Prospective cohort study of body mass index and the risk of hospitalisation: Findings from 246,361 participants in the 45 and Up Study

Running title: Body mass index and the risk of hospitalisation

Rosemary J. Korda, PhD,^{1,2} Bette Liu,³ MBBS, PhD, Mark S. Clements,⁴ PhD, Adrian E. Bauman, MBBS, PhD,⁵ Louisa R. Jorm, PhD,⁶ Hilary J. Bambrick, PhD,⁶ Emily Banks, MBBS, PhD^{1,7}

1. National Centre for Epidemiology and Population Health, The Australian National University

2. Australian Centre for Economic Research on Health, The Australian National University

3. The Kirby Institute, The University of New South Wales

4. Department of Medical Epidemiology and Biostatistics, Karolinska Institutet

5. Sydney School of Public Health, The University of Sydney,

6. School of Medicine, University of Western Sydney

7. The Sax Institute

Corresponding Author

Dr. Rosemary Korda

National Centre for Epidemiology and Population Health

The Australian National University

Building #62, Mills Road, Canberra 0200, Australia

Telephone: +61 2 6125 5583, Fax: +61 2 6125 9123

Email: Rosemary.Korda@anu.edu.au

Abstract

Objective: To quantify the risk of hospital admission in relation to fine increments in body mass index (BMI).

Design, setting and participants: Population-based prospective cohort study of 246,361 individuals aged ≥ 45 years, from New South Wales, Australia, recruited from 2006 to 2009. Self-reported data on BMI and potential confounding/mediating factors were linked to hospital admission and death data.

Main outcomes: Cox-models were used to estimate the relative risk (RR) of incident all-cause and diagnosis-specific hospital admission (excluding same day) in relation to BMI.

Results: There were 61,583 incident hospitalisations over 479,769 person-years (py) of observation. In men, hospitalisation rates were lowest for BMI $20 < 25 \text{ kg/m}^2$ (age-standardised rate: 120/1,000py) and in women for BMI $18.5 < 25 \text{ kg/m}^2$ (102/1,000py); above these levels, rates increased steadily with increasing BMI; rates were 203 and 183/1,000py, for men and women with BMI $35\text{--}50 \text{ kg/m}^2$, respectively. This pattern was observed regardless of baseline health status, smoking status and physical activity levels. After adjustment, the RRs (95% confidence interval) per 1 kg/m^2 increase in BMI from $\geq 20 \text{ kg/m}^2$ were 1.04(1.03 to 1.04) for men and 1.04(1.04 to 1.05) for women aged 45–64; corresponding RRs for ages 65–79 were 1.03(1.02 to 1.03) and 1.03(1.03 to 1.04); and for ages ≥ 80 years, 1.01(1.00 to 1.01) and 1.02(1.01 to 1.02). Hospitalisation risks were elevated for a large range of diagnoses, including a number of circulatory, digestive, musculoskeletal and respiratory diseases, while being protective for just two—fracture and hernia.

Conclusions: Above normal BMI, the relative risk of hospitalisation increases with even small increases in BMI, less so in the elderly. Even a small downward shift in BMI, among those who are overweight not just those who are obese, could result in a substantial reduction in the risk of hospitalisation.

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52 **Keywords:** body mass index, obesity, health services, hospitalisation, cohort study

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Introduction

Obesity rates have doubled or tripled in many countries over the past three decades, and in almost half of all Organization for Economic Co-operation and Development countries 50% or more of the population is now overweight or obese.¹ It is known that obesity, and to a lesser extent overweight, increases the risk of mortality^{2,3} and many chronic diseases.⁴ However, while pooled analyses have provided reliable evidence of increasing mortality with incremental increases in body mass index (BMI) above the normal range^{2,3} there is more limited information on the precise relationship between BMI and other important measures of disease and health service use, such as hospitalisation.⁵⁻¹¹ Moreover, while there is considerable evidence supporting the link between obesity and these outcomes (particularly total hospital use), the evidence on the risk of outcomes in people who are overweight but not obese is less clear. Further, there is little on the relationship between incremental changes in BMI and risk of being hospitalised, and how this might vary according to factors such as age (particularly in older age), pre-existing disease and other personal characteristics, and on the differential risks for hospitalisation for specific diagnoses. Studies of the gradient in risk add to the evidence on the health consequences of above-normal BMI relating to both fatal and non-fatal diseases and the likely optimal BMI.

In this study, we aim to quantify the relative risks of hospitalisation according to BMI. We report on the relationship of increasing increments of BMI to the risk of hospitalisation, including how the relationship varies by sex and age (particularly older age groups), across levels of smoking and physical activity, and for hospitalisation for a range of diagnoses.

