Public Health Nutrition: 22(4), 689–696 doi:10.1017/S1368980018002525

Short Communication

Fruit and vegetable consumption is associated with improved mental and cognitive health in older adults from non-Western developing countries

Kerstin H Gehlich[1,*], Johannes Beller[2], Bernhard Lange-Asschenfeldt[1,3], Wolfgang Köcher[4], Martina C Meinke[1] and Jürgen Lademann[1]

[1]Charité Universitätsmedizin Berlin, Klinik für Dermatologie, Venerologie und Allergologie, Charitéplatz 1, 10117 Berlin, Germany: [2]Technische Universität Braunschweig, Institut für Psychologie, Braunschweig, Germany: [3]Klinikum Klagenfurt am Wörthersee, Abteilung für Dermatologie und Venerologie, Klagenfurt am Wörthersee, Austria: [4]Biozoom GmbH, Kassel, Germany

Submitted 25 August 2017: Final revision received 7 June 2018: Accepted 22 August 2018: First published online 8 October 2018

Abstract

Objectives: Consumption of fruits and vegetables has been shown to contribute to mental and cognitive health in older adults from Western industrialized countries. However, it is unclear whether this effect replicates in older adults from non-Western developing countries. Thus, the present study examined the contribution of fruit and vegetable consumption to mental and cognitive health in older persons from China, India, Mexico, Russia, South Africa and Ghana.

Design: Representative cross-sectional and cross-national study.

Setting/Subjects: We used data from the WHO Study on Global Ageing and Adult Health (SAGE), sampled in 2007 to 2010. Our final sample size included 28 078 participants.

Results: Fruit and vegetable consumption predicted an increased cognitive performance in older adults including improved verbal recall, improved delayed verbal recall, improved digit span test performance and improved verbal fluency; the effect of fruit consumption was much stronger than the effect of vegetable consumption. Regarding mental health, fruit consumption was significantly associated with better subjective quality of life and less depressive symptoms; vegetable consumption, however, did not significantly relate to mental health.

Conclusions: Consumption of fruits is associated with both improved cognitive and mental health in older adults from non-Western developing countries, and consumption of vegetables is associated with improved cognitive health only. Increasing fruit and vegetable consumption might be one easy and cost-effective way to improve the overall health and quality of life of older adults in non-Western developing countries.

Keywords
Nutrition
Mental health
Cognition
Older adults
Developing countries

Consumption of fruits and vegetables has been shown to prevent several chronic diseases like CHD[1,2]. But health is more than just the absence of physical diseases, as recognized by the WHO definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'[3]. Thus, when examining the potential health benefits of fruit and vegetable consumption, one should also consider mental health and cognition.

Especially in older adults, mental health and cognitive performance have been described as one of the most important aspects in health maintenance. For example, cognitive functioning and mental health play an important role for social participation of older adults and vice versa[4]: to remain autonomous older adults must maintain their mental health and cognitive performance. Consequently, preservation of cognitive functioning has also been shown to improve quality of life and prevent

*Corresponding author: Email kerstin.gehlich@charite.de

morbidity[5]. Besides cognition, another important aspect of health is mental health[6,7]. For example, mental health has been shown to be independently correlated with mortality[8], with the mortality rate increasing as much as fourfold in older adults suffering from depression[9–11]. Thus, declining mental and cognitive health represent a substantial global health problem for an ageing world population.

Although the contribution of a healthy diet to physical health is widely acknowledged, only some studies have examined the association between nutrition and mental and cognitive decline[12], sometimes yielding inconsistent results regarding the role of fruit and vegetable consumption[13,14]. Even fewer studies have analysed this purported relationship with participants from non-Western and developing countries; most studies have been conducted using comparatively small samples from industrialized Western countries like the USA and Germany[1]. Thus, as previous studies have found difficulties in generalizing from populations like the US[15], it seems imperative to examine whether the results of previous studies are indeed robust and generalizable to other populations like those in non-Western developing countries. Examining the health benefits of fruit and vegetable consumption might be especially important in the case of developing countries because the health systems in these countries typically tend to be much more limited in their resources. As such, one might expect healthy nutrition to play an even more important role in healthy ageing of these older adults. Thus, in the current study we ask: is fruit and vegetable consumption associated with cognitive and mental health in a large, cross-national and cross-sectional sample of older adults from six non-Western developing countries?

