic and lifestyle factors in a well-characterized sample of community dwelling middle aged and older women.

Age was significantly related to executive functioning performance, as expected. This finding supports the large body of literature suggesting that increasing age leads to decreasing performance on executive functioning tasks [38, 41, 58, 59].

Table 2. Standard multiple regression predicting executive abilities using standard error estimates assuming homoscedasticity.

| Variable | Standard Error Estimator | | |
| | HCSE Regression | | |
	B	SE	p
Age	0.04	0.01	0.001
Audit Total score	-0.05	0.02	0.028
Blood pressure (Diastolic)	0.01	0.01	0.869
GAI Total score	0.01	0.01	0.082
GDS Total score	0.10	0.03	0.007
Doctor – Diabetes	-0.13	0.09	0.364
ENRICHD	-0.01	0.01	0.907
BMI	-1.12	0.53	0.023
Smoke – past	-0.07	0.10	0.310
Smoke – current	0.35	0.21	0.089
School Education	-0.42	0.15	0.003
University Education	-0.79	0.16	0.001
R^2=0.43	F(12, 271) = 15.19		p<0.001

GAI = Geriatic Anxiety Inventory; GDS = Geriatric Depression Scale; ENRICHD = ENRICHD Social Support Instrument; BMI = Body Mass Index.

Table 3. HCSE Regression Model Excluding non-significant Predictors.

Variable	B	SE	p
Age	0.04	0.01	0.001
AUDIT Total score	-0.05	0.02	0.024
GDS Total score	0.12	0.03	0.001
BMI	-1.20	0.50	0.017
School Education	-0.42	0.15	0.005
University Education	-0.82	0.16	0.001
R^2=0.41	F(6, 277) = 27.82		p<0.001

Note: Higher executive functioning scores are related to poorer executive abilities therefore negative coefficients indicate the independent variable has a positive relationship with executive functioning.
AUDIT = Alcohol Use Disorders Identification Test; GDS = Geriatric Depression Scale; BMI = Body Mass Index.

With respect to psychological factors, self-rated depression on the GDS was a significant predictor of executive functioning. As GDS score increased, executive functioning declined. This finding adds further support to existing research base indicating that depression is associated with poor performance on executive functioning tasks [10, 12-14, 60]. However, in the current study most participants (~97%) were under the cut-off for mild depression. This suggests that even slight elevations in depressive mood may be associated with reduced executive abilities for females in middle to late adulthood.

In contrast, self-rated anxiety on the GAI did not significantly predict executive functioning. The current sample was reasonably healthy (~8.4% above clinical cut-off score of 8) and the sample size might have been insufficient to demonstrate the impact of minor elevations in anxiety on executive functions. Further research is required on the relationship between anxiety and executive functioning.

Higher BMI predicted better executive functioning ability. Kuo and colleagues [61] showed improved cognition with higher BMI but did not assess executive abilities. In addition, recent research has highlighted that in older adult populations, those identified as overweight (BMI ~ 27) had the lowest risk of mortality [62]. Thus, our finding is not implausible, and might reflect an association of low BMI with poor health.

In the current study, diabetes did not significantly predict executive functioning. This finding stands in contrast to the findings of other studies [21, 22, 63, 64]. In the current study, participants were asked if they had seen a doctor for diabetes. This may have resulted in people responding yes even though they may not have had diabetes therefore invalidating the data. The 2008 LAW study sample was also reasonably healthy (only about 6% reported being seen by a doctor in relation to diabetes). Such a small proportion might have made it difficult to observe a relationship between diabetes and executive functioning.

Hypertension also did not significantly predict executive functioning performance. A systematic review by van

den Berg and colleagues [29] highlighted that only 25% of longitudinal and cross sectional studies found support for an adverse effect of hypertension on executive abilities. The lack of stability in these findings may be due to differences in underlying etiology and associated cardiovascular related changes. Another hypothesis is that the treatment of hypertension in developed countries, at least, has improved markedly in recent years, which may have influenced findings in the literature.

