20. Schneider LS, Olin JT, Doody RS *et al*. Validity and reliability of the Alzheimer's disease cooperative study-clinical global impression of change. The Alzheimer's disease cooperative study. Alzheimer Dis Assoc Disord 1997; 11: S22–32.
21. Chen P, Yu ES, Zhang M, Liu WT, Hill R, Katzman R. ADL dependence and medical conditions in Chinese older persons: a population-based survey in Shanghai, China. J Am Geriatr Soc 1995; 43: 378–83.
22. Zhang M, Katzman R, Yu E, Liu W, Xiao SF, Yan H. A preliminary analysis of incidence of dementia in Shanghai, China. Psychiatry Clin Neurosci 1998; 52: S291–4.
23. Cummings JL, Mega M, Gray K *et al*. The neuropsychiatric inventory: comprehensive assessment of psychopathology in dementia. Neurology 1994; 44: 2308–14.
24. Leung VP, Lam LC, Chiu HF, Cummings JL, Chen QL. Validation study of the Chinese version of the neuropsychiatric inventory (CNPI). Int J Geriatr Psychiatry 2001; 16: 789–93.
25. Wang T, Xiao S, Li X *et al*. Reliability and Validity of the Chinese Version of the neuropsychiatric inventory in Mainland China. Int J Geriatr Psychiatry 2012; 27: 539–44.
26. Birks J. Cholinesterase inhibitors for Alzheimer's disease. Cochrane Database Syst Rev 2006; 25: CD005593.
27. Rogers SL, Friedhoff LT, Donepezil Study Group. The efficacy and safety of donepezil in patients with Alzheimer's disease: results of US multicentre, randomized, doubleblind, placebocontrolled trial. Dementia 1996; 7: 293–303.
28. Rogers SL, Doody RS, Mohs RC, Friedhoff LT, Donepezil Study Group. Donepezil improves cognition and global function in Alzheimer disease. Arch Intern Med 1998; 158: 1021–31.
29. Burns A, Rossor M, Hecker J *et al*. The effects of donepezil in Alzheimer's disease—results from a multinational trial. Dement Geriatr Cogn Disord 1999; 10: 237–44.
30. CoreyBloom J, Anand R, Veach J, ENA 713 B352 Study Group. A randomized trial evaluating the efficacy and safety of ENA 713 (rivastigmine tartrate), a new acetylcholinesterase inhibitor, in patients with mild to moderately severe Alzheimer's disease. Int J Geriatr Psychopharmacol 1998; 1: 55–65.

Received 10 December 2015; editorial decision 18 January 2017

Age and Ageing 2017; **46:** 773–779
doi: 10.1093/ageing/afx018
Published electronically 23 February 2017

Lower risk of incident dementia among Chinese older adults having three servings of vegetables and two servings of fruits a day

Allen T. C. Lee[1], Marcus Richards[2], Wai C. Chan[3], Helen F. K. Chiu[1], Ruby S. Y. Lee[4], Linda C. W. Lam[1]

[1]Department of Psychiatry, The Chinese University of Hong Kong, Hong Kong
[2]MRC Unit for Lifelong Health and Ageing at UCL, UK
[3]Department of Psychiatry, The University of Hong Kong, Hong Kong
[4]Elderly Health Service, Department of Health, Hong Kong

Address correspondance to: L. C. W. Lam. Tel: (852) 26076026; Fax: (852) 26675464. Email: cwlam@cuhk.edu.hk

Abstract

Background: dietary modification can potentially reduce dementia risk, but the importance of fruits and the amount of vegetables and fruits required for cognitive maintenance are uncertain. We examined whether the minimal daily requirement of vegetables and fruits recommended by the World Health Organization (WHO) would independently lower dementia risk.

Methods: in this population-based observational study, we examined the diet of 17,700 community-living dementia-free Chinese older adults who attended the Elderly Health Centres in Hong Kong at baseline and followed their cognitive status for 6 years. In line with the WHO recommendation, we defined the cutoff for minimal intake of vegetables and fruits as at least three and two servings per day, respectively. The study outcome was incident dementia in 6 years. Dementia was defined by presence of clinical dementia in accordance with the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) or Clinical Dementia Rating of 1–3.

