Body mass index and waist circumference predict health-related quality of life, but not satisfaction with life, in the elderly

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Abstract

Objectives While obesity has been linked with lower quality of life in the general adult population, the prospective effects of present obesity on future quality of life amongst the elderly is unclear. This article investigates the cross-sectional and longitudinal relationships between obesity and aspects of quality of life in community-dwelling older Australians.

Method A 2-year longitudinal sample of community dwellers aged 70–90 years at baseline, derived from the Sydney Memory and Ageing Study (MAS), was chosen for the study. Of the 1037 participants in the original MAS sample, a baseline (Wave 1) sample of 926 and a 2-year follow-up (Wave 2) sample of 751 subjects were retained for these analyses. Adiposity was measured using body mass index (BMI) and waist circumference (WC). Quality of life was measured using the Assessment of Quality of Life (6 dimensions) questionnaire (AQoL-6D) as well as the Satisfaction with Life Scale (SWLS). Linear regression and analysis of covariance (ANCOVA) were used to examine linear and non-linear relationships between BMI and WC and measures of health-related quality of life (HRQoL) and satisfaction with life, adjusting for age, sex, education, asthma, osteoporosis, depression, hearing and visual impairment, mild cognitive impairment, physical activity, and general health. Where a non-linear relationship was found, established BMI or WC categories were used in ANCOVA.

Results Greater adiposity was associated with lower HRQoL but not life satisfaction. Regression modelling in cross-sectional analyses showed that higher BMI and greater WC were associated with lower scores for independent living, relationships, and pain (i.e. worse pain) on the AQoL-6D. In planned contrasts within a series of univariate analyses, obese participants scored lower in independent living and relationships, compared to normal weight and overweight participants. Longitudinal analyses found that higher baseline BMI and WC were associated with lower independent living scores at Wave 2.

Conclusions Obesity is associated with and predicts lower quality of life in elderly adults aged 70–90 years, and the areas most affected are independent living, social relationships, and the experience of pain.

Keywords Obesity · Body mass index · Fat mass · Cognition · Elderly · Quality of life

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Introduction

By 2025, it is estimated that 36.9% of the Australian population aged 65 years and over will be obese [1]. Similar rates have been proposed for the US, with France and other European nations not far behind at 17.9–30% [2]. Current weight recommendations amongst the elderly emphasise the increased risk of mortality and comorbidities associated with obesity [3], such as an increased risk of cardiovascular disease, diabetes, cancer, and dementia [4].

Significant associations exist between obesity and lower quality of life (QoL) in older people, especially for physical domains, including mobility, physical function, role limitations due to functional impairment, and bodily pain [5–8]. Obese older people are more likely to report poorer self-rated health and general health [9], but the QoL measure of the mental health domain seems largely unaffected in the elderly obese [10, 11]. Many of the previous studies in this area are cross-sectional in design, which limits their usefulness in tracking the effects of obesity on QoL as the population ages. One of our aims is therefore to elucidate the prospective relationship between obesity and QoL.

Well-being takes on a particular significance in older people, with longevity itself being only one marker of health [12]. Quality of life, at the most fundamental level, refers to the general well-being of the person. It takes into account the health state of the individual, as measured objectively via comparisons with community norms and expectations (i.e. mobility, ability to live independently, pain experienced) [5, 13, 14], as well as the individual's subjective evaluation of the quality of his/her life, represented in part by such concept as life satisfaction [15].

Although QoL and health-related quality of life (HRQoL) have been used interchangeably in literature, a narrower definition of HRQoL excludes the more subjective perception of life satisfaction. HRQoL and life satisfaction correspond to different aspects of well-being and, as such, should be examined separately [12]. HRQoL encompasses physical and mental domains, each constituting numerous sub-domains such as physical function, social functioning, mental health, and self-perceived health [16]. Within our study, we have chosen to examine well-being from two methodological standpoints: (1) HRQoL, which measures quality of life by comparing an individual's self-rated health status against community-derived standards, and (2) life satisfaction, whereby the individual's quality of life is assessed against his/her own chosen criteria and requires a cognitive, judgemental process. Although there is considerable overlap between the concepts of QoL and life satisfaction [17], these constructs have been measured separately in many studies. For example, in a study of 234 elderly Portuguese subjects, Fonseca

et al. described life satisfaction as a psychological dimension, while stating that QoL was associated with physical, socio-demographic and contextual variables [18]. Furthermore, Kulczycka et al.'s study of 83 patients with chronic illness concluded that while life satisfaction may form part of QoL, both parameters should be distinguished in order to form a full assessment of the state of the patient [20]. This study is the first to consider both QoL and life satisfaction in association with obesity within an elderly cohort.

Based on previous research in the general population, we hypothesised that higher body mass index and waist circumference in older people would be associated with lower HRQoL and less life satisfaction at baseline and at follow-up 2 years later. We also hypothesised that higher body mass index and waist circumference at baseline would predict lower QoL at 2-year follow-up.

Method

Participants

We used data from the Sydney Memory and Ageing Study (Sydney MAS), which examined a prospective cohort of 1037 non-demented, Sydney community dwellers aged 70–90 years at baseline [21]. 99% of participants were Caucasian. Participants were reassessed every 2 years. Data for this study were from baseline (Wave 1) in the year 2005 and at 2 years (Wave 2) in 2007. Between Wave 1 and Wave 2, 128 participants were reported to have withdrawn from the study or were deceased. Participants with incomplete data for the dependent variables or with missing data for BMI, waist circumference, age, sex, or education for each wave were excluded, leaving a sample of 926 participants for Wave 1, and 751 for Wave 2 for the cross-sectional analyses for each wave. There were no significant differences on main variables between the 175 that dropped out and the 751 that were retained ay Wave 2. Participants with complete Wave 1 and Wave 2 data for the main dependent variables (a sample of 699 participants) were used in the longitudinal analyses. Ethics approval for this study was obtained from the UNSW Australia and the South-Eastern Illawarra Area Health Service—Eastern sector. Written informed consent was obtained from all participants.