Methods

Study population

We used data from the first (and currently only available) wave of the WHO Study on Global Ageing and Adult Health (SAGE). The WHO SAGE collects cross-national data on health and well-being of older adults from low- and middle-income countries[16]. A multistage cluster sampling design was implemented by the WHO in China, India, Mexico, Russia, South Africa and Ghana. In all countries standardized face-to-face survey instruments were used by trained interviewers. Wave 1 collected data from 2007 to 2010. The data and more detailed sampling information are available on the SAGE website (www.who.int/healthinfo/systems/sage). Originally, 35 334 interviews with older adults were conducted. After deleting participants with missing values, we obtained a final sample size of 28 078 adults aged 50 years or older.

Variables

Fruits and vegetables

Participants were asked to indicate the number of servings of fruit and vegetables they consume on a typical day. Participants were provided with a list of country-specific examples of fruits and vegetables to improve response accuracy. We used the self-reported number of servings of fruits and vegetables as indicators for general fruit consumption and vegetable consumption.

Cognition

We used verbal recall, delayed verbal recall, digit span and verbal fluency as indicators of cognitive functioning. Regarding verbal recall, the participants had to repeat ten unrelated words and were asked to immediately recall as many words as possible. The delayed verbal recall was based on the same list of ten words which were asked to be repeated about 10 min later; we used the number of correct words as indicators. In the digit span test participants had to repeat a list of several unrelated digits forwards and backwards; we used the mean score of the longest series of correctly forward and backward repeated numbers as indicator. Regarding verbal fluency, participants had to name as many distinct animals as possible in 1 min; we used the total number of mentioned distinct animals as the indicator.

Mental health

We used quality of life and the number of depressive symptoms as indicators of mental health. Regarding quality of life, we used the sum score of the eight-item version of the WHO Quality of Life scale (WHOQOL)[17]. The WHOQOL is a cross-culturally applicable psychometrically sound self-report quality of life assessment that was developed by the WHO across fifteen international field centres[18].

Regarding depression, participants were first asked by the interviewer if they had a period, lasting more than 2 weeks, in the last year where they felt sad, empty, depressed, lost interest or were tired all the time. If they indicated to the interviewer that they had one such period, participants were further asked if they experienced different symptoms of depression during the last 2 weeks (loss of appetite, slowed-down thinking, problems falling asleep, waking up too early, difficulties concentrating, slowing down in moving around, feeling anxious or worried, being restless, feeling negative about oneself, feeling hopeless, losing interest in sex, suicidal ideation and suicidal behaviour). The number of depressive symptoms the respondent indicated to have experienced during the last 2 weeks was used as an indicator for depression. While it would have been preferable to use a psychometrically tested depression assessment procedure, the number of depressive symptoms is widely used as an

indicator of depression and has been shown to be strongly related to depression severity[19].

Covariates

As covariates we included self-reported gender, age, economic deprivation, smoking, daily alcohol consumption, physical activity and chronic conditions. Education was operationalized as the highest level of education completed. Economic deprivation was measured by asking participants how often in the last year they had to eat less because they had not enough food and were hungry but had not enough money to buy food. Smoking was measured by asking participants whether and how often they smoked currently. Alcohol consumption was measured by asking participants how many alcoholic beverages they drink on an average day. Physical activity was measured dichotomously by asking participants whether they engage in any form of moderate or vigorous physical work and/or sport activities in a typical week. The number of chronic conditions was measured by asking participants whether they were ever diagnosed with any number of seven common chronic health conditions (arthritis, stroke, angina, diabetes, chronic lung disease, asthma, hypertension) and using the sum of these conditions as the indicator.

Statistical analysis

All statistical analyses were performed with the R statistical software, version 3.50. We decided to analyse the aspects of cognitive and mental health separately to be as close to the literature as possible and to detect possible differential effects of our predictors. We first analysed the association between our variables via Pearson correlation analysis. As our participants are clustered within different countries, ignoring the multilevel structure of our sample could lead to biased estimates; consequently, to account for this, and the inter-correlations of our variables, we additionally used multilevel regression analysis, which is similarly interpreted to regular ordinary least-squares regression but is able to handle multilevel data. We predicted our several measures of health using all our predictors simultaneously (fruit consumption, vegetable consumption, gender, age, education, economic deprivation, smoking, daily alcohol consumption, physical activities and the number of chronic conditions).