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79 **Methods**

80 We used data from the 45 and Up Study, an Australian cohort involving 266,724 men and
81 women aged 45 and over from New South Wales (NSW), Australia. Potential participants were
82 randomly sampled from the database of Australia's universal health insurance provider,
83 Medicare Australia, which provides virtually complete coverage of the general population, and
84 were invited to take part. There were no exclusion criteria and the Study over-sampled, by a
85 factor of two, individuals aged 80 years and over and people resident in rural areas.
86 Participants joining the study completed a baseline questionnaire (between Jan 2006 and April
87 2009) and gave signed consent for follow-up and linkage of their information to a number of
88 health-related databases. The overall response rate was 18% meaning that 11% of the entire
89 NSW population aged 45 and over were included. Further details of the Study are described in a
90 separate publication,¹² and questionnaires can be viewed at <http://www.45andup.org.au>.

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92 Baseline survey data from study participants were linked to individual death data from the NSW
93 Registry of Births, Deaths and Marriages (to Jun 2010), hospital data from the NSW Admitted
94 Patient Data Collection (Jul 2000–Jun 2010), and cancer data from the NSW Central Cancer
95 Registry (Jan 2000–date of baseline survey). The NSW Admitted Patient Data Collection
96 includes records of all hospitalisations in NSW, dates of admission and discharge, and the
97 primary and additional reasons for admission (coded using ICD-10-AM).¹³ The NSW Central
98 Cancer Registry contains information on type of cancer diagnosis and date of diagnosis, and the
99 NSW Registry of Births, Deaths and Marriages includes information on the date of death. Data
100 were linked probabilistically by the Centre for Health Record linkage using personal information
101 (including full name, date of birth, sex and address), and quality assurance data show false
102 positive and negative rates for data linkage of <0.5% and <0.1%, respectively.¹⁴

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The main exposure, BMI, was calculated from weight and height as self-reported on the baseline survey. Because of the increased risk of measurement error in extreme BMI categories, and consistent with previous well-known studies (e.g.^{2,3}), participants with BMI $\geq$ 50kg/m² or BMI $<$ 15kgm² were excluded. BMI was then categorised using the following cut-points (WHO weight classification¹⁵ in brackets): 15– (underweight); 18.5–, 20– and 22.5– (normal weight); 25–and 27.5– (overweight); 30– 32.5– (obese class I) and 35– (obese class II-III). Data on potential confounding and modifying factors were derived from self-reported data from the baseline questionnaire.

The main outcome of interest was incident hospitalisation, defined as the first hospital admission after recruitment into the study which involved at least one night in hospital (*i.e.* day admissions to hospital were excluded), ascertained through linkage to the Admitted Patient Data Collection. We also examined incident hospitalisation for specific diagnoses, defined according to final primary diagnosis at discharge, based on the ICD-10-AM code (specific codes listed in Table 3). Where the admission was part of a transfer, the primary diagnosis of the first admission in the transfer was selected. The diagnoses examined in the analysis were selected based on *a priori* knowledge of conditions known to be associated with obesity,⁴ or to be major contributors to the burden of disease in Australia,¹⁶ or if they were among the top 20 diagnoses in this study (excluding rehabilitation and surgical follow-up care and complications following a procedure).

Survival methods were used to analyse the data, using age as the underlying time variable. Participants were followed from the date of recruitment to either the date of first hospital admission (any or cause-specific) or death, or June 30 2010 (the last date to which hospital data were available), whichever occurred first. Incident hospitalisation rates, standardised using 5-year age groups, were calculated according to baseline BMI. Rates were stratified by sex and

age group (45–64, 65–79 and 80+ years). We also examined rates stratified by smoking (never, past and current) given its strong association with both BMI and health outcomes, and by prior serious illness and tertile of physical activity given the complex relationship between these factors and BMI, including that they may lie on the causal pathway between BMI and health outcomes. Prior history of serious illness was defined as at least one of the following: a cancer diagnosis in the five years prior to enrolment (excluding non-melanoma skin cancer), ascertained from the cancer register; a hospital admission within the 5 years prior to enrolment that included a diagnosis of circulatory disease, diabetes or chronic obstructive pulmonary disease, ascertained from the hospital admission data; or a doctor diagnosis of either cancer, heart disease, stroke or diabetes self-reported on the questionnaire. Physical activity was assessed with the Active Australia questionnaire,¹⁷ which has documented reliability and validity.^{17,18} A score is generated based on the number of weekly sessions of walking, moderate and vigorous activity, weighted for intensity. This was categorised into tertiles. Interaction effects were tested using the likelihood-ratio test, comparing models with and without the interaction terms.