Quality of life

Two measures were used: the Assessment of Quality (AQoL-6D) instrument for the quantitative analysis of health-related quality of life (HRQoL), and the Satisfaction with Life Scale (SWLS), a measure of self-rated quality of life. AQoL-6D consists of 20 items which are computed to yield scores in

six dimensions: independent living, relationships, mental health, coping, pain, and senses. The six dimension scores generate an overall AQoL score. The dimension and overall AQoL scores generated from the 20-item questionnaire are in the form of utility weights which range from 0.00 (death) to 1.00 (best health state) [22]. Higher scores indicated better quality of life in each domain. The Satisfaction with Life Scale (SWLS) questionnaire developed by MAS which consists of 11 items, five of which are derived from the original SWLS developed and validated by Pavot et al. [23] and the others (items 6–11) were developed specifically for this sample as to gather data on satisfaction on different areas of their lives as well as life as a whole. SWLS 11 was used primarily, but analyses were conducted again using the SWLS 5. Items 6–11 on the questionnaire are as follows: I am satisfied with the area where I live; I am satisfied with my health and physical condition; I am satisfied with my financial situation; I am satisfied with my friendships; I am satisfied with my family life; I am satisfied with the way I handle problems that come up in my life. The SWLS may be construed as an indicator of self-rated well-being, in contrast to the AQoL which is based more on agreed ideals of HRQoL [22].

Anthropometric measures

BMI

Weight was measured with an electronic scale and rounded to the nearest tenth of a kilogram, and height was measured with a stadiometer. BMI was calculated as weight (kg) divided by height squared (m^2), as was used both as a continuous and categorical variable. Individuals were classified into BMI categories, as specified by Diehr et al. [32] for the elderly, and obesity was separated into obese and severely obese. BMI categories were defined as follows: elderly individuals with BMI under 20 kg m^{-2} were considered as underweight, based on research by Sergi et al. which found significantly higher mortality rates amongst those with BMI values under 20 kg m^{-2} amongst an elderly sample of 3110 participants [24]. BMI between 20 and 24.99 kg m^{-2} were classified as normal, BMI between 25 and 29.99 kg m^{-2} were classified as overweight, and BMI between 30 and 34.99 kg m^{-2} were classified as Obese Class I, and BMI equal to or above 35 kg m^{-2} were classified as Obese Class II/III. Scales used for the measurement of weight were manufactured by 'Wedderburn', which are high precision scales used for medical purposes. The same scales were used at baseline and follow-up and were calibrated as needed.

Waist circumference (WC) was measured at the mid-point between the lower border of the ribs and the iliac crest. WC was measured with a non-stretch clear measuring tape. WC of > 88 cm in females and > 102 cm in males was used to classify people as obese.

Covariates

All analyses of the relationships between adiposity measures and QoL were performed with participants' age, sex, and years of education as control variables (Model 1). Previous literature in this area included age [14, 25, 26], sex [6, 9, 13, 27, 28], education [13], chronic diseases: hypertension, diabetes, coronary heart disease (myocardial infarct and angina), osteoarthritis, cerebral vascular disease (stroke and TIA) asthma, chronic obstructive pulmonary disease (COPD), osteoporosis [6, 29, 30], smoking history [6], mild cognitive impairment (MCI) [31], depression [13, 32], sit-to-stand task (seconds) [33], and physical activity [8]. Each variable was singularly combined with BMI, age, sex, and education in a linear regression model to examine potential relationships with each of the main dependent variables. Those with $p < 0.1$ were retained for use as covariates in later analyses. The following covariates were selected based on this procedure: age, sex, education, asthma, osteoporosis, depression, impaired vision, impaired hearing, sit-to-stand task (in seconds), and MCI. General health and physical activity were also included, as these variables have been shown to impact both weight and QoL [14, 34].

Education was defined as the years of formal education received, and data on this were collected during the telephone screen prior to the face-to-face interview. Data on chronic diseases, visual impairments, and impairments in hearing were obtained via medical history interviews as part of the face-to-face assessments on consenting individuals who fulfilled the inclusion criteria of the MAS.

Physical activity was assessed with a self-completed questionnaire. It represents the sum of participation across eight listed activities (e.g. bicycling), other reported activities (e.g. yoga), and walking. For general health, participants rated their general health on a 5-point scale from poor to excellent. Depression was assessed using the Geriatric Depression Scale (GDS, range 0–15). The sum of its 15 items indicates the severity of depressive symptoms, with higher scores indicating more depressive symptoms.

For the timed sit-to-stand test, the participant is asked to sit on a chair with arms folded over the chest. Participants are then instructed to stand up all the way and sit down, as fast as possible, five times without using the arms. Timing with a stopwatch is started on the command 'go' and stopped when the participant sits down for the 5th time.

Consensus diagnoses of MCI were made by at least three experienced clinicians from a panel of psychogeriatricians, neuropsychiatrists, clinical and research neuropsychologists using current international consensus criteria [35]. Participants were classified as having MCI if the following criteria were met: (1) presence of a participant or informant cognitive complaint, (2) cognitive impairment on objective testing, (3) no dementia based

on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Revision criteria, American Psychiatric Association (2000), and (4) normal function or minimal impairment in instrumental activities of daily living [36]. Cognitive impairment was defined as a test score of 1.5 standard deviations or more below published normative data (age- and education-matched, where possible).

Statistical analyses

Cross-sectional analyses

Associations of BMI and waist circumference as continuous variables with each of the main dependent variables were examined by ordinary least squares (OLS) regression analysis, adjusting for age, sex, and education in Model 1 and for all covariates in our Model 2. Because previous studies have suggested that the relationship between adiposity and other variables, such as mortality [37, 38] and cognitive performance are not linear [39], non-linear relationships were also investigated by the addition of the squares of adiposity variables into the equations, with covariates as described above. For these analyses, adiposity variables were centred by subtracting the means to avoid multicollinearity between the variable and its squared value.