Results

Table 1 displays the descriptive statistics and inter-correlations of our variables across countries (basic descriptive statistics within countries are displayed in the Appendix). Both fruit consumption and vegetable consumption correlated significantly with all our dependent variables. Fruit consumption and vegetable consumption correlated positively with verbal recall, delayed verbal recall, digit span, verbal fluency and quality of life, and correlated negatively with depression. The correlations of fruit consumption and vegetable consumption were small and comparable in size.

The covariates were also associated with most outcome variables in the Pearson correlation analyses. Being female, being older, economic deprivation, smoking, daily alcoholic drinks and chronic conditions were, in general, associated with worse cognitive and mental health. Contrarily, education and physical activity were associated with better cognitive and mental health.

Table 2 displays the results of our multilevel regression analyses. When accounting for covariates (sex, age, education, economic deprivation, smoking, alcohol consumption, activities and chronic conditions) and the multilevel structure of our data (participants nested in countries: China, India, Mexico, Russia, South Africa and Ghana), different results emerged. Fruit consumption still predicted all our dependent variables significantly. Vegetable consumption predicted all dependent cognitive variables significantly but did not significantly predict the mental health dependent variables (WHOQOL and depression). Furthermore, the positive effects of fruit consumption were by far stronger than the positive effects of vegetable consumption.

In our multilevel regression analyses, all covariates, besides the number of daily alcoholic drinks, predicted mental and psychological health in older adults in general. Being female, being older, economic deprivation, smoking and chronic conditions predicted, in general, worse cognitive and physical health. On the other hand, education and physical activity predicted, in general, better cognitive and mental health.

Discussion

The aim of the present study was to test whether fruit and vegetable consumption was associated with improved mental and cognitive health of older adults in low- and middle-income countries. We found strong associations between the frequency of fruit and vegetable intake and mental health and cognitive functioning. Specifically, fruit consumption showed strong effects for all our variables, whereas vegetable consumption seemed to be associated with improved cognitive functioning only.

Our findings are consistent with and build upon the literature. Several studies have shown that, besides sociodemographic factors like education and other lifestyle factors like smoking, a diet rich in fruits and vegetables is an important tool for prevention of physical, psychological and cognitive decline[20–22], but studies were lacking that analysed this relationship in non-Western low- and middle-income countries. Additionally, studies had shown conflicting findings regarding possible

Table 1 Means, SD and inter-correlations (Pearson) of cognitive health, psychological health, and fruit and vegetable consumption in older adults from China, India, Mexico, Russia, South Africa and Ghana (*n* 28 078); WHO Study on Global Ageing and Adult Health (SAGE), 2007–2010

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Verbal recall	5·63	1·55	–														
2. Delayed verbal recall	4·88	2·17	0·68***	–													
3. Digit span	4·28	1·44	0·42***	0·38***	–												
4. Verbal fluency	12·28	4·95	0·39***	0·34***	0·33***	–											
5. WHOQOL-8	3·54	0·61	0·22***	0·20***	0·27***	0·18***	–										
6. Depression	0·42	1·97	−0·07***	−0·04***	−0·14***	−0·03***	−0·17***	–									
7. Fruit consumption	1·84	1·90	0·14***	0·11***	0·24***	0·14***	0·13***	−0·07***	–								
8. Vegetable consumption	3·90	3·71	0·04***	0·07***	0·37***	0·11***	0·12***	−0·10***	0·30***	–							
9. Sex (female)	1·54	0·50	−0·05***	−0·03***	−0·12***	−0·09***	−0·08***	0·05***	0·03***	−0·05***	–						
10. Age	63·34	9·57	−0·29***	−0·27***	−0·22***	−0·15***	−0·15***	0·02***	−0·03***	−0·08***	0·01	–					
11. Education	2·14	1·33	0·32***	0·25***	0·44***	0·27***	0·20***	−0·07***	0·16***	0·02***	−0·14***	−0·16***	–				
12. Economic deprivation	1·27	0·74	−0·04***	−0·03***	−0·24***	−0·03***	−0·21***	0·12***	−0·03***	−0·19***	0·01	0·02**	−0·15***	–			
13. Smoking (yes)	1·52	0·86	−0·03***	−0·01	−0·02***	−0·02***	0·02**	0·01	−0·15***	0·03***	−0·39***	−0·09***	−0·05***	0·01	–		
14. Daily drinks	0·63	2·52	0·02**	0·01	0·05***	0·05***	0·04***	−0·02***	−0·02***	0·06***	−0·19***	−0·04***	0·02***	0·00	0·16***	–	
15. Activities	1·66	0·48	0·07***	0·05***	−0·02**	0·10***	0·07***	0·01	−0·02***	0·05***	−0·02***	−0·19***	0·00	0·01	0·05***	0·04***	–
16. Chronic conditions	0·79	1·01	−0·06***	−0·06***	0·04***	−0·02**	−0·19***	0·08***	0·02*	−0·02**	0·11***	0·20***	0·13***	−0·04***	−0·10***	−0·04***	−0·09***

