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SYSTEMATIC REVIEWS

The risk of overweight/obesity in mid-life and late life for the development of dementia: a systematic review and meta-analysis of longitudinal studies

Emilio Pedditizi[1], Ruth Peters[2], Nigel Beckett[3]

[1]Medicine, Imperial College, London, UK
[2]Imperial College London, London, UK
[3]Care of the Elderly, Imperial College London, London, UK

Address correspondence to: N. Beckett. Tel: (+44) 0207 188 7188. Email: nigel.beckett@gstt.nhs.uk

Abstract

Scope: it has been suggested that overweight/obesity as a risk factor for incident dementia differs between mid-life and later life. We performed a systematic review and meta-analysis of the up-to-date current literature to assess this.
Search Methods: inclusion criteria included epidemiological longitudinal studies published up to September 2014, in participants without cognitive impairment based on evidence of cognitive assessment and aged 30 or over at baseline assessment with at least 2 years of follow-up. Pubmed, Medline, EMBASE, PsychInfo and the Cochrane Library were searched using combinations of the search terms: Dementia, Alzheimer disease, Vascular Dementia, Multi-Infarct Dementia, Cognitive decline, Cognitive impairment, Mild Cognitive Impairment/Obesity, Overweight, Adiposity, Waist circumference (limits: humans, English language). Handsearching of all papers meeting the inclusion criteria was performed. A random-effects model was used for the meta-analysis.
Results: of the 1,612 abstracts identified and reviewed, 21 completely met the inclusion criteria. Being obese below the age of 65 years had a positive association on incident dementia with a risk ratio (RR) 1.41 (95% confidence interval, CI: 1.20–1.66), but the opposite was seen in those aged 65 and over, RR 0.83 (95% CI: 0.74–0.94).
Conclusions: this systematic review and meta-analysis suggests a positive association between obesity in mid-life and later dementia but the opposite in late life. Whether weight reduction in mid-life reduces risk is worthy of further study.

Keywords: *obesity, overweight, dementia, aged, systematic review, older people*

Introduction

The increase in the number of older adults is a major healthcare challenge for the 21st century. Given this demographic ageing in society and the high correlation with age, dementia will become an increasing global public health issue with an ever-increasing impact on health and social care resources. Currently, in the UK, dementia affects over 830,000 people with 23 million having a close friend or family member with dementia [1].

Epidemiological studies addressing the risk of overweight/obesity and dementia have reported equivocal results, particularly when the risk is considered with regard to the age at which the presence of overweight/obese is assessed. Studies have suggested that obesity in mid-life is related to a greater risk of subsequent dementia [2–4], although in older adults this has not always been observed [5–7]. Previous systematic reviews [8–10] have reported an association between obesity and dementia, especially in studies with long follow-up periods, although they have not all assessed whether the impact is different depending on whether overweight/obesity is present in mid-life or late life. A review in 2010 by Anstey *et al.* [11] did look by at BMI in mid-life and late life reporting that continuous BMI was not associated with

dementia in late life, although that due to small numbers of studies the generalisability of the findings was reduced and that additional studies were warranted. More studies [12–18] have been published since the review by Anstey with regard to the possible association of overweight/obesity and the subsequent development of dementia, providing the opportunity to expand on previous analyses.

Our objective was to use longitudinal epidemiological studies to evaluate whether overweight/obesity in mid-life or in late life, in those free of cognitive impairment, was associated with the later development of dementia.

Methods

Protocol

Before performing the review, a protocol was generated by E.P. and N.B. for which external review was sought and subsequent revisions made. The protocol stipulated the objective, search strategy, criteria for inclusion of studies, data to be extracted and quality assessment. The hypothesis was to assess whether being overweight or obese either in mid-life or in late life was associated with the subsequent development of dementia and whether the association differed depending on the stage in life when assessed. A cut-off of 65 years was proposed for considering whether the population being studied was mid-life or late life. This decision was based on a limited search of the literature as part of a scoping exercise before generation of the protocol.

Search strategy and selection criteria

Eligibility criteria

To be eligible for inclusion studies needed to be longitudinal, with at least 2 years of follow-up with an assessment performed for incident dementia. Studies were included if they stated that they had assessed for prevalent cases of dementia at baseline and evidence was provided of some form of cognitive assessment at baseline or if the mean age plus 2 standard deviations (SD) at entry to the study was <60 years as it was assumed prevalent cases of dementia would be extremely rare prior to this.