Results: multivariable logistic regression analysis showed that the estimated odds ratios for incident dementia were 0.88 (95% confidence interval 0.73–1.06; $P = 0.17$) for those consuming at least three servings of vegetables per day, 0.86 (0.74–0.99; $P < 0.05$) for those consuming at least two servings of fruits per day and 0.75 (0.60–0.95; $P = 0.02$) for those consuming at least these amounts of both at baseline, after adjusting for age, gender, education, major chronic diseases, physical exercise and smoking.
Conclusion: having at least three servings of vegetables and two servings of fruits daily might help prevent dementia in older adults.

Keywords: *vegetables, fruits, healthy diet, nutrition, dementia, older people.*

Introduction

Dementia is now a global health concern [1]. In the absence of disease modifying treatment, finding ways to prevent or slow dementia onset is of great clinical and public health importance [2–4]. Dietary modification can potentially reduce dementia risk [5], as people consuming more vegetables appear to have better cognition [6–8]. Interestingly, evidence for fruits lowering dementia risk is comparatively less [9], despite they are equally rich in vitamins compared to vegetables and both are in the same food group. While recent studies showed that diets rich in vegetables and fruits, such as the Mediterranean diet, the Dietary Approach to Systolic Hypertension (DASH) diet, and a combination of these two known as the Mediterranean-DASH diet Intervention for Neurodegenerative Delay (MIND) diet, might slow cognitive decline [10, 11], possibly mediated by vitamins and other nutrients present in these diets [12], they examined the effects of vegetables and fruits together and in combination with other nutrients. Moreover, it is uncertain how much vegetables or fruits one should eat for better brain health. Currently, the World Health Organization (WHO) recommends eating five servings of vegetables and fruits daily for a healthy diet [13], whereas others suggest an even larger proportion of vegetable and fruit intake is needed for prevention of heart diseases and cancer [14, 15]. Nevertheless, consensus on the recommended daily intake of vegetables and fruits for cognitive maintenance is lacking.

In this study, we examined the amount of vegetable and fruit intake and followed the cognitive status of a large cohort of dementia-free older adults for 6 years. The objective was to investigate whether those consuming at least three servings of vegetables and two servings of fruits daily, in line with the WHO recommendation [13], were at a lower risk of incident dementia. The findings could potentially provide some insight into the daily amount of vegetables and fruits required for cognitive maintenance, and might highlight the importance of consuming not only vegetables but also fruits in dementia prevention.

Methods

Study design and participants

The present study shared the same design and cohort as our previous study [16]. In brief, this was a 6-year observational study of 18,298 local residents who received annual health assessment and dementia screening at the Elderly Health Centers (EHCs) of the Department of Health of the Government of Hong Kong between 2005 and 2011. Those without re-assessment since 2008 were traced and offered a follow-up cognitive examination conducted by geriatric psychiatrists either at the EHCs, at their homes, or by phone in 2011. Inclusion criteria for this study were age 65 years and older, ethnic Chinese and dementia-free. Exclusion criteria were having clinical dementia or scoring below the education-specific cutoff on the Cantonese version of the Mini-Mental State Examination (C-MMSE) at baseline [17].

Assessment and quantification of vegetable and fruit consumption

During the health assessments, nurses used a food frequency questionnaire to probe for participants' typical daily vegetable and fruit consumption in the past 1 month. For participants who had difficulty in recalling their diet, relatives or caregivers were invited to provide collateral information. The amount of vegetable and fruit intake was quantified as the number of servings of vegetables and fruits per day (see Supplementary data, Appendix 1, available in *Age and Ageing* online) [18, 19]. The cutoff for minimal intake of vegetables and fruits was defined as at least three and two servings per day, respectively [13].

Covariables at baseline

Participants' demographics (age, sex, and education), medical and psychiatric history (hypertension, diabetes, hypercholesterolemia, heart diseases, stroke, Parkinson's disease, body mass index, unintentional weight loss of 10% or more within a year, depression and dementia), and lifestyle (physical exercise and smoking) were examined during the health assessment. All diseases were verified and classified by primary care physicians at the EHCs in accordance with the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) [20]. Physical exercise, specifically aerobic (such as running, swimming and cycling) and mind-body (Tai Chi and yoga) exercises, was assessed and classified as previously reported [16]. Smoking was defined as daily smoking in the past 1 month.

