Self-efficacy is independently associated with brain volume in older women

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Abstract

Background: ageing is highly associated with neurodegeneration and atrophy of the brain. Evidence suggests that personality variables are risk factors for reduced brain volume. We examine whether falls-related self-efficacy is independently associated with brain volume.

Method: a cross-sectional analysis of whether falls-related self-efficacy is independently associated with brain volumes (total, grey and white matter). Three multivariate regression models were constructed. Covariates included in the models were age, global cognition, systolic blood pressure, functional comorbidity index and current physical activity level. MRI scans were acquired from 79 community-dwelling senior women aged 65–75 years old. Falls-related self-efficacy was assessed by the activities-specific balance confidence (ABC) scale.

Results: after accounting for covariates, falls-related self-efficacy was independently associated with both total brain volume and total grey matter volume. The final model for total brain volume accounted for 17% of the variance, with the ABC score accounting for 8%. For total grey matter volume, the final model accounted for 24% of the variance, with the ABC score accounting for 10%.

Conclusion: we provide novel evidence that falls-related self-efficacy, a modifiable risk factor for healthy ageing, is positively associated with total brain volume and total grey matter volume.

Trial Registration: ClinicalTrials.gov Identifier: NCT00426881.

Keywords: self-efficacy, brain volume, older women, elderly
Introduction

Cognitive decline and dementia is a significant healthcare and societal issue. Currently worldwide, 24.3 million people have dementia; the 4.6 million new cases of dementia that occur annually represent one new case every 7 s [1]. The number of people affected is projected to double every 20 years to over 80 million by 2040 [1].

The risk of cognitive impairment and dementia increases with age. Age is believed to increase risk for dementia because it is independently associated with brain atrophy [2]. Between the ages 30 and 90 years, roughly 15% of the cerebral cortex and 25% of white matter in humans are lost [3]. Given that by 2030, 14% of the world’s population will be over age 65, there is an urgent need to identify modifiable risk factors for age-related neurodegeneration [4].

Well-known modifiable risk factors for reduced brain volume in older adults include physical inactivity, high body mass index and chronic conditions such as hypertension [5]. Evidence also suggests that personality variables such as low self-esteem are risk factors. Specifically, Pruessner et al. [6] found that high self-esteem moderated age-related patterns in cognitive decline, cortisol regulation and global brain volume decline in older adults aged 60–84 years old. Most recently, Jackson et al. [7] demonstrated the effect of personality on age-related reduction in brain volume. Compared with individuals who displayed higher conscientiousness (i.e. their ability to complete tasks they committed to), those with higher neuroticism demonstrated significantly reduced brain volume in prefrontal and medial temporal regions [7].

A personality variable that has not been previously examined in the context of age-related reduction in brain volume is self-efficacy. Self-efficacy is distinct from self-esteem. Self-efficacy is defined as confidence in one’s ability to achieve a desired outcome, whereas self-esteem is a general feeling about one’s self-worth. According to Bandura’s Social Cognitive Theory [8], an individual’s perceived capability to perform an activity is a better predictor of activity in a particular domain than an individual’s actual physical ability to complete the activity.

Previous studies highlight the importance of self-efficacy in healthy ageing [9, 10]. For example, a large population-based study demonstrated that older men’s instrumental efficacy beliefs at baseline were positively associated with change in verbal memory over a 2.5-year follow-up [10]. Falls-related self-efficacy is also independently associated with mobility performance in older adults [9]. In turn, both cognitive function and mobility performance are related to brain health [11]. Thus, we hypothesise that falls-related self-efficacy may be of particular importance to brain volume and an essential component of healthy ageing. In this study, we examined whether falls-related self-efficacy independently associated with brain volume in community-dwelling older women after accounting for global cognitive function and known covariates.