Information sources, search strategy and study selection

Two reviewers (N.B. and R.P.) independently searched Medline from 1946 to 28th September 2014, Embase from 1947 to 28th September 2014, Psychinfo from 1806 to 28th September 2014 and the Cochraine Library to September 2014. The combinations of the following terms were searched: dementia, vascular dementia, multi-infarct, Alzheimer disease, cognitive decline, cognitive impairment, obesity, overweight, adiposity or waist circumference. (See Supplementary data, Appendix S1, available in *Age and Ageing* online for search parameters.) The limits of 'humans' and 'English language' were applied to the search criteria as funding was not available for translations.

Following the removal of duplicates from the initial searches, abstracts were reviewed to identify potentially eligible studies. Once identified full-text review was performed. If a study reported results more than once, the most recent eligible publication was taken. A handsearch of the references of all papers that met the inclusion criteria and of other published systematic reviews found during the search was performed. Published letters, editorials and expert opinions found during the search were not included. The reviewers independently determined if each study was eligible for inclusion according to a pre-specified protocol. Any differences were resolved by discussion and consensus by all authors. Details of the data extraction can also be found in Supplementary data, Appendix S1, available in *Age and Ageing* online.

Risk of bias in individual studies

Quality assessment of eligible studies was performed based on a tool utilised by Gorospe and Dave [7], but further developed based on recommendations from Tooth *et al.* [19]. Studies were scored according to multiple criteria with a final score ranging between 0 and 23 (see Supplementary data, Appendix S2, available in *Age and Ageing* online for scoring template and criteria).

Results

A total of 5,186 records were identified of which 1,612 abstracts were screened. Of these, 54 met the criteria for full-text assessment and of these a further 33 were excluded, the most common reason being for not reporting incident dementia. This left 21 studies to be included. Figure 1 shows the steps in identifying the studies for inclusion. A summary table of all the studies can be found in Supplementary data, Appendix S3, available in *Age and Ageing* online.

In terms of quality, this was generally high with a mean score of 15.8 (range 12.5–18) out of 23. The score was mostly influenced by the absence of covariate adjustment, neuro-imaging and the consideration of biases, particular drop-outs. There was little difference in the mean scores for those reporting on mid-life or late life. The sampling processes for recruitment were detailed in all studies, either in the original manuscript or in a sister publication apart from one study [20].

Study populations

Most of the studies were conducted either in the USA ($n = 11$) [3, 4, 13, 15, 16, 21–25] or in Europe ($n = 7$) [6, 12, 13, 26–29] with one in Japan [20], one in Australia [14] and one in Israel [17]. Ethnicity was reported in studies from the USA and included Japanese Americans [25], Latinos [24] and African Americans [4, 15]. Sixteen reported on those aged 65 and over [4, 6, 13, 15, 16, 18, 20–22, 26–29] with five focusing on younger participants aged below 65 [3, 12, 17, 23, 29] and two on both [4, 18]. For all those that were defined as late life, the mean age at baseline was over 65 (range 69–82 in those that reported this), for mid-life below 65 (range 42–50.4).