Where statistically significant non-linear relationships were found, in order to understand the nature of these relationships better, the BMI and WC measures were converted to categorical ones, and ANCOVAs, followed by paired comparisons between the groups, were performed. For all Wave 1 cross-sectional analyses, Wave 1 covariate data were used and all Wave 2 cross-sectional analyses used Wave 2 covariate data. Missing data for covariates were replaced with values obtained through expectation–maximisation (EM) imputation in SPSS. Bonferroni correction for multiple testing was performed and *p* value for all of the above analyses was set at .0125.

Longitudinal analyses

The prospective relationships, both linear and non-linear, of BMI and WC at Wave 1 with the main dependent variables at Wave 2 were also examined using OLS regression analyses, adjusting for age, sex, and education in Model 1 and for all covariates in our Model 2. In each of these analyses, Wave 2 values were the dependent variable, with the corresponding Wave 1 values included as a covariate. For all prospective analyses of Wave 1 BMI/WC predicting Wave 2 QoL variables, Wave 1 covariates were included.

Results

Descriptive statistics

Table 1 presents descriptive statistics of the dependent and independent variables and covariates of the study sample at baseline (Wave 1) and follow-up (Wave 2).

Cross-sectional relationships between anthropometric measurements and quality of life

Regression analyses

The results of cross-sectional regression analyses examining relationships between anthropometric measures and quality of life at baseline and at Wave 2 are presented in Tables 2 and 3. Table 2 presents the results of analyses involving BMI, and Table 3 the analyses involving WC. Model 1 refers to the use of age, sex, and education only for covariates, while Model 2 represents the use of all covariates.

Body mass index

For both waves, the linear effects of BMI on independent living and pain were statistically significant, even after the inclusion of all covariates (e.g. Model 1 and Model 2), with higher BMI associated with lower independent living and worse pain scores. In Wave 1, BMI was also associated with total AQoL and relationships, but these findings were only replicated in Wave 2 for total AQoL.

For the non-linear relationships, there were statistically significant quadratic effects for the relationship between BMI and independent living in both Models 1 and 2, and in both waves. In addition, for Wave 2, non-linear relationships were evident between BMI and overall AQoL, relationships, and coping in Model 1, but after the inclusion of the additional covariates (Model 2) only the quadratic effect for relationships remained significant. The negative regression coefficients of the BMI-squared term indicates relationships with a downward curvature, that is, a stronger negative effect of BMI on the dependent variables for increasing values of BMI.

Waist circumference

Regression analyses showed that waist circumference (WC) as a continuous variable was significantly and consistently associated with independent living, relationships, and pain scores, in a similar way to BMI, with higher WC being associated with lower independent living scores, lower

Table 1 Descriptive statistics for participants at baseline and 2-year follow-up

	Baseline (Wave 1)	Follow-up (Wave 2)
Age [M (SD)]	78.7 (4.7) $n=926$	80.1 (4.6) $n=751$
Sex (female)	55.5% $n=514$	55.7% $n=418$
BMI (kg m^{-2}) [M (SD)]	27.1 (4.5) $n=926$	27.1 (4.5) $n=751$
BMI categories		
Underweight (< 19.99 kg m^{-2})	3.2% $n=30$	3.6% $n=27$
Normal weight (20.00–24.99 kg m^{-2})	30.0% $n=278$	29.8% $n=224$
Overweight (25.00–29.99 kg m^{-2})	43.4% $n=402$	43.8% $n=329$
Obese Class I (30.00–34.99 kg m^{-2})	17.8% $n=165$	17.7% $n=133$
Obese Classes II and III (≥ 35.00 kg m^{-2})	5.5% $n=51$	5.1% $n=38$
Waist circumference (cm) [M (SD)]	96.4 (13.0) $n=920$	95.9 (13.2) $n=744$
Education (years) [M (SD)]	11.6 (3.5) $n=926$	11.7 (3.5) $n=751$
Asthma	6.9% $n=64$	8.0% $n=60$
Osteoporosis	21.2% $n=196$	26.9% $n=202$
Visual impairment	9.3% $n=86$	13.7% $n=103$
Hearing impairment	40.4% $n=374$	36.6% $n=275$
Sit-to-stand time (s) [M (SD)]	16.8 (5.7) $n=926$	15.7 (4.8) $n=751$
MCI	36.8% $n=296$	41.8% $n=314$
Physical activity [M (SD)]	1.6 (1.1) $n=923$	1.5 (1.1) $n=751$
General health [M (SD)]	3.4 (1.0) $n=923$	3.3 (0.9) $n=751$
GDS	2.3 (2.1) $n=923$	2.4 (2.3) $n=751$
AQoL-6D (z-score)	(1.0) $n=926$	−0.003 (1.0) $n=751$
Satisfaction with Life Scale	60.3 (9.8) $n=923$	55.8 (17.3) $n=751$

M mean, *SD* standard deviation, *BMI* body mass index, *MCI* mild cognitive impairment

relationship scores, and worse pain scores in both models and in both waves. Interestingly, WC was also associated with overall AQoL at both waves; this relationship disappeared once all covariates were added in Wave 1, but remained in Wave 2. Mental health was associated with WC in Wave 1 after inclusion of covariates, whereas coping was associated with WC in Wave 2, in both models. No significant non-linear relationships were found between WC and AQoL at either wave. These results are presented in Table 3.