Cox regression was used to estimate the hazard ratios (referred to henceforth as relative risks (RR)) for incident hospitalisation according to BMI. For all-cause hospitalisations, the analyses were performed separately for men and women and were stratified by age group (45–64, 65–79 and 80+ years). The reference BMI group was 20–22.5kg/m² and tests for linear trend were also performed excluding those with a BMI of <20kg/m². Adjustment was made for potential confounding variables, including area of residence (major city, regional or remote based on the Accessibility / Remoteness Index of Australia Plus,¹⁹ derived from postcode of residence), education (six categories from ‘did not complete secondary school’ to university degree), pre-tax annual household income (seven income brackets, from AUD <\$5,000 to \$70,000 or more per year), smoking (never, past and current), alcohol intake (0 / 0–14 / 15 or more drinks per week),

and private health insurance (additional to universal health insurance). Participants with any missing values on any of these variables were assigned to a separate category for that variable. In addition, we performed a sensitivity analysis to examine the possible impact of any potential reverse causality, i.e. the effect of illness on baseline BMI, by excluding all person-years and hospitalisations in the first year of follow-up. We also examined the effects of additional adjustment for country of birth, classified into 13 regions, with a separate category for 'Australian-born' based on a modified version of that used in the Global Burden of Disease Study.²⁰

For hospitalisations for specific diagnoses, we stratified by age group, but combined males and females, and used broader BMI categories, comparing rates in overweight ($25 < 30 \text{ kg/m}^2$) and obese ($30\text{--}50 \text{ kg/m}^2$) to normal weight ($18.5 < 25 \text{ kg/m}^2$), in order to retain statistical power, while adjusting for all confounders including sex. The proportional hazards assumption was satisfied for all models. All analyses were performed using Stata version 12.0.²¹

Ethics approval for this project was obtained from the NSW Population and Health Services Research Ethics Committee and the Australian National University Human Research Ethics Committee.

Results

After excluding those with BMI $< 15 \text{ kg/m}^2$ ($n=303$) or $> 50 \text{ kg/m}^2$ ($n=2,463$) or missing ($n=17,600$), we followed 246,361 participants (92.4%), with the average time between baseline survey and end of the study period (or death) being 2.3 years (range: 1 day to 4.5 years).

The characteristics of the sample are shown in Table 1. Just under half the sample (47%) comprised men, with the majority of participants (62%) aged 45–64 years and 10% aged 80 years or older. Regarding BMI, 62% of the sample were overweight or obese (40% and 22%, respectively), two-thirds of men (47% overweight and 22% obese) and just over half of the women (33% overweight and 23% obese); this proportion was considerably lower in those who were aged 80 years or older (48% overweight/obese).

There were 61,583 incident hospitalisations over 479,769 person-years of observation; a rate of 128 per 1,000 person years (95% CI: 127 to 129) overall, 143 (95% CI: 142 to 145) in males and 115 (95% CI: 114 to 117) in females. Age-adjusted incident hospitalisation rates according to BMI are presented in Figure 1. Amongst men, incident hospitalisation rates were lowest in those with a BMI between 20 and 25kg/m² (age-adjusted rate of 120 per 1,000 py) and amongst women with a BMI of between 18.5 and 25kg/m² (102 per 1,000 py); rates were highest in the highest BMI category (35–50kg/m²) for both men and women (rates of 203 and 183 per 1,000 py respectively). Excluding those with a BMI < 20kg/m², there was a significant linear trend of increasing rate of hospitalisation with increasing BMI ($p < 0.0001$ for both males and females).

When examined separately by age group (Figure 2), while the absolute rates of hospitalisation rose with increasing age, as expected, the pattern of rising relative rates of hospitalisation with increasing BMI was attenuated with increasing age. After adjustment for potential confounding variables (see Table 2), the trend of increasing hospitalisation with increasing above-normal BMI remained apparent with trends in both men and women stronger in the youngest age group (RR 1.04 per 1kg/m² increase) and weaker in the 80+ age group (RR 1.01 per 1kg/m² increase). Amongst those aged 45–64, the risk of hospitalisation for the severely obese group (BMI 35–50kg/m²) was twice that of the group with normal BMI (male RR:1.86, 95%CI:1.69 to 2.05;

female RR:2.09; 95%CI:1.96 to 2.23), and amongst those aged 65–79 years the corresponding risks were 50–60% higher (Male RR:1.48, 95%CI:1.34 to 1.64; female RR:1.61; 95%CI:1.47 to 1.76). In people aged 80 years or older, although risks were elevated in those with a BMI of 27.5 kg/m² or higher and the overall trend was significant, there was considerable overlap in the confidence intervals of these risk estimates. Additional adjustment for region of birth made no material difference to the results (not shown). The sensitivity analysis excluding the first year of follow-up (n=242,829; 39,821 events over 282,243 person-years) showed little change in the RRs (see Supplementary Table).