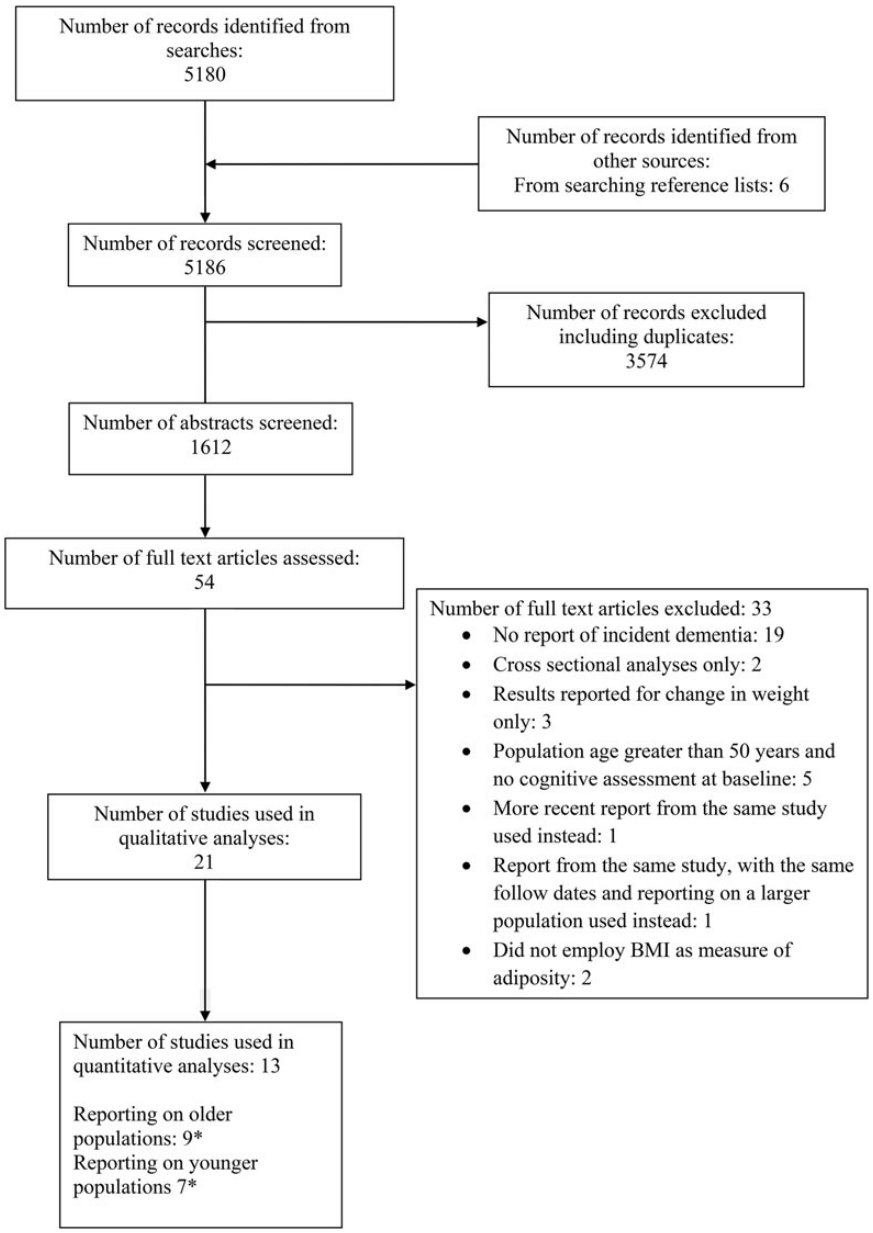

Figure 1. Flow of included studies. Search strategy adopted during the systematic research of literature meta-analyses (BMI, body mass index). *Three studies reported on both younger and older populations.

Only one study recruited fewer than 500 subjects [26] with the majority ($n = 16$) >1,000. In total 62,425 subjects were included with most recruiting men and women. Gender split was not reported in all studies and results were usually not split by gender, although results were usually adjusted for gender. Two only included men [19, 22] and two only women [12, 13] with one study recruiting twins [29]. Participants recruited were generally community dwelling, with one carried in Catholic clergy [21], one in participants in a clinical trial [13] and one only in diabetics [15]. Educational status was not reported in all studies and varied between those that did, ranging from 28.7 to 75.8% for attaining high-school level. When education was reported, the results were adjusted for this co-variate.

Assessment of cognition and overweight/obesity

All studies except two carried out some form of cognitive assessment at baseline [3, 17], although both fitted the protocol accepted definition for inclusion when lacking such assessments. In those that carried out assessments, these varied from a cognitive test battery, simple screening with the mini-mental state examination (MMSE) to clinical evaluation. All employed BMI to define obesity, although some collected data on waist circumference (WC) and waist–hip ratio (WHR). In one study [9], both weight and height were self-reported. With regard to defining overweight or obesity, the standard WHO defined cut-offs for BMI were used in most studies but in one [6] overweight was defined as a BMI >27 and in one [5] obese as a BMI of >29.6. In reporting the

results, BMI was used as a categorical variable in 14 studies, as a continuous variable in 10.