Analyses of covariance for BMI

To examine more closely the nature of the non-linear effects of BMI on the QoL variables, independent living and relationships, we examined the differences in QoL across the 5 BMI category groups. Statistically significant differences were found between BMI groups for independent living scores at baseline $F(4, 909) = 13.77$, $p = 0.001$ (Fig. 1) and at Wave 2 $F(4, 734) = 14.33$, $p = 0.001$ (Fig. 2), and for

Table 2 Cross-sectional linear and curvilinear regression analyses of body mass index and QoL parameters

	Wave 1				Wave 2			
	Model 1		Model 2		Model 1		Model 2	
	BMI $N=926$ β (t) [95% CI]	BMI2 $N=926$ β (t) [95% CI]	BMI $N=926$ β (t) [95% CI]	BMI2 $N=926$ β (t) [95% CI]	BMI $N=751$ β (t) [95% CI]	BMI2 $N=751$ β (t) [95% CI]	BMI $N=751$ β (t) [95% CI]	BMI2 $N=751$ β (t) [95% CI]
SWLS (11-item)	.01 (.20) [−.06, .07]	−.02 (−.56) [−.05, .03]	.05 (1.68) [−.01, .11]	−.01 (−.35) [−.04, .03]	−.02 (−.55) [−.05, .03]	−.08 (−1.93) [−.05, .00]	.01 (.38) [−.03, .05]	−.02 (−.43) [−.03, .02]
SWLS (5-item)	.02 (.45) [−.06, .09]	.01 (.27) [−.04, .06]	.05 (1.46) [−.02, .12]	.02 (.54) [−.03, .06]	.00 (.06) [−.07, .08]	−.07 (−1.72) [−.09, .01]	.03 (.90) [−.04, .10]	−.02 (−.43) [−.05, .03]
Overall AQoL	−.10 (−3.16)* [−.17, −.04]	−.05 (−1.30) [−.07, .01]	−.04 (−1.42) [−.09, .01]	−.04 (−1.41) [−.05, .01]	−.10 (−2.74)* [−.18, −.03]	−.11 (−2.77)* [−.11, −.02]	−.05 (−1.81) [−.11, .00]	−.03 (−1.17) [−.06, .01]
Independent living	−.26 (−8.44)* [−.31, −.19]	−.09 (−2.55)* [−.09, −.01]	−.19 (−7.21)* [−.24, −.14]	−.07 (−2.57)* [−.07, −.01]	−.25 (−7.48)* [−.32, −.19]	−.14 (−3.93)* [−.12, −.04]	−.20 (−6.92)* [−.26, −.14]	−.09 (−2.77)* [−.09, −.02]
Relationships	−.16 (−5.04)* [−.22, −.10]	−.07 (−2.04) [−.08, −.00]	−.11 (−3.81)* [−.17, −.05]	−.06 (−2.01) [−.07, −.00]	−.09 (−2.47) [−.16, −.02]	−.15 (−3.78)* [−.13, −.04]	−.06 (−1.81) [−.12, .01]	−.10 (−2.75)* [−.10, −.02]
Mental health	.03 (1.03) [−.03, .10]	.00 (.05) [−.04, .04]	.07 (2.28) [.01, .13]	.01 (.22) [−.03, .04]	.04 (1.07) [−.03, .11]	−.03 (−.66) [−.06, .03]	.06 (1.86) [−.00, .12]	.03 (.87) [−.02, .06]
Coping	−.05 (−1.47) [−.11, .02]	−.05 (−1.46) [−.07, .01]	.01 (.44) [−.04, .07]	−.04 (−1.45) [−.06, .01]	−.06 (−1.68) [−.13, .01]	−.10 (−2.60)* [−.11, −.02]	−.02 (−.77) [−.08, .04]	−.03 (−1.02) [−.06, .02]
Pain	−.18 (−5.51)* [−.24, −.11]	−.01 (−.32) [−.05, .03]	−.13 (−4.34)* [−.19, −.07]	−.00 (−.13) [−.04, .03]	−.18 (−4.99)* [−.26, −.11]	−.06 (−1.60) [−.08, .01]	−.14 (−4.18)* [−.21, −.07]	−.01 (−.30) [−.05, .04]
Senses	.01 (.40) [−.05, .08]	−.03 (−.74) [−.06, .03]	.04 (1.48) [−.01, .10]	−.04 (−1.23) [−.06, .01]	−.01 (−.30) [−.08, .06]	−.04 (−1.01) [−.07, .02]	.03 (.96) [−.03, .10]	−.03 (−.97) [−.06, .02]

Covariates included in Model 1 are age, sex, and education. Covariates included in Model 2 are age, sex, and education, as well as past and current history of asthma and osteoporosis, depressive symptoms based on the GDS, vision impairment, hearing impairment, sit-to-stand time, MCI, physical activity, and general health

BMI body mass index (kg m^{-2})

*$p \leq 0.0125$ level of significance

relationships at Wave 2 $F(4, 734) = 4.72$, $p = 0.001$ only (Fig. 3).

In summary, for independent living scores at Wave 1, normal weight participants had significantly higher scores than Obese Class I and Class II/III participants, but no significant difference to overweight and underweight. Overweight participants had significantly higher scores compared to both obese groups. Underweight participants had significantly higher scores compared to Obese Class II/III only. Obese Class I had significantly higher scores than Obese Class II/III.

For relationships, normal weight participants had significantly higher scores than Obese Class I participants, but not significantly different to underweight, overweight, and Obese Class II/III participants. Overweight participants had significantly higher scores compared to both obese groups. All other comparisons were not significant at the $p \leq 0.0125$ level.

Prospective relationships between anthropometric measurements with quality of life

The relationships between BMI and waist circumference at Wave 1 and QoL measures at Wave 2 are shown in Table 4. We found that baseline BMI was a significant predictor of Wave 2 pain, when adjusting for only age, sex, education, and Wave 1 pain scores and after Bonferroni correction ($p < 0.0125$). After adjusting for all other covariates, higher baseline BMI was a significant predictor of lower Wave 2 independent living scores only.

Higher baseline waist circumference predicted lower independent living scores and higher pain scores at Wave 2, after adjusting for age, sex, education, and Wave 1 independent living or pain scores, respectively. The association with independent living remained after inclusion of all other covariates. There were no quadratic associations between BMI/WC and QoL.