Identification of dementia cases

Cognitive examinations were performed as in our previous study [16]. In brief, participants received the C-MMSE and clinical examination by physicians at the EHCs. Those with follow-up cognitive examination by geriatric psychiatrists received clinical examination, the C-MMSE and/or the Clinical Dementia Rating (CDR) [21], depending on whether the interview was conducted face-to-face or over the phone. The study outcome was incident dementia in 6 years. Dementia was defined by the presence of clinical dementia in accordance with ICD-10 or CDR of 1–3.

Statistical analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) software version 22 (SPSS, Chicago, IL, USA). The number of participants with follow-up in 6 years was expressed as person-years. The χ^2 test was used to compare the proportion of participants having at least three servings of vegetables and/or two servings of fruits daily at baseline between those with and without incident dementia. The level of statistical significance was set at P less than 0.05.

To ascertain that incident dementia was associated with inadequate consumption of vegetables and/or fruits at baseline rather than a longitudinal decrease of intake, participants developing dementia at Years 4–6 were selected, and the proportion of those having less than three servings of vegetables and/or two servings of fruits daily at baseline was compared with that at Year 3 using the McNemar's test.

To investigate if maintaining daily consumption of three servings of vegetables and/or two servings of fruits was associated with lower dementia incidence, the proportion of participants who continued having these servings 3 years after baseline was compared between those with and without incident dementia at Years 4–6.

To test if having at least three servings of vegetables and/or two servings of fruits daily was associated with lower dementia risk years later, the proportion of participants having these servings at baseline was compared between those with and without incident dementia at Years 4–6.

Multivariable logistic regression analysis was performed on the same subgroup to test if having these servings of vegetables and/or fruits at baseline was associated with lower dementia incidence, after adjustment for confounding factors with statistical significance of P less than 0.1. The odds ratios (ORs) were computed to yield point estimates with 95% confidence intervals (CIs). Given health behaviours tend to cluster together, the analysis was repeated by additionally adjusted for physical exercise and smoking.

Results

Dementia incidence in 6 years

About 17,700 older adults were included in this study (see Supplementary data, Appendix 2, available in *Age and Ageing* online). About 14,250 (80.5%) had at least one cognitive examination since 2008, contributing to a total of 76,624 person-years of follow-up in 6 years. About 1,620 (9.2%) participants developed incident dementia. Table 1 showed the differences in baseline characteristics between those with and without incident dementia. Except for diabetes, heart diseases and stroke, there was no significant difference in sociodemographic factors, other health problems, or vegetable and fruit intake between those with ICD-10-diagnosed dementia and

Table 1. Comparison of baseline characteristics between participants who remained dementia-free and those who developed dementia in 6 years

	Incident dementia		Statistics (*P*-value)
	No (n = 16,080)	Yes (n = 1,620)	
Age, years (interquartile range)	74 (71–77)	76 (73–80)	<0.001[a]
Female, n (%)	10,087 (62.7)	1,166 (72.0)	<0.001[b]
No schooling received, n (%)	4,151 (25.8)	606 (37.4)	<0.001[b]
Hypertension, n (%)	10,386 (64.6)	1,137 (70.2)	<0.001[b]
Diabetes mellitus, n (%)	2,460 (15.3)	286 (17.7)	0.01[b]
Hypercholesterolemia, n (%)	6,711 (41.7)	689 (42.5)	0.54[b]
Heart disease, n (%)	1,876 (11.7)	237 (14.6)	<0.001[b]
Stroke, n (%)	525 (3.3)	98 (6.0)	<0.001[b]
Parkinson's disease, n (%)	68 (0.4)	13 (0.8)	0.03[b]
Depression, n (%)	643 (4.0)	102 (6.3)	<0.001[b]
Body mass index, kg/m^2 (interquartile range)	24.0 (21.8–26.2)	24.0 (21.8–26.3)	0.54[a]
Weight loss, n (%)	150 (1.2)	20 (1.6)	0.22[b]
Aerobic exercise, n (%)	5,285 (35.1)	392 (25.8)	<0.001[b]
Mind-body exercise, n (%)	3,668 (24.3)	310 (20.4)	0.001[b]
Daily smoking, n (%)	833 (5.2)	76 (4.7)	0.40[b]
At least three servings of vegetables consumed daily, n (%)	13,028 (81.0)	1,279(79.0)	0.04[b]
At least two servings of fruits consumed daily, n (%)	8,899 (55.3)	817 (50.4)	<0.001[b]
At least three servings of vegetables and two servings of fruits consumed daily, n (%)	7,808 (48.6)	718 (44.3)	0.001[b]

[a]Mann–Whitney U-test.
[b]χ^2 test.

those with CDR 1–3 (see Supplementary data, Appendix 3, available in *Age and Ageing* online).