WHOQOL-8, eight-item WHO Quality of Life scale.
*$P < 0·05$; **$P < 0·01$; ***$P < 0·001$.

Table 2 Multilevel regression analysis of fruit and vegetable consumption predicting mental and psychological health in older adults from China, India, Mexico, Russia, South Africa and Ghana (*n* 28 078); WHO Study on Global Ageing and Adult Health (SAGE), 2007–2010

	B	SE	χ^2	*P*
DV: Verbal recall				
Fruit consumption	0·07	0·00	192·09	<0·001
Vegetable consumption	0·02	0·00	25·19	<0·001
Sex (female)	−0·04	0·02	4·30	0·038
Age	−0·04	0·00	1674·81	<0·001
Education	0·30	0·01	1712·16	<0·001
Economic deprivation	−0·06	0·01	24·75	<0·001
Smoking (yes)	−0·02	0·01	4·71	0·03
Number of daily drinks	0·00	0·00	1·69	0·194
Activities	0·07	0·02	14·80	<0·001
Chronic conditions	−0·07	0·01	69·89	<0·001
DV: Delayed verbal recall				
Fruit consumption	0·05	0·01	57·49	<0·001
Vegetable consumption	0·03	0·00	39·92	<0·001
Sex (female)	0·00	0·03	0·01	0·913
Age	−0·05	0·00	1382·34	<0·001
Education	0·36	0·01	1186·74	<0·001
Economic deprivation	−0·02	0·02	1·88	0·17
Smoking (yes)	−0·01	0·02	0·15	0·7
Number of daily drinks	−0·01	0·00	2·74	0·098
Activities	0·09	0·03	12·41	<0·001
Chronic conditions	−0·08	0·01	41·37	<0·001
DV: Digit span				
Fruit consumption	0·03	0·00	68·53	<0·001
Vegetable consumption	0·01	0·00	9·88	0·002
Sex (female)	−0·26	0·01	350·46	<0·001
Age	−0·02	0·00	1224·51	<0·001
Education	0·37	0·00	4683·38	<0·001
Economic deprivation	−0·11	0·01	154·94	<0·001
Smoking (yes)	−0·02	0·01	5·12	0·024
Number of daily drinks	0·00	0·00	0·48	0·487
Activities	0·00	0·01	0·07	0·791
Chronic conditions	0·00	0·01	0·06	0·8
DV: Verbal fluency				
Fruit consumption	0·13	0·02	69·13	<0·001
Vegetable consumption	0·10	0·01	101·43	<0·001
Sex (female)	−0·52	0·06	71·14	<0·001
Age	−0·06	0·00	425·34	<0·001
Education	0·91	0·02	1476·89	<0·001
Economic deprivation	−0·10	0·04	6·86	0·009
Smoking (yes)	0·06	0·04	3·13	0·077
Number of daily drinks	0·01	0·01	1·58	0·209
Activities	0·80	0·06	180·15	<0·001
Chronic conditions	−0·01	0·03	0·07	0·786
DV: WHOQOL-8				
Fruit consumption	0·03	0·00	257·23	<0·001
Vegetable consumption	0·00	0·00	0·03	0·864
Sex (female)	−0·06	0·01	54·98	<0·001
Age	0·00	0·00	159·05	<0·001
Education	0·09	0·00	855·77	<0·001
Economic deprivation	−0·13	0·00	758·86	<0·001
Smoking (yes)	−0·01	0·00	6·00	0·014
Number of daily drinks	0·00	0·00	3·50	0·061
Activities	0·10	0·01	174·57	<0·001
Chronic conditions	−0·12	0·00	1142·92	<0·001
DV: Depression				
Fruit consumption	−0·03	0·01	26·16	<0·001
Vegetable consumption	0·00	0·00	0·08	0·779
Sex (female)	0·20	0·03	57·97	<0·001
Age	0·00	0·00	0·03	0·86
Education	−0·05	0·01	20·82	<0·001
Economic deprivation	0·26	0·02	244·61	<0·001
Smoking (yes)	0·02	0·02	2·19	0·139
Number of daily drinks	0·00	0·00	0·00	0·947
Activities	0·02	0·02	0·33	0·565
Chronic conditions	0·21	0·01	306·99	<0·001