**Table 3** Cross-sectional linear and curvilinear regression analyses of waist circumference and QoL parameters

	Wave 1				Wave 2			
	Model 1		Model 2		Model 1		Model 2	
	WC $N=920$ β (t) [95% CI]	WC2 $N=920$ β (t) [95% CI]	WC $N=920$ β (t) [95% CI]	WC2 $N=920$ β (t) [95% CI]	WC $N=744$ β (t) [95% CI]	WC2 $N=744$ β (t) [95% CI]	WC $N=744$ β (t) [95% CI]	WC2 $N=744$ β (t) [95% CI]
SWLS (11-item)	.001 (.02) [−.07, .07]	.005 (.14) [−.04, .05]	.05 (1.49) [−.02, .11]	.02 (.79) [−.02, .05]	−.04 (−1.55) [−.08, .01]	−.003 (−.24) [−.03, .002]	−.01 (−.54) [−.05, .03]	.002 (.17) [−.02, .02]
Overall AQoL	−.13 (−3.51)* [−.20, −.06]	−.02 (−1.1) [−.07, .02]	−.04 (−1.38) [−.09, .02]	−.004 (.25) [−.04, .03]	−.19 (−4.84)* [−.27, −.11]	−.01 (−.42) [−.05, .03]	−.12 (−3.88)* [−.18, −.06]	−.001 (−.09) [−.03, .03]
Independent living	−.35 (−1.72)* [−.41, −.29]	−.07 (−3.55)* [−.11, −.03]	−.26 (−8.94)* [−.31, −.19]	−.05 (−1.51) [−.08, −.02]	−.35 (−9.73)* [−.42, −.27]	−.04 (−2.21) [−.08, −.01]	−.27 (−8.86)* [−.34, −.21]	−.03 (−2.11) [−.07, −.002]
Relationships	−.18 (−5.04)* [−.24, −.11]	−.04 (−1.81) [−.7, .003]	−.11 (−3.35)* [−.17, −.04]	−.04 (−1.21) [−.06, .01]	−.16 (−4.29)* [−.24, −.09]	−.01 (−−.66) [−.05, .03]	−.12 (−3.40)* [−.19, −.05]	−.01 (−.45) [−.04, .03]
Mental health	.07 (1.79) [−.006, .14]	.03 (1.12) [−.01, .07]	.11 (3.23)* [.04, .17]	.03 (1.75) [−.00, .07]	.01 (.27) [−.07, .09]	.02 (.95) [−.02, .06]	.04 (1.22) [−.03, .11]	.03 (1.53) [−.01, .07]
Coping	−.09 (−2.35) [−.16, −.01]	−.03 (−1.4) [−.07, .01]	−.004 (−.13) [−.06, .06]	−.22 (−.85) [−.05, .02]	−.15 (−3.71)* [−.23, −.07]	−.03 (−1.40) [−.07, .01]	−.09 (−2.74)* [−.16, −.03]	−.02 (−1.31) [−.06, −.01]
Pain	−.22 (−6.17)* [−.29, −.15]	−.02 (−.93) [−.06, .02]	−.16 (−4.67)* [−.22, −.09]	−.003 (−.15) [−.04, .04]	−.24 (−6.05)* [−.32, −.16]	−.004 (−.18) [−.05, .04]	−.18 (−4.84)* [−.25, −.11]	.002 (.10) [−.04, .04]
Senses	.03 (.80) [−.42, .10]	−.01 (−.76) [−.6, .03]	.06 (1.87) [.003, .12]	−.006 (−.33) [−.04, .03]	−.08 (−2.01) [−.15, .00]	.02 (.70) [−.03, .06]	−.02 (−.51) [−.09, .05]	.01 (.35) [−.03, .04]

Covariates included in Model 1 are age, sex, and education. Covariates included in Model 2 are age, sex, and education, as well as past and current history of asthma and osteoporosis, depressive symptoms based on the GDS, vision impairment, hearing impairment, sit-to-stand time, MCI, physical activity, and general health

WC waist circumference (cm)

*$p \leq 0.0125$ level of significance

Fig. 1 Mean values of independent living for participants in each BMI category (with all the covariates) at Wave 1. Differences in adjusted means are significant at $p < 0.002$ for the following comparisons: UW versus OB II/III, NW versus OB I, NW versus OB II/III, OW versus OB II/III, OW versus OB I, OB I versus OB II/III. *UW* underweight; *NW* normal weight (BMI 20–24.99 kg m^{-2}); *OW* Obese Class I (BMI 30–34.99 kg m^{-2}); Obese Class II/III (BMI ≥ 30 kg m^{-2})
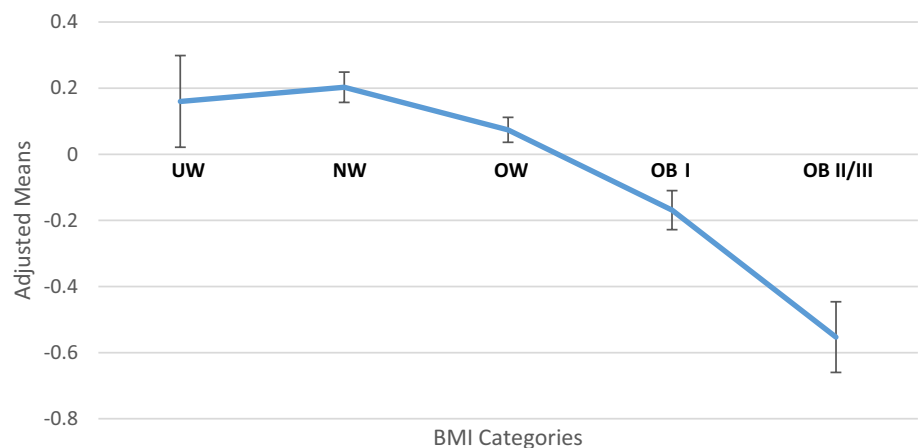
Discussion