Cases

The length of follow-up varied from 4 to 42 years. The majority followed up participants for <10 years. Subjects were generally seen every 2–5 years, although one study only saw subjects at baseline and 8 years later [28] and 2 only 36 years after baseline [3, 17]. Those that looked at the association between mid-life and later, dementia had a longer duration of follow-up (range 23–42 years) compared with late life (range 3.2–18 years). Consequently, the attrition from baseline was higher in those reporting on mid-life.

Overall, there were 5,303 cases of dementia of which 1,555 were reported in those solely reporting on mid-life. One did not report the actual number of cases [6]. The method most commonly used to identify incident cases was initial case identification either by screening with a general screening tool or a cognitive test battery followed by diagnostic assessment with standardised criteria, with the DSM III-R/DSM-IV and NINCDS/ADRAD most frequently used. Most reported all dementia, although what was included within this varied. Two reported only on AD [21, 23], eight reported results for incident cases of VaD and AD [4, 5, 12, 20, 22, 25, 26, 29], of which three reported results on mid-life [4, 12, 29]. There was variability as to which cases were included within each subtype. In those that reported AD, there were 1,253 cases and for VaD 490. The ratio of AD to VaD varied from 0.84 to 3.23, with all those focusing on mid-life reporting a 2-fold higher number of AD than VaD. Those focusing on late life were more varied ranging from more VaD to AD cases to a 3-fold higher number of AD.

Mid-life obesity/overweight and incident dementia

Of the seven studies that reported results for being overweight in mid-life, two [3, 29] reported a positive association, the others non-significant results (see Table 1). With regard to obesity, only five of the studies reported results [3, 4, 17, 18, 23] and of those one reported a positive association [3] and four showed non-significant results, although the point estimate was above 1 in all. Four [3, 4, 17, 18] reported results suitable for inclusion in the meta-analyses (Supplementary data, Figures S2A and B, available in *Age and Ageing* online). There were 599 dementia cases in the 6,065 considered to be overweight compared with 653 in 7,979 in the control group. The overall relative risk (RR) was 1.10 (95% CI: 0.99–1.22). With regard to obesity, there were 166 cases with a RR of 1.41 (95% CI: 1.20–1.65). There was no evidence of heterogeneity. The results with regard to the subtype of dementia were in line for all dementia for both overweight and obese.

Late-life obesity/overweight and incident dementia

Of the 16 studies reporting on late life, 10 reported on BMI as a continuous variable. Of these, six [12, 16, 18, 20, 25, 27] showed no significant association, three [15, 21, 28] a negative association and one [26] positive. Seven reported results for being overweight of which four [4, 6, 12, 18] reported non-significant results and three [5, 24, 27] a negative association. With regard to obesity of the six studies that reported results, three [14, 18, 25] reported non-significant results, two [4, 24] a negative association and one [22] positive. Five of the studies [4, 5, 14, 18, 27] reported results suitable for inclusion in the meta-analyses for overweight and four [4, 5, 18, 27] for obesity (Supplementary data, Figures S3A and B, available in *Age and Ageing* online). There were 989 cases of dementia in the 8,413 considered to be overweight compared with 896 in the control group ($n = 5{,}866$). The overall RR was 0.88 (95% CI: 0.76–1.02). For obesity, there were 362 cases from 3,262 compared with 691 from 5,190 controls with a RR of 0.83 (95% CI: 0.74–0.94). There was no evidence of heterogeneity for obesity, although there was for being overweight with an I^2 of 53%, $P = 0.09$. Again the results with regard to subtype were in line for all dementia for overweight and obese.

Discussion

The results of this systematic review and meta-analyses suggest a positive association with being overweight/obese below the age of 65 years and the later development of dementia, although the opposite for aged 65 and over.

These findings are in line with individual studies for mid-life obesity/overweight and subsequent dementia as well as other recent systematic reviews [30]. The negative association with regard to late life is in line with previous results but with the addition of new data now shows a significant result that has not been previously reported. In the review by Anstey *et al.*, which included only two studies for obese vs. not obese in late life for all dementia, the RR was 1.11 (95% CI: 0.80–1.55). They did not report results for obese vs. normal BMI for late life.

The results for mid-life were consistent across the studies with no heterogeneity and simply add to the consistent data linking obesity in mid-life to the later development of dementia. The current trends in the prevalence of obesity within many societies can be expected to impact further on the predicted increase dementia from ageing alone. With the current levels of obesity, it has been suggested that the number of those with dementia could be up to 9–19% higher than the number predicted based on ageing alone [30, 31]. However, the reverse should also be considered. Reducing obesity prevalence to 20% over the next 10 years could lead to a 10% reduction in the number of people aged 65–69 with dementia in 2050 [31].