Comparison of baseline vegetable and fruit consumption between cognitively stable and incident dementia groups

A larger proportion of participants reported having at least three servings of vegetables, two servings of fruits, or both daily at baseline in the cognitively stable group (Table 1).

Longitudinal changes of vegetable and fruit consumption before dementia onset

There was no increase in the proportion of participants who had less than three servings of vegetables and/or two servings of fruits daily over the first 3 years among those with incident dementia at Years 4–6 (see Supplementary data, Appendix 4, available in *Age and Ageing* online).

Maintenance of vegetable and fruit consumption and dementia incidence

The proportion of participants maintaining daily consumption of at least two servings of fruits in the first 3 years was larger in those who remained dementia-free at Years 4–6. A similar trend was observed in the proportion of participants maintaining daily consumption of vegetables or both vegetables and fruits, though the result did not reach statistical significance (see Supplementary data, Appendix 5, available in *Age and Ageing* online).

Baseline vegetable and fruit consumption and future risk of dementia

As older people might have already experienced some cognitive impairment and thereby adopted a relatively less healthy diet before the clinical onset of dementia, the association between vegetable and fruit consumption and dementia risk was re-examined by excluding those who developed dementia within 3 years after baseline. Consistent with the above findings, the proportion of participants having at least three servings of vegetables and/or two servings of fruits daily at baseline was larger in the cognitively stable group (Table 2).

The estimated OR for incident dementia was significantly lower for those consuming vegetables or fruits daily and was even lower for those consuming both at baseline, after adjusting for age, gender, educational level, hypertension, diabetes, heart diseases, stroke, Parkinson's disease and depression. After additionally adjusted for physical exercise and smoking, the OR for incident dementia remained significantly lower for those consuming fruits daily and was even lower for those consuming both vegetables and fruits at baseline (Table 3).

Discussion

By following the cognitive status of 17,700 dementia-free older adults for 6 years, we found that baseline fruit consumption was associated with dementia risk, even after adjusted for age, education, major chronic diseases and other health-related behaviours. More importantly, the risk appeared to be even lower in those who consumed both fruits and vegetables daily. Our findings suggest that not only could fruits independently modulate dementia risk, but fruits and vegetables could not substitute one another despite they belong to the same food group. Having at least three servings of vegetables and two servings of fruits daily might help prevent dementia in late life.

Comparison with other studies

The present findings are consistent with previous epidemiological observation that low vegetable intake (1–2 servings/

Table 2. Differences in the proportion of participants having the minimal daily intake of vegetables and/or fruits at baseline between those free of dementia and with incident dementia at Years 4–6

	Incident dementia		Statistics[a] (*P*-value)
	No (*n* = 11,838)	Yes (*n* = 880)	
At least three servings of vegetables consumed daily, *n* (%)	9,848 (83.2)	700 (79.5)	<0.01
At least two servings of fruits consumed daily, *n* (%)	6,796 (57.4)	460 (52.3)	<0.01
At least three servings of vegetables and two servings of fruits consumed daily, *n* (%)	6,042 (51.0)	407 (46.3)	<0.01

[a] χ^2 test.

Table 3. Estimated ORs and 95% CIs for incident dementia using multivariable logistic regression analysis

Daily consumption at baseline	Model 1[a]		Model 2[b]	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
At least three servings of vegetables	0.84 (0.70–0.99)	<0.05	0.88 (0.73–1.06)	0.17
At least two servings of fruits	0.83 (0.72–0.95)	<0.01	0.86 (0.74–0.99)	<0.05
At least three servings of vegetables and two servings of fruits	0.70 (0.57–0.87)	0.001	0.75 (0.60–0.95)	0.02

[a]Adjusted for age, gender, educational level, hypertension, diabetes, heart diseases, stroke, Parkinson's disease and depression.
[b]Adjusted for physical exercise and smoking in addition to factors in Model 1.

day) is associated with cognitive decline [6–8]. Interestingly, the majority of our participants reported having three or more servings of vegetables daily. Although this could be due to self-reporting bias, consuming healthy quantities of vegetables every day might be a common practice among our participants because they are all ethnic Chinese, who typically eat more rice and vegetables and less meat than the Western populations, and are more health conscious, attending the EHCs regularly for health assessment and health talks. Given other health-related behaviours might confound the association between vegetables and cognitive function, physical exercise and smoking were included in our analysis. The odds of developing dementia not only remained low for those having vegetables daily, though no longer being statistically significant, but was even lower for those having both vegetables and fruits daily. Therefore, our findings suggest that vegetables are important to cognitive health in older adults.