Method

Participants

The total sample for this cross-sectional analysis consisted of 79 women who consented and completed a randomised controlled trial of exercise (NCT00426881) that aimed to examine the effect of once weekly and twice-weekly resistance training (RT) on cognitive performance of executive functions. The design and the primary results of the Brain Power study have been reported elsewhere [12]. Briefly, participants enrolled in Brain Power were: aged 65–75 years, community dwelling, and had a Mini-Mental State Examination (MMSE) score ≥24. Participants were enrolled and randomised by the Research Coordinator to one of three groups: once-weekly RT (1× RT), twice-weekly RT (2× RT) or twice-weekly balance and tone.

This study was approved by the relevant university and hospital ethics boards. All participants gave written informed consent prior to participants in the study.

Dependent variable: brain volume—MRI

The brain volume was measured via high-resolution, T1-weighted structural MRI images obtained using a Philips Achieva 3T scanner (TR = 8 ms, TE = 3.7 ms, bandwidth = 2.26 kHz, voxel size = 1 × 1 × 1 mm). The brain tissue volume, normalised for the subject head size, was estimated with SIENAX [13], part of FSL (FMRIB’s Software Library, Version 4.1.4) [14]. SIENAX starts by extracting brain and skull images from the single whole-head T1 image [15]. The brain image was then affine registered to Montreal Neurological Institute (MNI) 152 space. Next, tissue-type segmentation with partial volume estimation was carried out in order to calculate total volume of brain tissue, total white matter volume and total grey matter volume.

Independent variables

Comorbidity

The functional comorbidity index (FCI) was calculated to estimate the degree of comorbidity associated with physical functioning [16]. This scale’s score is the total number of comorbidities.

Global cognition

We assessed global cognition using the MMSE. The MMSE is a widely used and well-known questionnaire used to screen for cognitive impairment (i.e. MMSE < 24) [17]. It is scored on a 30-point scale with a median score of 28 for healthy community-dwelling octogenarians with more than 12 years of education [17]. The MMSE may underestimate cognitive impairment for frontal system disorders because it has no items specifically addressing cognitive function [17].
Self-efficacy is independently associated with brain volume

Results

Of the 155 participants who consented and were randomised at baseline, 135 completed the 12-month trial. Seventy-nine of the 135 participants consented and completed baseline MRI scanning.

Participants

Table 1 reports descriptive statistics for our variables of interest for this cohort. Participants included in our MRI substudy were similar on demographic characteristics. At baseline, this cohort of community-dwelling senior women has a mean total brain volume of 14.0E5 ± 0.06 mm³, a mean total grey matter region of 7.33E5 ± 0.03 mm³ and a mean total white matter region of 6.70E5 ± 0.03 mm³. Further, the mean ABC score was 89 ± 12 (max 100).

Correlation coefficients

Table 2 reports the correlation coefficients between independent variables of interest and brain volume. Systolic blood pressure and physical activity levels were significantly associated with total brain volume (P < 0.05). Age (P < 0.01) and systolic blood pressure (P < 0.05) were

Table 1. Characteristics of the Brain Power cohort at baseline

<table>
<thead>
<tr>
<th>Variable at baseline</th>
<th>(n = 79)</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total brain volume (mm³)</td>
<td>14.0E5</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Total grey matter volume (mm³)</td>
<td>7.3E5</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Total white matter volume (mm³)</td>
<td>6.7E5</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>69</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Function comorbidity index</td>
<td>1.8</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>MMSE (max 30 points)</td>
<td>28</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>139</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Physical activity scale for the elderly</td>
<td>129</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Activities-specific balance confidence (%)</td>
<td>89</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Correlation coefficient matrix for brain volume (n = 79)

<table>
<thead>
<tr>
<th>Variable at baseline</th>
<th>Total brain volume (mm³)</th>
<th>Grey matter volume (mm³)</th>
<th>White matter volume (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>−0.165</td>
<td>−0.288**</td>
<td>−0.108</td>
</tr>
<tr>
<td>Function comorbidity index</td>
<td>0.024</td>
<td>0.091</td>
<td>−0.038</td>
</tr>
<tr>
<td>Mini-Mental State</td>
<td>−0.007</td>
<td>0.033</td>
<td>−0.111</td>
</tr>
<tr>
<td>Examination (max 30)</td>
<td>−0.166*</td>
<td>−0.242*</td>
<td>−0.073</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>−0.201*</td>
<td>0.154</td>
<td>0.093</td>
</tr>
<tr>
<td>Physical activities scale for the elderly</td>
<td>0.352**</td>
<td>0.401**</td>
<td>0.224*</td>
</tr>
</tbody>
</table>