The results for late life raise the possibility of a decreased risk of developing dementia. However, there was a degree of heterogeneity with regard to being overweight, and the result did not reach statistical significance. For obesity, no heterogeneity was seen, although again the overall number of studies was small. Such a result could be related to the fact that lower weight in late life is frequently associated with

Table 1. Main results for overweight and obese for individual studies according to whether study cohort was aged 65 years and over or below 65 years at entry

Study (Participants)	Older population: baseline mean age ≥65 years		Younger (mid-life) population: baseline mean age <65 years	
	Overweight classified as a BMI ≥25 unless otherwise specified (no upper limit) and relationship to incident dementia compared with normal weight	Obese classified at BMI ≥30 unless otherwise specified and relationship to incident dementia compared with normal weight	Overweight classified as a BMI ≥25 unless otherwise specified (no upper limit) and relationship to incident dementia compared with normal weight	Obese classified at BMI ≥30 unless otherwise specified and relationship to incident dementia compared with normal weight
Nourhashemi *et al.* [6]	All dementia RR 0.83 (0.59–1.18)			
Hayden *et al.* [22]		Dementia: HR 1.76 (95% CI: 1.03–2.88) AD: HR 1.93 (95% CI: 1.05–3.36) VaD: HR 1.16 (95% CI: 0.37–3.12)		
Whitmer *et al.* [3]			AD: HR 2.09 (1.69–2.60) VaD: HR 1.95 (1.29–2.96)	AD: HR 3.1 (2.19–4.38) VaD: HR 5.01(2.98–8.43)
Luchsinger *et al.* [5]	Overweight BMI 26.3–29.6) Dementia: HR 0.6 (95% CI: 0.4–0.9) AD: HR 0.5 (95% CI: 0.3–0.9) DAS: HR 0.9 (95% CI: 0.4–1.8)	Obese (BMI >29.6) Dementia: HR 0.8 (95% CI: 0.5–1.2) AD: HR 0.9 (95% CI: 0.5–1.6) DAS: HR 0.8 (95% CI: 0.4–1.7)		
Atti *et al.* [27] [Results for 0–9 years follow-up]	Dementia HR 0.75 (95% CI: 0.59–0.96) AD: HR 0.66 (95% CI: 0.50–0.88)			
Beydoun *et al.* [results for age 50] [23]			AD: HR 0.94 (0.64–1.38) men HR 1.11 (0.61–2.04) women	AD: HR 0.52 (0.13–2.17) men HR 2.43 (0.34–7.02) women
Hassing *et al.* [29]			Overweight (BMI ≥26.5) Dementia: OR 1.55 (95% CI: 1.18–2.04) AD: OR 1.68 (1.21–2.33) VaD: OR 1.36 (0.82–2.56)	
West *et al.* [24] (n = 1,351)	Dementia/CIND: HR 0.46 (95% CI: 0.25–0.86)	Dementia/CIND: HR 0.24 (95% CI: 0.10–0.54)		
Gustafson *et al.* [17]	All dementia HR 0.26 (0.12–1.59) (BMI measured when population aged 70–92)		All dementia HR 0.84 (0.59–1.21) (BMI measured when population aged 38–60 at baseline)	
Fitzpatrick *et al.* [4]	All dementia: HR 0.92 (0.72–1.18) AD: HR 0.74 (0.52–1.05) VaD: HR 1.20 (0.83–1.76)	Dementia: HR 0.63 (0.44–0.91) AD: HR 0.58 (0.36–0.96) VaD: HR 0.72 (0.41–1.27)	All dementia: HR 1.01 (0.83–1.35) AD: HR 1.04 (0.74–1.47) VaD: HR 1.00 (0.70–1.44)	All dementia: HR 1.36 (0.94–1.95) AD: HR 1.25 (0.74–2.11) VaD: HR 1.33 (0.78–2.29)
Power *et al.* [14]		All dementia: HR 0.82 (0.67–1.01)		
Tolppanen *et al.* [18]	All dementia: HR 0.5 (0.25–1.04) AD: HR 0.57 (0.27–1.19)	All dementia: HR 0.55 (0.23–1.34) AD: HR 0.40 (0.15–1.08)	All dementia: HR 1.04 (0.58–1.87) AD: HR 0.89 (0.47–1.68)	All dementia: HR 1.81 (0.91–3.57) AD: HR 1.57 (0.75–3.29)
Ravona-Springer *et al.* [17]			All dementia: HR 1.05 (0.79–1.40)	All dementia: 1.25 (0.73–2.14)