The study investigated the cross-sectional and longitudinal relationships between adiposity, as measured by body mass index (BMI) and waist circumference (WC), and two measures of quality of life, health-related quality of life and life satisfaction, in a large group of elderly Australians. As hypothesised, in cross-sectional analyses we found that BMI was associated with lower HRQoL in
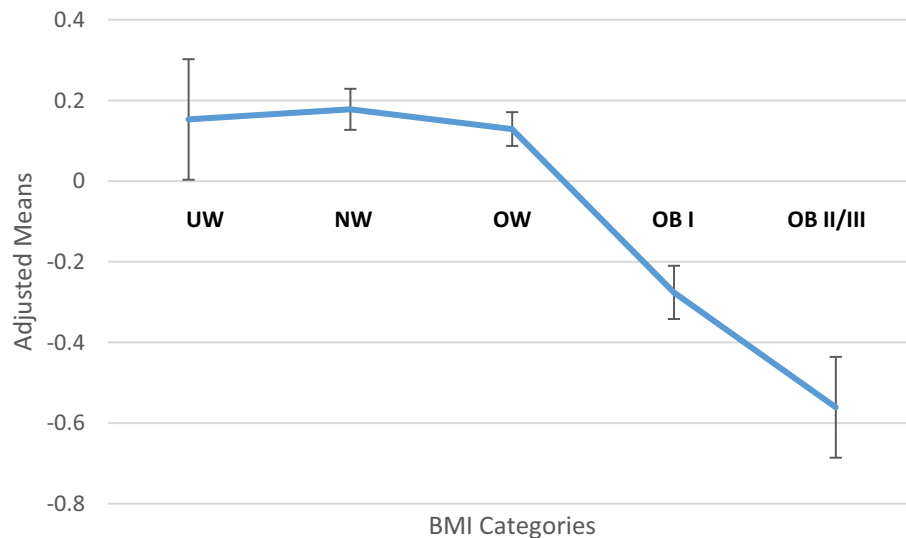
Fig. 2 Mean values at Wave 2 of independent living for participants in each BMI category (Model 2). *UW* underweight (BMI > 20kg m^{-2}); *NW* normal weight (BMI 20–24.99 kg m^{-2}); *OW* overweight (BMI 25–29.99 kg m^{-2}); Obese Class I (BMI 30–34.99 kg m^{-2}); Obese Class II/III (BMI ≥ 30 kg m^{-2}). Differences in adjusted means are significant at $p = 0.000$ for the following comparisons: *UW* versus OB II/III, NW versus OB I, NW versus OB II/III, OW versus OB I, OW versus OB II/III. Difference in adjusted means is significant at $p = 0.009$ for the following comparison: UW versus OB I
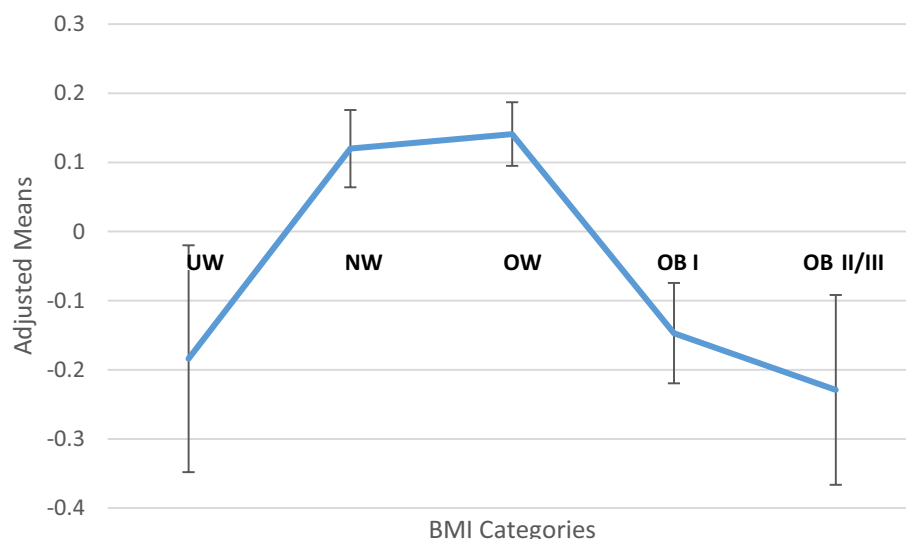

Fig. 3 Mean values at Wave 2 of relationships for participants in each BMI category (Model 2). *UW* underweight (BMI > 20kg m^{-2}); *NW* normal weight (BMI 20–24.99 kg m^{-2}); *OW* overweight (BMI 25–29.99 kg m^{-2}); Obese Class I (BMI 30–34.99 kg m^{-2}); Obese Class II/III (BMI ≥ 30 kg m^{-2}). Difference in adjusted means is significant at $p = 0.001$ for the following comparison: OW versus OB I. Difference in adjusted means is significant at $p = 0.004$ for the following comparison: NW versus OB I. Difference in adjusted means is significant at $p = 0.011$ for the following comparison: OW versus OB II/III. Means shown are adjusted for all covariates as listed in the text. Vertical bars are standard errors of measurement

the elderly, compared with their non-obese counterparts. However, contrary to our hypothesis, obese individuals in our sample did not report lower satisfaction with life. Cross-sectionally, higher BMI was significantly associated with lower scores in overall AQoL, independent living, relationships, and pain, after adjusting for age, sex, and

education (Model 1). Illness-related covariates (Model 2: asthma, osteoporosis, depression, vision and hearing impairment, stand-to-sit time, MCI, physical activity, and general health) eliminated the association between BMI and overall AQoL, but all other associations remained significant. Cross-sectional analyses of baseline BMI