*P < 0.05.
**P < 0.01.
significantly associated with total grey matter volume. The ABC score was significantly associated with both total brain volume (Figure 1A) and total grey matter volume (Figure 1B) \((P < 0.01)\).

Multivariate linear regression

The ABC score was significantly associated with total brain volume and total grey matter volume after adjusting for known covariate \((P < 0.05)\). The total variance accounted for by the final model for total brain volume was 17% and for total grey matter volume was 24% (Table 3). The ABC scale accounted for an additional 8% of the total variance in the final model for total brain volume. The ABC scale accounted for an additional 10% of the total variance in the final model for total grey matter volume.

Discussion

This study provides novel evidence that falls-related self-efficacy is positively and independently associated with brain volume (both total and grey matter) among high functioning community-dwelling senior women. To our knowledge, our study is the first to demonstrate the independent contribution of falls-related self-efficacy to brain volume after accounting for key covariates (i.e. age, FCI, global cognition, systolic blood pressure and physical activity). Importantly, falls-related self-efficacy was independently associated with grey matter—brain tissue that is particularly sensitive to ageing effects and pathological processes (e.g. Alzheimer’s disease) [19]. In addition, Taki et al. [20] recently showed that the total grey matter volume was significantly associated with cognitive performance in healthy older adults. Hence, our findings extend previous investigations that highlight the importance of falls-related self-efficacy for healthy ageing [9].

Falls-related self-efficacy does not exist only among older adults with a history of falls; reduced falls-related self-efficacy is reported by 30% or more of older adults who have no history of falling [21]. Fear of falling may lead to self-imposed activity restriction that is not due to actual physical impairments [22]. Further, fear of falling independently contributes to functional decline and the loss of independence among older adults [23]. Taking the results of our study with those of previous studies, self-efficacy appears to be an essential psychosocial characteristic of healthy ageing [7]. Studies have highlighted the importance of self-efficacy for the maintenance of mobility, balance,

![Figure 1. (A) Total brain volume (mm\(^3\)) versus falls-related self-efficacy (ABC Score) (B) Total grey matter brain volume (mm\(^3\)) versus falls-related self-efficacy (ABC Score).](image)