Comparing to the previous studies which did not find fruits slowing cognitive decline [9], our study showed that fruit consumption was associated with lower dementia risk, independently of the amount of vegetable intake. A possible explanation for the difference in findings is that the studies differed in the assessment of diet. Here, we used a nurse interview instead of a self-administered questionnaire to examine the participants' diet, and we quantified the servings of different types of fruits and vegetables in accordance with the WHO recommendation. The large variety of fresh fruits widely available in our locality might also account for the difference.

As the participants' diet might change during the study period, one could argue that the elevated risk of incident dementia is due to a longitudinal decrease of vegetable and/or fruit intake. Nevertheless, we did not find any increase in the proportion of participants with inadequate vegetable or fruit intake over the years. Interestingly, the association between maintenance of vegetable intake and dementia prevention did not reach statistical significance. Because most of our participants reported consuming healthy quantities of vegetables daily, we speculate that the additional cognitive benefit brought by maintenance of vegetable consumption might be limited by a ceiling effect.

Proposed mechanisms of how vegetables and fruits modulate dementia risk

Although this study did not examine how vegetables and fruits independently modulate dementia risk, we speculate that inadequate intake might exacerbate onset of clinical dementia through various mechanisms. First, vegetables and fruits are rich sources of nutrients, including vitamin B, vitamin E, flavonoids and beta-carotenoids, which have antioxidant and anti-inflammatory properties. As oxidative stress and inflammation are thought to be involved in the development and progression of dementia [22], with animal studies showing that deficiency of these bioactive compounds could aggravate the dementia pathologies [23–26], not eating enough vegetables or fruits might decrease resilience against the neurodegenerative processes. Second, this vegetable- and fruit-mediated cognitive benefit is likely dependent on the bioavailability of multiple compounds rather than a single nutrient. Indeed, taking dietary supplements has not been found to be effective in preventing dementia [27, 28], whereas diets rich in vegetables and fruits such as the Mediterranean, DASH and MIND diets might slow cognitive decline [10, 11]. Third, an additive or synergistic interaction might exist between vegetables and fruits [29], as our data suggested that the dementia risk was higher in those with inadequate intake of both than of either one alone. With numerous types of nutrients present in different parts of a plant, it is plausible that the cognitive benefit could be best achieved when both vegetables and fruits are consumed. All these potential mechanisms might explain insufficient intake of either vegetables or fruits alone increasing dementia risk.

Limitations and strengths

Given the nature of the study design, we could not make an inference about a causal relationship between inadequate vegetable and fruit intake and development of dementia. The possibility of reverse causation, such as the effect of baseline cognitive capacity on the choice of diet, and the effect of unmeasured factors, such as duration of dietary habit practicing prior to this study, could not be completely excluded. Moreover, we did not examine if the observed association is dose-dependent. Given the possible inverted U-shaped association between nutrition and optimal cognitive function [30], future studies should confirm whether having three servings of vegetables and two servings of fruits daily is adequate for dementia prevention. Also, care needs to be taken when applying our findings to the general older population and other ethnicities as the participants of this study were relatively health conscious and were all Chinese. Other lifestyle factors such as different ways of food preparation, tea and alcohol consumption, and participation of mental exercise might confound the observed association.

Regarding the strengths of this study, we followed a large territory-wide community cohort for a long time. The attrition rate was low, with most participants having a recent cognitive examination. Also, we quantified in sufficient detail the vegetable and fruit intake at baseline and at follow-up.

Conclusion

This study provides evidence for the need of consuming not only vegetables but also fruits daily for dementia prevention in older adults. Future studies should confirm whether the observed association is present in other large cohorts of older adults from different ethnicities.

Key points

- Consuming at least two servings of fruits a day might independently lower risk of dementia.
- The risk appeared to be even lower in those who consumed at least three servings of vegetables and two servings of fruits a day.
- The importance of eating both vegetables and fruits daily for dementia prevention should be emphasised in the older populations.