Table 4 Prospective regression analyses modelling baseline BMI or WC predicting Wave 2 QoL parameters, controlling for covariates

z-Scores	Baseline BMI predicting Wave 2 QoL				Baseline WC predicting Wave 2 QoL			
	Model 1		Model 2		Model 1		Model 2	
	BMI $N=699$ β (t) [95% CI]	BMI2 $N=699$ β (t) [95% CI]	BMI $N=699$ β (t) [95% CI]	BMI2 $N=699$ β (t) [95% CI]	WC $N=692$ β (t) [95% CI]	WC2 $N=692$ β (t) [95% CI]	WC $N=692$ β (t) [95% CI]	WC2 $N=692$ β (t) [95% CI]
SWLS (11-item)	−.01 (−.50) [−.04, .02]	.02 (.53) [−.02, .03]	.00 (.06) [−.03, .03]	.01 (.61) [−.01, .03]	−.03 (−1.5) [−.06, .01]	.002 (.21) [−.02, .02]	−.02 (−1.0) [−.06, .02]	.01 (.49) [−.02, .03]
Overall AQoL	−.03 (−1.1) [−.08, .02]	−.00 (−.03) [−.03, .03]	−.02 (−.96) [−.07, .03]	.00 (.15) [−.04, .03]	−.06 (−2.0) [−.11, −.001]	.01 (.54) [−.02, .04]	−.04 (−1.5) [−.10, .01]	.00 (.60) [.00, .00]
Independent living	**−.06 (−2.2)** [−.10, −.01]	−.03 (−1.3) [−.05, .01]	**−.06 (−2.5)** **[−.11, −.01]***	−.02 (−1.2) [−.05, .01]	**−.09 (−3.2)** **[−.14, −.03]***	−.02 (−1.5) [−.05, .01]	**−.09 (−3.3)** **[−.14, −.04]***	−.02 (−1.3) [−.05, .01]
Relationships	.01 (.38) [−.05, .07]	−.03 (−.87) [−.06, .02]	.01 (.48) [−.05, .08]	−.02 (−.89) [−.06, .02]	−.01 (−.18) [−.07, .06]	.01 (.42) [.03, .05]	.003 (.9) [−.07, .07]	.01 (.45) [−.03, .05]
Mental health	.01 (.32) [−.05, .07]	.03 (.84) [−.02, .05]	.02 (.7) [−.04, .08]	.03 (.87) [−.02, .06]	−.01 (−.37) [−.07, .05]	.03 (1.62) [−.01, .07]	.01 (.22) [−.06, .07]	.03 (1.7) [−.004, .07]
Coping	−.04 (−1.5) [−.10, .01]	−.02 (−.76) [−.05, .02]	−.03 (−.83) [−.08, .03]	−.03 (−.97) [−.06, .02]	−.06 (−2.0) [−.13, −.001]	−.02 (−.82) [−.05, .02]	−.04 (−1.2) [−.10, .03]	−.02 (−.9) [−.05, .02]
Pain	**−.08 (−2.7)** **[−.13, −.02]***	−.01 (−.33) [−.04, .03]	−.07 (−2.5) [−.13, −.02]	−.01 (−.33) [−.04, .30]	**−.08 (−2.6)** **[−.15, −.02]***	−.02 (−.97) [−.06, .02]	−.07 (−2.1) [−.13, −.01]	−.02 (−.8) [−.05, .02]
Senses	−.02 (−.58) [−.08, .04]	.01 (.39) [−.03, .05]	.01 (.36) [−.05 .07]	.01 (.36) [−.03, .05]	−.07 (−2.3) [−.14, −.01]	.03 (1.7) [−.01, .07]	−.04 (−1.3) [−.11, .02]	.04 (1.8) [−.003, .07]

Covariates included in Model 1 are age, sex, education, and Wave 1 QoL. Covariates included in Model 2 are age, sex, and education, as well as past and current history of asthma and osteoporosis, depressive symptoms based on the GDS, vision impairment, hearing impairment, sit-to-stand time, MCI, physical activity, general health, and Wave 1 QoL

BMI body mass index (kg m^{-2}), *WC* waist Circumference (cm)

*p ≤ 0.0125 level of significance

If underlined $p \leq 0.025$

categories found that Obese Class I participants reported lower independent living scores compared with normal and overweight participants, while Obese Class II/III participants reported the independent living scores lower than all groups. Furthermore, Obese Class I participants reported lower relationships scores than normal and overweight participants.

Similar results were found when WC was used as the measure of adiposity, with a few key exceptions. Firstly, when all covariates were added, greater WC was associated with higher Mental Health scores at baseline, but this association was not present in Wave 2. We found both BMI and WC to be significant predictors of QoL scores at 2 years. Baseline BMI and baseline WC predicted higher pain scores at Wave 2, in Model 1, and lower independent living at Wave 2 in Model 2.

The consistent association between obesity and the impaired ability to live independently is consistent with findings reported by various other studies [5, 13, 40, 41]. The AQoL-6D assesses four key aspects to form a composite score for this dimension: (1) the ability to independently carry out household tasks such as food preparation and cleaning; (2) the ease with which an individual carries out tasks outside the home, such as shopping and visiting; (3) toileting and personal hygiene; and (4) the degree of mobility, ranging from being bedridden to walking or running with ease. We expected that obesity would correlate with a greater degree of mobility limitation and functional disability, since excess adiposity is often associated with poor physical fitness [42], large-joint osteoarthritis [41], and lower cognitive function, which directly impair function [4]. However, in our study we controlled for physical fitness, osteoarthritis, and cognitive function, which may indicate that excess weight affects independent living independently of these conditions. A study of 8966 community dwellers aged 65–101 years found a strong association between obesity and impaired mobility, with the highest odds ratio in severely obese women (BMI ≥ 35 kg m^{-2}) [13]. Our results indicate that participants classed as Obese II/III (BMI ≥ 35 kg m^{-2}) had the worst independent living scores compared with all other BMI categories.

Functional limitation amongst the elderly has serious implications for the individual and the community. Our results indicate that a higher BMI or greater WC at

baseline is associated with reduced self-scoring in the capacity to live independently at 2 years. Previous studies have linked an objectively assessed functional limitation with disability over a longitudinal period and disability has been shown to be related with institutionalisation and mortality [43]. In a study of 85-year-olds, overweight and obese participants perceived more impairment in performing instrumental activities of daily living (IADLs), such as the use of public transport, cleaning, small- and large-scale shopping, and washing, than normal weight participants, and obese participants had more frequent use of home visits, a greater need for assistive technology and formal services [5].