B, regression coefficient; DV, dependent variable; WHOQOL-8, eight-item WHO Quality of Life scale.

protective effects of fruits and vegetables concerning depression[23–26]: while some studies showed that fruit and vegetable intake was associated with lower depression scores[24,27], other publications failed to find effects of dietary patterns in predicting depression[25,28]. Our results support the former studies in that fruit consumption showed strong protective effects on depression scores. Consequently, our results support the notion that fruits and, to a lesser degree, vegetables are essential for a healthy diet also among older adults in developing countries[29–31].

There are several possible mechanisms that might link fruit and vegetable consumption with mental and cognitive health. For example, the antioxidant status of fruits and vegetables might play a key role in preventing oxidative stress and thus protecting against damage of neural cell components, which occurs by reactive oxygen species and other free radicals[20,31–34]. Additionally, it is well known that mental and cognitive health and inflammation are contingent on one another[35]. For example, patients with major depressive disorder also experience higher blood cytokine levels[36–39]. Fruit and vegetable consumption might influence these inflammation processes and, thereby, prevent depression. Moreover, a diet rich in fruits and vegetables generates a high fibre intake that positively influences gut microbiota, which might also be associated with better mental and cognitive health[40,41]. Finally, fruits and vegetables contain several nutrients like zinc that have been shown to have direct neuroprotective effects[42]. Future research must analyse which mechanisms are responsible for the observed protective effects of fruit and vegetable consumption.

Information about these mechanisms might also inform the creation and examination of interventions that try to increase the intake of vegetables and fruits, such as information campaigns, low-cost fruit and vegetable supplies or biofeedback[31,43,44]. Especially in low- and middle-income countries with limited health-care resources, increasing fruit and vegetable intake might represent one cost-effective general prevention strategy. However, especially given that vegetable intake failed to significantly predict depression scores, future studies will be needed to investigate the detailed mechanisms of the influence of fruits and vegetables on the prevention of mental and cognitive decline.

There are several limitations regarding the current study. First, given the large sample size, we could only operationalize our measures using short assessment procedures like the eight-item version of the WHOQOL, instead of the full questionnaire. In the same vein, fruit and vegetable intake could only be included via aggregate measures. As such, the effects of fruit and vegetable consumption might also be due to specific sorts of fruits and vegetables or part of overall diet quality[45]. Future studies might thus use more specific and comprehensive questionnaires to assess nutrition, mental health and cognitive functioning to examine this relationship more differentially. Additionally, we employed cross-sectional data and as such one must be careful to not ascribe causality to our effects. For example, it has been noted that depression is also associated with a lower intake of fruits and vegetables, so that the possibility of reverse causality must be taken into account when interpreting our results. Thus, future studies must use longitudinal data to replicate our results.

Conclusion

In conclusion, our study confirms the overall health benefits of a diet rich in fruits and vegetables: consumption of fruits is associated with improved cognitive and mental health in older adults from non-Western developing countries, and consumption of vegetables is associated with improved cognitive health. Thus, nutrition might be one promising factor to improve older adults' overall health and well-being across the world. Future research must replicate the current study using more comprehensive operationalizations and should determine why the effects of fruit consumption and vegetable consumption differed.