BMI, body mass index; AD, Alzheimer's disease; VaD, vascular dementia; DAS, dementia after stroke; HR, hazard ratio; CI, confidence interval; CIND, cognitive impairment no dementia.

other co-morbidities, and moreover, an accelerated decline in BMI during late life may precede the clinical detection of dementia [32]. Unplanned weight loss can be a marker for preclinical Dementia. For both mid-life and late life, similar results were seen for AD and VaD.

One of the problems in assessing whether being overweight/obese is causally associated with later dementia is that it is often associated with other co-morbidities especially cardiovascular risk factors that themselves are associated with an increased risk of dementia. Being overweight/obese is often associated with hypertension that has been shown to be related to the subsequent development of dementia. To allow for this, the most adjusted reported results were considered for our review. This aside, there are various mechanistic evidences linking obesity and dementia. Keller *et al.* [33] have suggested a potential genetic link for increased body mass and dementia reporting that the FTO AA genotype increased the risk for dementia, and in particular AD, independently of physical inactivity, BMI, diabetes and CVD. Also there is evidence linking increased BMI and brain pathology such as temporal atrophy and grey and white matter changes in mid-life [34, 35]. However, the correlation between BMI and brain volumes is unlikely to be direct but via some factor or mechanisms that cause brain volume reduction, including hypercortisolaemia, inflammation, cardiovascular risk factors, as well as low levels of exercise. The interplay between increased vascular risk, metabolic disturbance and adipose-related hormones (leptin and adiponectin) that exist in those who are overweight/obese and the impact on dementia-related neuropathologies is complex and not yet fully understood [36]. Going against our findings is that higher BMI has been shown to be associated with lower grey matter and white matter volumes throughout the brain in cognitively normal individuals aged 65 and over [37, 38].

There was a wide variation in the way cognitive impairment was assessed between the different studies, although generally was more robust at follow-up than at baseline. The differentiation between AD and VaD can be difficult with both pathologies often present at post-mortem. Thus, the focus of this review was overall dementia. Even then, there was variation between studies as to the different types that were included within the overall diagnosis of dementia. We felt it was important to ensure that some assessment of cognition was performed at baseline to try to ensure that those included in the analysis were at least initially considered to be cognitively intact. During our search, we identified several papers relating overweight/obesity in mid-life and later dementia that did not meet our inclusion criteria because of the lack of a specified baseline cognitive assessment. Although we feel this makes these results more robust, it could have lead to the loss of important data.

With regards to the issue of the assessment of obesity, we only included studies that reported results for BMI to maximise consistency across the studies, although even then not all studies used standard accepted cut-offs. With ageing, there is an increase in fat mass and decline in lean mass. Thus, the use of BMI in older individuals will not adequately reflect fat accumulation. Measures of absolute girth are likely to be better surrogate measures of body fat and may be more reliable for older individuals. The association seen for late life may simply be a result of BMI being a poor marker for obesity in such individuals.

The choice of age cut-offs for defining mid-life and late life is arbitrary and as such caution should be exercised in drawing conclusions in regard to this. The choice was driven by the cut-offs used by the individual studies themselves. However, in all the studies included in the meta-analysis for mid-life, the mean age of participants was around 50 years; for those reporting on late life, it was above 70 for most. The length of follow-up will also impact on any association and those studies focusing on mid-life not surprisingly had a longer follow-up than those focusing on late life. It may be that it is the number of years exposed to being overweight/obese that is critical. It has been suggested that a new metric for consideration of risk could be that of 'obesity-years' [39] akin to that of pack-years for cigarette smoking.