**Table 3.** Multiple regression summary for brain volume versus falls-related self-efficacy \((n = 79)\)

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Total brain volume (mm(^3))</th>
<th>Unstandardised (\beta), (standard error)</th>
<th>(P)-value</th>
<th>Total grey volume (mm(^3))</th>
<th>Unstandardised (\beta), (standard error)</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>(R^2 = 0.090)</td>
<td>(-2962 (2842))</td>
<td>0.300</td>
<td>(R^2 = 0.144)</td>
<td>(-2914 (1423))</td>
<td>0.044*</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>-2962 (2842)</td>
<td>0.300</td>
<td></td>
<td>-2914 (1423)</td>
<td>0.044*</td>
</tr>
<tr>
<td>FCI</td>
<td></td>
<td>383 (4878)</td>
<td>0.938</td>
<td></td>
<td>2133 (2443)</td>
<td>0.385</td>
</tr>
<tr>
<td>MMSE</td>
<td></td>
<td>-3057 (8500)</td>
<td>0.640</td>
<td></td>
<td>-511 (3255)</td>
<td>0.876</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td></td>
<td>-426 (378)</td>
<td>0.264</td>
<td></td>
<td>-245 (189)</td>
<td>0.200</td>
</tr>
<tr>
<td>PASE</td>
<td></td>
<td>236 (119)</td>
<td>0.052</td>
<td></td>
<td>96 (60)</td>
<td>0.113</td>
</tr>
<tr>
<td>Model 2</td>
<td>(R^2 = 0.172)</td>
<td>(-1011 (2824))</td>
<td>0.721</td>
<td>(R^2 = 0.244)</td>
<td>(-1801 (1393))</td>
<td>0.200</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>-1011 (2824)</td>
<td>0.721</td>
<td></td>
<td>-1801 (1393)</td>
<td>0.200</td>
</tr>
<tr>
<td>FCI</td>
<td></td>
<td>2261 (4735)</td>
<td>0.635</td>
<td></td>
<td>3202 (2337)</td>
<td>0.175</td>
</tr>
<tr>
<td>MMSE</td>
<td></td>
<td>-4365 (6260)</td>
<td>0.488</td>
<td></td>
<td>-1256 (3089)</td>
<td>0.685</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td></td>
<td>-370 (363)</td>
<td>0.311</td>
<td></td>
<td>-213 (179)</td>
<td>0.238</td>
</tr>
<tr>
<td>PASE</td>
<td></td>
<td>172 (117)</td>
<td>0.147</td>
<td></td>
<td>59 (58)</td>
<td>0.308</td>
</tr>
<tr>
<td>ABC scale</td>
<td></td>
<td>1677 (626)</td>
<td>0.009**</td>
<td></td>
<td>955 (309)</td>
<td>0.003**</td>
</tr>
</tbody>
</table>

\*\(P < 0.05\).

\**\(P < 0.001\).

FCI, functional comorbidity index; MMSE, Mini Mental State Examination; PASE, physical activity scale for the elderly; ABC, activities of balance confidence scale.
functional status, social function and cognitive function among older adults [7, 9]. More recently, studies have demonstrated an association between personality and differences in regional brain volume associated with healthy ageing [7]. We also recently demonstrated that improved falls-related self-efficacy is positively and independently associated with increased usual gait speed among community-dwelling older women [12]; improved gait speed is associated with substantial reduction in mortality [24]. Previous research has also demonstrated the association between brain atrophy and poor gait speed [25]. Further, spatial characteristics of gait are associated with distinct brain networks in older adults [26]. Hence, targeting falls-related self-efficacy may also have indirect benefits on mobility in older adults. In summary, it would appear that healthy ageing promotion strategies should target self-efficacy. Further, given the establish relationship between falls and cognition [12], it seems only appropriate to target falls-related self-efficacy in the context of promoting healthy ageing in seniors.

This study generates numerous research questions as to the mechanisms that underpin the independent association between falls-related self-efficacy and measures of brain volume. An underlying mechanism may relate to allostatic load, defined by McEwen and Gianaros [27] as the wear-and-tear on the body and brain that results from chronic dysregulation (i.e. overactivity or underactivity) of mediators of allostatics. Allostasis is defined as the active process of responding to a challenge to the body (e.g. psychological stress) by triggering chemical mediators of adaptations that operate in a non-linear network.

Low self-efficacy is a form of psychological stress. When faced with a challenging everyday cognitive–behavioural task, healthy older adults with low self-efficacy experience greater stress, as demonstrated by an exaggerated response of the hypothalamic–pituitary–adrenal (HPA) axis and increased production of glucocorticoids (GCs), compared with those without low self-efficacy [28].

Without intervention, low self-efficacy also is a persistent psychological state. According to Schulkin et al. [29], chronic psychological stress results in allostatic load. Specifically, chronic stress can lead to poor habituation of the HPA axis and dysregulation of the GCs release. Documented central effects of chronic psychological stress include shortening of dendrites, loss of spine synapses, suppression of neurogenesis, and reduced brain volume—especially in the hippocampus [30].

Finally, lifestyle behaviours of older adults with low falls-related falls efficacy may increase the negative effect of allostatic load. For example, older adults with low falls-related falls efficacy often restrict activity to reduce the risk of falling. However, this often leads to social isolation and a sedentary lifestyle. Yet, both social integration and physical activity are identified by McEwen and Gianaros [27] as two of the most important interventions approaches for allostatic load.