As described above, the results from this study suggest that, compared with normal weight and overweight individuals, elderly participants with obesity on average experience less happiness from their close and intimate (including sexual) relationships, and feel that they are less able to carry out their role as part of a family unit and a member of community due to their health. Social participation has been shown to contribute positively to general well-being amongst older adults, including findings of improved psychological and physical well-being, a decreased likelihood of mortality, and greater functional health [44]. The association we found between obesity and lower relationship scores may be partially explained by Puhl and Brownwell's findings that stigma attached to obesity contributes to less social engagement for obese individuals [45]. Watson and Britton [44] found that weight was positively correlated with social participation, with heavier participants in their study reporting greater engagement in social activities [44]. Our study, on the other hand, found that higher BMI negatively affected relationship scores on the AQoL-6D. Unlike Watson and Britton's study, which looked at the *quantity* of social participation, questions on the AQoL-6D relating to the "relationships" domain appeared to evaluate the participant's subjective appraisal of the *quality* of existing social interactions. Diminished 'relationships' scores amongst our obese cohort may have had less to do with the reported deleterious consequences obesity has on social skills [46], and more to do with the impaired mobility and functional limitation experienced by our elderly obese participants. Indeed, after controlling for 'independent living' and 'pain' dimension scores, the association between BMI and the 'relationship' dimension was eliminated.

We found that obesity was associated with more pain at each wave. The prevalence of hip arthritis, knee arthritis, and knee osteoarthritis has been reported to be higher amongst obese individuals [41]. Even after controlling for osteoarthritis in our study, the association between obesity and pain remained significant, suggesting that excess body weight may contribute to increased pain via other mechanisms, or that pain limits mobility and worsens obesity. Our results indicate that higher BMI and greater WC at baseline are significant predictors of more pain at Wave 2.

The association between BMI and the mental components of quality of life is less well documented. We found greater adiposity to be significantly associated with better scores in the "mental health" dimension of the AQoL-6D at Wave 1, only after controlling for all covariates and only when using WC as our adiposity measure. Existing literature on the subject suggest that obesity may be associated with worse mental health in adult women [9, 13, 26, 27, 30, 47] and increased odds of developing a mental illness [13, 27, 47–49]; however, those studies utilised a predominantly younger adult population, and there is evidence that ageing may attenuate obesity's impact on mental health [27]. That is, poorer general health and low physical activity may be related to lower mental health, so that a significant positive correlation may only be seen after controlling for either or both covariates. When deleting these two covariates from the model, the association between obesity and mental health QoL disappeared. The correlation coefficient remained positive at Wave 2, but the association lost significance, indicating that whatever protective effects a higher WC may have on mental health possibly become less pronounced over time.

Questionnaires such as the SWLS relate to an emerging area of research which combine economic and psychological principles to derive a measure of utility based on such concepts as happiness and life satisfaction [12]. One study found that, although disability or serious illness impacted negatively on happiness levels, individuals tended to return to their initial happiness levels over time, signifying an adaptation process [50]. Indeed, life satisfaction has been suggested as one potential indicator of successful ageing and psychological adaptation [51]. On the topic of obesity and life satisfaction, one study which utilised data from Australia, Germany, and the United Kingdom reported that obesity had a negative effect on life satisfaction in the former two countries [52]. This incongruity to our findings may be due to our use of a different measure of life satisfaction, but at the same time may suggest an independent effect of age on life satisfaction. Perhaps as people age they become more satisfied with their lives, regardless of their weight status.

Our study is the first to examine life satisfaction in conjunction with quality of life in an elderly Australian sample. Other strengths of our study include a large sample size at both waves, and our use of prospective analyses to examine the predicative power of our variables. Additionally, our use of multiple covariates indicates that there exists a strong relationship between our adiposity and quality of life. However, our study has several limitations too. Firstly, our study used a predominantly healthy sample, with the majority of participants rating their health as 'better than average'. This opens up the possibility of a survivor bias amongst our

sample, whereby our results may have underestimated the deleterious effects of obesity on both quality of life and life satisfaction, as those with poorer quality of life and life satisfaction may have succumbed to obesity-related conditions at a much younger age. Furthermore, as has been discussed extensively elsewhere [3, 37, 53, 54], BMI may not be the best measure of adiposity in the elderly. We attempted to overcome this limitation by including WC as an anthropometric measure. Future studies may benefit from utilising more accurate measures of adiposity, such as dual-energy X-ray absorptiometry (DEXA).

Six of the eleven items of the Satisfaction with Life questionnaire used in the MAS were created specifically for the MAS and have not been validated. Analyses were performed using the 11-item total score, and then re-run using the 5-item total score, and the latter analyses yielded no changes to our findings. Future studies using the 11-item questionnaire would strengthen the validity of our own findings. We note that the cut-off values for waist circumference used in our study are for Caucasian people. Caucasian people comprised 98% of the participants included in our Wave 1 and Wave 2 analyses. The clinical utility of our data in non-Caucasian populations may therefore be limited.

In conclusion, obesity is associated with lower scores on the AQoL-6D for the dimensions of independent living, relationships, mental health, pain (i.e. worse pain), and overall quality of life. There is also a negative correlation between waist circumference and the same AQoL-6D dimensions, but not overall quality of life. Higher BMI or WC at Wave 1 is also predictive of worse AQoL-6D dimension scores for independent living and pain. No associations were found between any of our anthropometric measures of obesity and satisfaction with life.

Compliance with ethical standards

Ethics approval Ethics approval was granted for the Memory and Ageing Study (Sydney MAS) by the Ethics Committees of the University of New South Wales, and the South Eastern Sydney and Illawarra Area Health Service.

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