Acknowledgements

Acknowledgements: The authors wish to express gratitude to the WHO for providing the data used in the current study. The WHO bears no responsibility for the interpretations presented or conclusions reached based on analysis of the data. *Financial support:* This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. *Conflict of interest:* There is no conflict of interest. *Authorship:* K.H.G. and J.B. contributed equally to the paper. K.H.G. developed the study concept, wrote the first draft of the manuscript and wrote the final draft of the manuscript together with J.B. J.B. performed the data analysis, provided critical revisions to the first draft of the manuscript and wrote the final draft of the manuscript together with K.H.G. B.L.-A., W.K., M.C.M. and J.L. proofread the paper and provided critical revisions. *Ethics of human subject participation:* Not applicable.

References

1. Boeing H, Bechthold A, Bub A *et al.* (2012) Critical review: vegetables and fruit in the prevention of chronic diseases. *Eur J Nutr* **51**, 637–663.
2. Dauchet L, Amouyel P, Hercberg S *et al.* (2006) Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies. *J Nutr* **136**, 2588–2593.

3. World Health Organization (1948) Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19–22 June 1946; signed on 22 July 1946 by the representatives of 61 States and entered into force on 7 April 1948. Official Records of the World Health Organization no. 2, p. 100. http://apps.who.int/iris/bitstream/handle/10665/85573/official_record2_eng.pdf?sequence=1 (accessed September 2018).
4. Glei DA, Landau DA, Goldman N *et al.* (2005) Participating in social activities helps preserve cognitive function: an analysis of a longitudinal, population-based study of the elderly. *Int J Epidemiol* **34**, 864–871.
5. Sun FW, Stepanovic MR, Andreano J *et al.* (2016) Youthful brains in older adults: preserved neuroanatomy in the default mode and salience networks contributes to youthful memory in superaging. *J Neurosci* **36**, 9659–9668.
6. Austin MP, Mitchell P & Goodwin GM (2001) Cognitive deficits in depression: possible implications for functional neuropathology. *Br J Psychiatry* **178**, 200–206.
7. Khan Shahbaz A, Vssr R, Bhat PS *et al.* (2014) Structural changes and cognitive deficits in depression and their clinical correlates. *Asian J Psychiatr* **7**, 99–100.
8. Blazer DG, Hybels CF & Pieper CF (2001) The association of depression and mortality in elderly persons: a case for multiple, independent pathways. *J Gerontol A Biol Sci Med Sci* **56**, M505–M509.
9. Pilania M, Bairwa M, Kumar N *et al.* (2013) Elderly depression in India: an emerging public health challenge. *Australas Med J* **6**, 107–111.
10. Kulkarni RS & Shinde RL (2015) Depression and its associated factors in older Indians: a study based on Study of Global Aging and Adult Health (SAGE) – 2007. *J Aging Health* **27**, 622–649.
11. Bruce ML & Leaf PJ (1989) Psychiatric disorders and 15-month mortality in a community sample of older adults. *Am J Public Health* **79**, 727–730.
12. Nooyens AC, Bueno-de-Mesquita HB, van Boxtel MP *et al.* (2011) Fruit and vegetable intake and cognitive decline in middle-aged men and women: the Doetinchem Cohort Study. *Br J Nutr* **106**, 752–761.
13. Kang JH, Ascherio A & Grodstein F (2005) Fruit and vegetable consumption and cognitive decline in aging women. *Ann Neurol* **57**, 713–720.
14. Miller MG, Thangthaeng N, Poulose SM *et al.* (2017) Role of fruits, nuts, and vegetables in maintaining cognitive health. *Exp Gerontol* **94**, 24–28.
15. Henrich J, Heine SJ & Norenzayan A (2010) The weirdest people in the world? *Behav Brain Sci* **33**, 61–83.
16. Kowal P, Chatterji S, Naidoo N *et al.* (2012) Data resource profile: the World Health Organization Study on global AGEing and adult health (SAGE). *Int J Epidemiol* **41**, 1639–1649.
17. Anon. (1995) The World Health Organization Quality of Life assessment (WHOQOL): position paper from the World Health Organization. *Soc Sci Med* **41**, 1403–1409.
18. Anon. (1993) Study protocol for the World Health Organization project to develop a Quality of Life assessment instrument (WHOQOL). *Qual Life Res* **2**, 153–159.