Taking the results of our study with those of previous studies, self-efficacy appears to be an essential personality variable for healthy ageing [7]. Studies have highlighted the importance of self-efficacy for the maintenance of mobility, balance, functional status, cognitive function and social function among older adults [7, 9, 12]. Hence, it would appear that healthy ageing promotion strategies should target self-efficacy.

We recognise that our cross-sectional study design did not allow us to ascertain the temporal relationship between falls-related self-efficacy and brain volume. Also, we did not assess the association between falls-related self-efficacy and the specific regions that are primarily responsible for the allostatic processes, such as the hippocampus, amygdala and the prefrontal cortex [27]. Further, we highlighted that previous studies demonstrated personality-related factors such as self-esteem [6] and personality [7] to directly affect age-related brain volume. Although our study highlighted an additional and unique personality variable—self-efficacy independently contributes to brain volume, a limitation of our study is that we cannot compare directly the contribution of self-efficacy with other personality-related factors because we did not measure such factors. Last, we note that our study sample included only high functioning community-dwelling older women without cognitive impairments. The relationship between falls-related self-efficacy and brain volume may differ in lower functioning older adults, cognitively impaired older adults or older men. Thus, future prospective population-based studies are needed to determine whether our present findings can be generalised to more heterogeneous populations.

**Conclusion**

Our study, conducted among older community-dwelling women, for the first time highlights that falls-related self-efficacy is positively associated with brain volume (both total and grey matter) after accounting for age, FCI, global cognition, systolic blood pressure and physical activity.

**Key points**

- No previous studies have examined the independent contribution of falls-related self-efficacy to brain volume.
- Falls-related self-efficacy was independently associated with brain volume—total and grey matter.
- Promotion of self-efficacy may be an essential component of healthy ageing.

**Acknowledgements**

We thank the Brain Power study participants.
Authors’ contributions

T.L.A. was principal investigator for the Brain Power study. T.L.A. and J.C.D. were responsible for study concept and design, acquisition of data, data analysis and interpretation, writing and reviewing of the manuscript. J.C.D., T.L.A., L.S.N., C.L.H. and J.B drafted and revised the manuscript. J.C.D., L.S.N., C.L.H. and T.L.A. acquired and analysed the data.

Conflicts of interest

None declared.

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References

No increased mortality with unexplained anaemia

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Abstract

Background: in older persons, anaemia is associated with a number of unfavourable outcomes. In approximately 30% of older persons with anaemia, the cause of the anaemia is unexplained. We assessed the clinical differences between subjects with explained and unexplained anaemia and investigated whether these subjects have different mortality patterns compared with subjects without anaemia.

Design: observational prospective follow-up study.

Setting: the Leiden 85-plus study.

Participants: four hundred and ninety-one persons aged 86 years.

Methods: the study population was divided in three groups: (i) no anaemia (reference group, n = 377), (ii) explained anaemia (iron deficiency, folate deficiency, vitamin B12 deficiency, signs of myelodysplastic syndrome or renal failure, n = 74) and (iii) unexplained anaemia, (n = 40). Mortality risks were estimated with Cox-proportional hazard models.

Results: haemoglobin levels were significantly lower in subjects with explained anaemia than in subjects with unexplained anaemia (P < 0.01). An increased risk for mortality was observed in subjects with explained anaemia [HR: 1.93 (95% CI: 1.47–2.52), P < 0.001], but not in subjects with unexplained anaemia [HR: 1.19 (95% CI: 0.85–1.69), P = 0.31]. Adjusted analyses (sex, co-morbidity, MMSE, institutionalised and smoking) did not change the observed associations for both explained and unexplained anaemic subjects.

Conclusion: older subjects with unexplained anaemia had similar survival compared with non-anaemic subjects. Increased mortality risks were observed in subjects with explained anaemia compared with non-anaemic subjects.

Keywords: anaemia, elderly, mortality risk, unexplained