With respect to lifestyle factors, alcohol was found to significantly predict executive functioning performance. While the relationship between AUDIT total score and executive functioning suggests that higher scores are related to superior executive abilities, it is likely that this positive relationship was driven mainly by mild alcohol consumption. Investigation of the range of AUDIT total scores revealed that those who reported alcohol use generally displayed low total scores, thus indicating mild alcohol use. This finding confirms prior research investigating moderate levels of alcohol use and cognitive functioning [32, 34, 36]. Chronic alcohol abuse has been linked to sustained cognitive deficits across a wide range of cognitive skills, including executive functioning, many of which persist even in the face of abstinence for 12 months or more [65]. Vascular risk factors may be important in the development of MCI, dementia and AD; among lifestyle factors, alcohol intake has been shown to have both protective and adverse effects, and so more research in this area is required [66].

Past or current smoking did not predict executive functioning performance. Of the limited research using specific executive functioning measures, Razani and colleagues [67] found that smoking did not predict performance on most executive functioning measures. Further, Schinka and colleagues [31] showed intensity of smoking use did not predict performance on the Trail Making Test and the Stroop Test. Therefore, the results from the current study highlight that smoking nicotine may not have a relationship with executive abilities. Smoking can, however, cause many secondary medical complications that can have adverse vascular effects on the brain, and depending on the site of this associated damage, executive abilities deficits may occur.

Social support was also found not to predict executive functioning performance. While the variation in scores on the ESSI appeared appropriate perhaps other measures of social support could be utilized in future research to help explore this relationship further. It could be speculated that individuals with poor executive functioning might find it difficult to recruit or retain social support networks. It may also be that reducing social support could lead to decreased executive abilities in later life therefore the direction of this relationship needs further investigation. Given the findings of the current study it does not appear that social support has a relationship with executive functioning performance.

As anticipated, school based education and university education were positively related to executive functioning performance compared with no formal education, which supports prior research [38, 39, 41, 58]. The cognitive reserve hypothesis of aging suggests that exposure to environmental factors such as education influences the reserve capacity of the brain to withstand the effects of both healthy and pathological aging [68]. The effects of education are also invariably linked to other sociodemographic factors [41] therefore the impact of education on executive function may be multifaceted.

The findings from the current study may help clinicians to construct putative intervention strategies to help maintain or improve executive functioning abilities with advancing age. It would appear that treating depressed mood in older populations may have the effect of improving both mood as well as cognition, including executive functioning. Positive modification of lifestyle choices form an important focus for both psychoeducational approaches as well as potential interventions with older patients. Our data on BMI and alcohol consumption suggest that maintaining a healthy diet and consuming alcohol in moderation may help to reduce the risk of executive dysfunction with advancing age. As the data were obtained on an exclusively female population, these findings remain to be confirmed in men.

Interventions for executive functioning may have multiple benefits as poor executive function has been linked to poor treatment response in depression [69] and is a good cognitive predictor of functional decline (ADLs) and mortality in older adults [70]. Novel interventions such as mindfulness have shown promising results in positively influencing executive functioning in older adults [71]. Such intervention strategies will need research and validation in order to adequately prepare clinicians for the increasing prevalence of executive functioning deficits in the world's aging population.

The main strengths of the current study were access to a relatively large well characterized sample of participants and the assessment of executive functioning with multiple measures. The main limitations of the study were the relatively healthy nature of our sample leading to decreased variability on certain measures including psychological functioning and alcohol use.

Conclusion

In this study of middle aged and older women, executive functioning was found to be negatively associated with age and depression, and positively associated with BMI, alcohol and education. These findings have potential implications for the development of interventions to preserve or improve executive functioning in middle age and later life.

Abbreviations

AUDIT: Alcohol use disorders identification test; AD: Alzheimer's Disease; BMI: Body mass index; COAST: California older adult stroop test D-KEFS: Delis-Kaplan executive function system; ESSI: ENRICHD

social support instrument; GAI: Geriatric anxiety inventory; GDS: Geriatric depression scale; LAW: Longitudinal Assessment of Women; MCI: Mild cognitive impairment; PCA: Principal components analysis; WCST: Wisconsin card sorting test; WMHs: White matter hyperintensities

Competing interests

The authors declare no conflict of interest.

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