19. Park SC, Sakong J, Koo BH *et al.* (2016) Clinical significance of the number of depressive symptoms in major depressive disorder: results from the CRESCEND Study. *J Korean Med Sci* **31**, 617–622.
20. Polidori MC, Pratico D, Mangialasche F *et al.* (2009) High fruit and vegetable intake is positively correlated with antioxidant status and cognitive performance in healthy subjects. *J Alzheimers Dis* **17**, 921–927.
21. Lamport DJ, Saunders C, Butler LT *et al.* (2014) Fruits, vegetables, 100% juices, and cognitive function. *Nutr Rev* **72**, 774–789.
22. Leenders M, Boshuizen HC, Ferrari P *et al.* (2014) Fruit and vegetable intake and cause-specific mortality in the EPIC study. *Eur J Epidemiol* **29**, 639–652.
23. Martinez-Gonzalez MA & Sanchez-Villegas A (2016) Food patterns and the prevention of depression. *Proc Nutr Soc* **75**, 139–146.
24. Xia Y, Wang N, Yu B *et al.* (2017) Dietary patterns are associated with depressive symptoms among Chinese adults: a case–control study with propensity score matching. *Eur J Nutr* **56**, 2577–2587.
25. Chan R, Chan D & Woo J (2014) A prospective cohort study to examine the association between dietary patterns and depressive symptoms in older Chinese people in Hong Kong. *PLoS One* **9**, e105760.
26. Fresan U, Bes-Rastrollo M, Segovia-Siapco G *et al.* (2018) Does the MIND diet decrease depression risk? A comparison with Mediterranean diet in the SUN cohort. *Eur J Nutr*. Published online: 7 March 2018. doi: 10.1007/s00394-018-1653-x.
27. Saghafian F, Malmir H, Saneei P *et al.* (2018) Consumption of fruit and vegetables in relation with psychological disorders in Iranian adults. *Eur J Nutr* **57**, 2295–2306.
28. Northstone K, Joinson C & Emmett P (2018) Dietary patterns and depressive symptoms in a UK cohort of men and women: a longitudinal study. *Public Health Nutr* **21**, 831–837.
29. Lucas M, Chocano-Bedoya P, Schulze MB *et al.* (2014) Inflammatory dietary pattern and risk of depression among women. *Brain Behav Immun* **36**, 46–53.
30. Virmani A, Pinto L, Binienda Z *et al.* (2013) Food, nutrigenomics, and neurodegeneration – neuroprotection by what you eat! *Mol Neurobiol* **48**, 353–362.
31. Lademann J, Schanzer S, Meinke M *et al.* (2011) Interaction between carotenoids and free radicals in human skin. *Skin Pharmacol Physiol* **24**, 238–244.
32. Souza C, Maia Campos P *et al.* (2017) Radical-scavenging activity of a sunscreen enriched by antioxidants providing protection in the whole solar spectral range. *Skin Pharmacol Physiol* **30**, 81–89.
33. Wolfle U, Seelinger G, Bauer G *et al.* (2014) Reactive molecule species and antioxidative mechanisms in normal skin and skin aging. *Skin Pharmacol Physiol* **27**, 316–332.
34. Yu RX, Kocher W, Darvin ME *et al.* (2014) Spectroscopic biofeedback on cutaneous carotenoids as part of a prevention program could be effective to raise health awareness in adolescents. *J Biophotonics* **7**, 926–937.
35. Kiecolt-Glaser JK, Derry HM & Fagundes CP (2015) Inflammation: depression fans the flames and feasts on the heat. *Am J Psychiatry* **172**, 1075–1091.
36. Liu Y, Ho RC & Mak A (2012) Interleukin (IL)-6, tumour necrosis factor α (TNF-α) and soluble interleukin-2 receptors (sIL-2R) are elevated in patients with major depressive disorder: a meta-analysis and meta-regression. *J Affect Disord* **139**, 230–239.
37. Hughes A & Kumari M (2017) Associations of C-reactive protein and psychological distress are modified by antidepressants, supporting an inflammatory depression subtype: findings from UKHLS. *Brain Behav Immun* **66**, 89–93.
38. Howren MB, Lamkin DM & Suls J (2009) Associations of depression with C-reactive protein, IL-1, and IL-6: a meta-analysis. *Psychosom Med* **71**, 171–186.
39. Dowlati Y, Herrmann N, Swardfager W *et al.* (2010) A meta-analysis of cytokines in major depression. *Biol Psychiatry* **67**, 446–457.
40. Miki T, Eguchi M, Kurotani K *et al.* (2016) Dietary fiber intake and depressive symptoms in Japanese employees: the Furukawa Nutrition and Health Study. *Nutrition* **32**, 584–589.
41. Calvani R, Picca A, Lo Monaco MR *et al.* (2018) Of microbes and minds: a narrative review on the second brain aging. *Front Med (Lausanne)* **5**, 53.