Supplementary data

Supplementary data are available at *Age and Ageing* online.

Acknowledgement

We thank the staff of the Elderly Health Service for conducting assessment at the EHCs, cross-checking the defaulted participants with the Deaths Registry and providing the anonymised data. We also thank the research assistants (Ada Fung, Shelly Leung, Janette Chow, Alicia Chan, Jeanie Law and Jonathan Liu) for tracing the defaulted participants. Last but not least, we thank the participants and their family members in this study.

Conflict of interest

None declared.

Funding

This work was supported by the Health and Health Services Research Fund of the Government of Hong Kong in 2011 [grant 09100071], which had no role in the design, execution, analysis, interpretation of data or writing of the study.

Ethical approval

This study was approved by both the Ethics Committee of the Department of Health of the Government of Hong Kong and the Joint Clinical Research Ethics Committee of the Chinese University of Hong Kong and the New Territories East Cluster of the Hospital Authority.

References

1. World Health Organization and Alzheimer's Disease International. 2012. Dementia—a Public Health Priority. http://www.who.int/mental_health/publications/dementia_report_2012/en (20 June 2016, date last accessed).
2. Brookmeyer R, Johnson E, Ziegler-Graham K, Arrighi HM. Forecasting the global burden of Alzheimer's disease. Alzheimers Dement 2007; 3: 186–91.
3. Barnes DE, Yaffe K. The projected effect of risk factor reduction on Alzheimer's disease prevalence. Lancet Neurol 2011; 10: 819–28.
4. Norton S, Matthews FE, Barnes DE, Yaffe K, Brayne C. Potential for primary prevention of Alzheimer's disease: an analysis of population-based data. Lancet Neurol 2014; 13: 788–94.
5. Baumgart M, Snyder HM, Carrillo MC *et al.* Summary of the evidence on modifiable risk factors for cognitive decline and dementia: a population-based perspective. Alzheimers Dement 2015; 11: 718–26.
6. Kang JH, Ascherio A, Grodstein F. Fruit and vegetable consumption and cognitive decline in aging women. Ann Neurol 2005; 57: 713–20.
7. Morris MC, Evans DA, Tangney CC, Bienias JL, Wilson RS. Associations of vegetable and fruit consumption with age-related cognitive change. Neurology 2006; 67: 1370–6.
8. Chen X, Huang Y, Cheng HG. Lower intake of vegetables and legumes associated with cognitive decline among illiterate elderly Chinese: a 3-year cohort study. J Nutr Health Aging 2012; 16: 549–52.
9. Loef M, Walach H. Fruit, vegetables and prevention of cognitive decline or dementia: a systematic review of cohort studies. J Nutr Health Aging 2012; 16: 626–30.
10. Tangney CC, Li H, Wang Y *et al.* Relation of DASH- and Mediterranean-like dietary patterns to cognitive decline in older persons. Neurology 2014; 83: 1410–6.
11. Morris MC, Tangney CC, Wang Y *et al.* MIND diet slows cognitive decline with aging. Alzheimers Dement 2015; 11: 1015–22.
12. Luchsinger JA, Mayeux R. Dietary factors and Alzheimer's disease. Lancet Neurol 2004; 3: 579–87.
13. World Health Organization. 2015. Healthy Diet. http://www.who.int/mediacentre/factsheets/fs394/en (20 June 2016, date last accessed).
14. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th edition. https://health.gov/dietaryguidelines/2015/resources/2015-2020_Dietary_Guidelines.pdf (23 September 2016, date last accessed).
15. Oyebode O, Gordon-Dseagu V, Walker A, Mindell JS. Fruit and vegetable consumption and all-cause mortality: analysis of Health Survey of England data. J Epidemiol Community Health 2014; 68: 856–62.
16. Lee AT, Richards M, Chan WC, Chiu HF, Lee RS, Lam LC. Intensity and types of physical exercise in relation to dementia risk reduction in community-living older adults. J Am Med Dir Assoc 2015; 16: 899. e1–7.
17. Chiu HF, Lam LC, Chi I *et al.* Prevalence of dementia in Chinese elderly in Hong Kong. Neurology 1998; 50: 1002–9.
18. World Health Organization. 2015. Measuring Intake of Fruit and Vegetables. http://www.who.int/dietphysicalactivity/publications/f&v_intake_measurement.pdf?ua=1 (20 June 2016, date last accessed).
19. Department of Health, The Government of the Hong Kong Special Administrative Region. Food Type—Fruits and Vegetables. http://www.cheu.gov.hk/eng/info/Adults_4.htm (20 June 2016, date last accessed).
20. World Health Organization. 2004. International Statistical Classification of Diseases and Related Health Problems, 10th revision. http://apps.who.int/classifications/apps/icd/icd10online2004/fr-icd.htm (20 June 2016, date last accessed).