These results are in line with the concept of the obesity paradox. Various explanations have been suggested for this, although whether it truly exists remains a point of debate [40]. A cohort of obese individuals in late life will be a heterogenous group of those who have been obese for sometimes and those who were of normal weight but have gained weight in later years. The reverse will be true for normal weight. A study of Finnish men followed up from mid-life to late life showed that in old age both normal weight and overweight were a mixture of individuals with different weight trajectories and that overweight and high cardiovascular risk in mid-life with subsequent weight decrease predicted the worst outcome in late life [41]. It may well be that changes in body mass is the better predictor for incident dementia and is worthy of further study. A study of over 4,000 men in Australia aged 65–84 showed that those who maintained a stable body mass had the lowest incidence of dementia [42].

The quality of the studies included in the review was assessed using a scale used in a previous systematic review of BMI and dementia [7] although modified based on recommendations for improving the quality of reporting of longitudinal observational research [19]. We feel that it is in line with the recommendations suggested by the quality assessment tool for quantitative studies as proposed by the Effective Public Health Practice Project [43]. The overall quality of the studies included in the review was generally high with little difference in the mean scores for those reporting on mid-life and late life. The studies included in the meta-analyses all scored above average.

In summary, this systematic review and meta-analyses provide evidence to support the association between overweight/obesity in mid-life and the subsequent development of dementia. In late life, a reverse association was seen. The results are likely to reflect that maintaining ones weight in later life is a sign of health, and unplanned weight loss is a cause for concern. However, one can not extrapolate to suggest that intentional weight loss in late life in those who are overweight or obese may not have an advantageous effect on health and

well-being. Such an observation would fit with the obesity paradox that has been proposed for various other diseases and should be considered in any future studies when assessing the association between obesity and dementia. However, even if this association is true there is as yet no evidence to suggest that weight loss in mid-life will lead to a reduction in incident dementia, although these results support the inclusion of weight loss in any future preventive trials carried out in mid-life.

Key points

- Mid-life obesity is associated with an increased risk of incident dementia.
- Late-life obesity shows a negative association with incident dementia.
- The obesity paradox is seen with regard to dementia and ageing.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

Conflicts of interest

None declared.

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(The very long list of references supporting this review has meant that only the most important are listed here and are represented by bold type throughout the text. The full list of references is given in Supplementary data, available in *Age and Ageing* online.)

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Yoga-based exercise improves balance and mobility in people aged 60 and over: a systematic review and meta-analysis

Sabrina Youkhana[1], Catherine M. Dean[1], Moa Wolff[2], Catherine Sherrington[3], Anne Tiedemann[3]

[1]Department of Health Professions, Macquarie University, Sydney, NSW 2109, Australia
[2]Centre for Primary Health Care Research, Malmö, Lund University, Lund, Sweden
[3]The George Institute for Global Health, Sydney Medical School, The University of Sydney, Sydney, NSW 2000, Australia

Address correspondence to: A. Tiedemann. Tel: (+61) 2 96570393; Fax: (+61) 2 96570301. Email: atiedemann@georgeinstitute.org.au

Abstract

Objective: one-third of community-dwelling older adults fall annually. Exercise that challenges balance is proven to prevent falls. We conducted a systematic review with meta-analysis to determine the impact of yoga-based exercise on balance and physical mobility in people aged 60+ years.

Methods: searches for relevant trials were conducted on the following electronic databases: MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, CINAHL, Allied and Complementary Medicine Database and the Physiotherapy Evidence Database (PEDro) from inception to February 2015. Trials were included if they evaluated the effect of physical yoga (excluding meditation and breathing exercises alone) on balance in people aged 60+ years. We extracted data on balance and the secondary outcome of physical mobility. Standardised mean differences and 95% confidence intervals (CI) were calculated using random-effects models. Methodological quality of trials was assessed using the 10-point Physiotherapy Evidence Database (PEDro) Scale.

Results: six trials of relatively high methodological quality, totalling 307 participants, were identified and had data that could be included in a meta-analysis. Overall, yoga interventions had a small effect on balance performance (Hedges' $g = 0.40$, 95% CI 0.15–0.65, 6 trials) and a medium effect on physical mobility (Hedges' $g = 0.50$, 95% CI 0.06–0.95, 3 trials).

Conclusion: yoga interventions resulted in small improvements in balance and medium improvements in physical mobility in people aged 60+ years. Further research is required to determine whether yoga-related improvements in balance and mobility translate to prevention of falls in older people.

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Keywords: *yoga, aged, systematic review, randomised controlled trial, balance, mobility, older people*