42. Borre YE, Panagaki T, Koelink PJ *et al.* (2014) Neuroprotective and cognitive enhancing effects of a multitargeted food intervention in an animal model of neurodegeneration and depression. *Neuropharmacology* **79**, 738–749.
43. Black CN, Penninx BW, Bot M *et al.* (2016) Oxidative stress, anti-oxidants and the cross-sectional and longitudinal association with depressive symptoms: results from the CARDIA study. *Transl Psychiatry* **6**, e743.
44. Stahl W & Sies H (2012) Photoprotection by dietary carotenoids: concept, mechanisms, evidence and future development. *Mol Nutr Food Res* **56**, 287–295.
45. Marx W, Moseley G, Berk M *et al.* (2017) Nutritional psychiatry: the present state of the evidence. *Proc Nutr Soc* **76**, 427–436.

Appendix

Descriptive statistics of the variables in older adults, by country; WHO Study on Global Ageing and Adult Health (SAGE), 2007–2010

	China		Ghana		India		Mexico		Russia		South Africa	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Verbal recall	5·60	1·66	5·82	1·40	5·41	1·37	5·21	1·44	6·09	1·55	5·91	1·59
Delayed verbal recall	4·95	2·26	4·85	2·12	4·58	1·91	4·21	2·37	5·11	2·09	5·59	2·11
Digit span	5·20	1·21	3·52	1·22	3·28	1·08	3·53	0·99	4·67	1·15	4·14	1·34
Verbal fluency	12·68	4·88	13·71	5·22	10·55	3·54	14·39	4·98	13·11	6·45	10·31	3·98
WHOQOL-8	3·64	0·59	3·32	0·64	3·50	0·61	3·67	0·52	3·45	0·61	3·47	0·60
Depression	0·10	0·98	0·67	2·58	0·89	2·70	0·54	2·11	0·35	1·76	0·31	1·79
Fruit consumption	2·42	2·39	2·12	1·78	0·90	0·99	1·60	1·12	1·54	1·27	1·65	1·24
Vegetable consumption	6·96	4·25	2·03	0·95	1·99	0·98	1·69	1·10	1·88	1·30	2·00	1·33
Sex (female)	1·54	0·50	1·48	0·50	1·49	0·50	1·62	0·49	1·67	0·47	1·61	0·49
Age	63·03	9·24	64·08	10·5	61·63	8·86	67·95	9·08	64·76	10·03	62·71	9·61
Education	2·16	1·22	1·85	1·30	1·82	1·26	1·76	1·23	3·79	0·95	1·94	1·20
Economic deprivation	1·02	0·18	1·74	1·04	1·27	0·70	1·51	1·00	1·19	0·62	1·57	1·04
Smoking (yes)	1·51	0·86	1·21	0·59	1·92	0·98	1·30	0·67	1·30	0·70	1·45	0·81
Daily drinks	0·72	2·24	0·67	1·76	0·22	1·46	1·04	5·71	0·85	2·03	0·67	2·87
Activities	1·62	0·48	1·78	0·41	1·74	0·44	1·45	0·50	1·80	0·40	1·44	0·50
Chronic conditions	0·80	0·98	0·42	0·71	0·61	0·88	0·89	0·94	1·65	1·33	0·81	1·00

WHOQOL-8, eight-item WHO Quality of Life scale.