21. Morris JC. Clinical dementia rating: a reliable and valid diagnostic and staging measure for dementia of the Alzheimer type. Int Psychogeriatr 1997; 9: 173–6.
22. Butterfield D, Castegna A, Pocernich C, Drake J, Scapagnini G, Calabrese V. Nutritional approaches to combat oxidative stress in Alzheimer's disease. J Nutr Biochem 2002; 13: 444–63.
23. Behl C, Davis J, Cole GM, Schubert D. Vitamin E protects nerve cells from amyloid beta protein toxicity. Biochem Biophys Res Commun 1992; 186: 944–50.
24. Kruman II, Kumaravel TS, Lohani A *et al*. Folic acid deficiency and homocysteine impair DNA repair in hippocampal neurons and sensitize them to amyloid toxicity in experimental models of Alzheimer's disease. J Neurosci 2002; 22: 1752–62.
25. Obulesu M, Dowlathabad MR, Bramhachari PV. Carotenoids and Alzheimer's disease: an insight into therapeutic role of retinoids in animal models. Neurochem Int 2011; 59: 535–41.
26. Vauzour D, Martinsen A, Layé S. Neuroinflammatory processes in cognitive disorders: is there a role for flavonoids and n-3 polyunsaturated fatty acids in counteracting their detrimental effects? Neurochem Int 2015; 89: 63–74.
27. Malouf R, Grimley Evans J. Folic acid with or without vitamin B12 for the prevention and treatment of healthy elderly and demented people. Cochrane Database Syst Rev 2008; 4: CD004514.
28. Farina N, Isaac MG, Clark AR, Rusted J, Tabet N. Vitamin E for Alzheimer's dementia and mild cognitive impairment. Cochrane Database Syst Rev 2012; 11: CD002854.
29. Liu RH. Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. Am J Clin Nutr 2003; 78: 517S—20S.
30. Morris MC, Tangney CC. A potential design flaw of randomized trials of vitamin supplements. JAMA 2011; 305: 1348–9.

Received 10 July 2016; editorial decision 13 December 2016

Age and Ageing 2017; **46:** 779–786
doi: 10.1093/ageing/afx042
Published electronically 5 April 2017

Observational cohort study examining apolipoprotein E status and preoperative neuropsychological performance as predictors of post-operative delirium in an older elective arthroplasty population

Emma Louise Cunningham[1], Tim Mawhinney[2], David Beverland[2], Seamus O'Brien[2], Daniel F McAuley[3], Rebecca Cairns[4], Peter Passmore[1], Bernadette McGuinness[1]

[1]Centre for Public Health, Institute of Clinical Sciences, Block B, Queens University Belfast, Royal Victoria Hospital, Belfast BT12 6BA, UK
[2]Belfast Health and Social Care Trust, Belfast, UK
[3]Centre for Experimental Medicine, Queen's University Belfast, Belfast, UK
[4]Northern Health and Social Care Trust, Ballymena, UK

Address correspondence to: E. L. Cunningham. Tel: (+44) (0)28 90635009; Fax: (+44) (0)28 90235900.
Email: ecunningham03@qub.ac.uk

Abstract

Introduction: delirium following surgery is common and is associated with negative outcomes. Preoperative cognitive impairment has been shown to be a risk factor for post-operative delirium. Often the cognitive tests used are cumbersome. This study tests the hypothesis that the quantification of brain vulnerability, using Apolipoprotein E (ApoE) status and neuropsychological tests, both traditional and more easily administered, can quantify the risk of post-operative delirium following elective primary arthroplasty surgery.
Methods: this observational cohort study recruited participants aged 65 years or older admitted prior to elective primary hip or knee arthroplasty. Baseline data was collected and participants underwent neuropsychological testing and had blood taken for ApoE genotyping preoperatively. Post-operatively participants were assessed daily for delirium using the