To allow for closer examination of the effect of prior serious illness, smoking status and physical activity on the relationship between BMI and hospitalisation, age-adjusted rates are also presented separately for those with and without serious illness, by current, past and never smokers, and by tertile of physical activity (Figure 3). This shows that the trend of increasing rate of hospitalisation as BMI increased from normal weight to severely obese was apparent regardless of history of prior serious illness, smoking status or physical activity level. These trends remained in the Cox regression analyses, following adjustment for potential confounding factors, and there was no significant difference in the relationship between BMI and hospitalisation in any sex/age group examined, except amongst males aged 45–64 (p(interaction)=.002), where the strength of the relationship was weaker among current smokers than past or never smokers (RRs per 1kg/m² increase in BMI where BMI>20kg/m² of 1.02 (1.01–1.03), 1.04 (1.03–1.05) and 1.04 (1.04–1.05), respectively), and amongst males aged 80+, where the effect size was stronger in those with high than lower levels of physical activity (RRs per 1kg/m² increase in BMI where BMI>20kg/m² of 1.00 (0.98–1.01), 1.02 (1.01–1.03) and 1.04 (1.02–1.05), in lowest, middle and top tertile of physical activity respectively).

The rates of hospitalisation due to specific diagnoses in overweight and obese individuals, relative to those of normal weight ($18 < 25 \text{ kg/m}^2$), are presented in Table 3 for the three age groups (males and females combined). For most diagnoses there was an increased risk of hospitalisation associated with obesity and to a lesser extent overweight, with effect sizes generally weaker with increasing age. The diagnoses for which these relationships were particularly strong—i.e. where the effect sizes were at least moderate, showed a gradient from overweight to obese and were evident in both younger and older age groups—included diabetes, ischaemic heart disease, chest pain, diverticular disease, gallbladder disease, osteoarthritis, asthma (excluding 65–79 year age group), sleep apnoea, and cellulitis. Risks were also elevated in the 45–64 year old age group for atrial fibrillation and cerebrovascular disease, as well as for depression (a non-significant reverse trend was shown in the older people) and prolapsed uterus. Overweight/obesity appeared to be protective for two conditions—hernia and fracture (particularly in the 80+ age group).

Discussion

The risk of hospitalisation rises gradually with increasing above-normal BMI, in both men and women. This pattern of increasing risk is evident among past, current and never smokers and among both physically active and inactive people. The relative risks of hospitalisation associated with above-normal BMI are highest among younger mid-age adults (45–64 years), with the risk of hospitalisation amongst those with a BMI $> 35 \text{ kg/m}^2$ approximately double that of those with BMI $20\text{--}22.5 \text{ kg/m}^2$. Relative risks are not as high in older mid-age people (65–79 years) but are still substantial, while the pattern of increasing relative risk of hospitalisation with increasing above-normal BMI is fairly weak in older people (80 years and older). The increased

257 risk of hospitalisation associated with overweight and, to a greater extent, obesity is evident for
258 a large range of conditions in all age groups, including those aged 80 years or more.

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260 Causality between BMI and hospitalisation cannot be confirmed in this study. However, the
261 dose-response relationship between BMI and hospitalisation amongst those with a BMI $\geq$ 25
262 kg/m², which remained after adjusting for a range of important confounders and after
263 stratification for smoking and physical activity, and which was evident for a large range of
264 causes consistent with previous evidence,⁴ supports a causal relationship. Together with the
265 knowledge that hospitalisation is a costly and not uncommon event, and that there is a high
266 prevalence of overweight and obesity in the population (in Australia, 40% of people aged 45 and
267 over are overweight and 30% are obese²²), the findings indicate that overweight, not just
268 obesity, is a substantial contributor to health service use and health costs in the population.

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270 The findings of increasing risk of hospitalisation with increasing BMI are broadly consistent with
271 other studies, which have shown that obesity, but less consistently overweight, is associated
272 with increased rates of hospitalisation, in either the shorter or longer term.⁵⁻¹¹ It is also broadly
273 consistent with findings of stronger associations amongst mid-age than older people in some
274 studies,^{9,11} although others have found no clear patterns with respect to age.⁶ While caution
275 should be applied in interpreting the absolute value of BMI at which risk increases, the level at
276 which risk of hospitalisation was lowest in this study—20–<25 in men and 18.5–<25kg/m² in
277 women—is also consistent with these previous studies, as well as with studies on BMI and
278 incidence of disease⁴ and all-cause mortality.^{2,3} That risks were lowest in these ranges is also
279 concordant with the WHO definition of 18.5–<25 kg/m² being in the 'normal' range, with the
280 exception that in our study risk was actually elevated in the low normal weight range (18.5–<20
281 kg/m²) among the younger men. This may partly reflect reverse causality due to pre-existing

disease, as hospitalisation rates were not elevated in this low normal weight range amongst people without serious pre-existing disease.

We found overweight, and to a greater extent, obesity is associated with an increased risk of hospitalisation for a heterogeneous range of conditions. These included potentially life-threatening diseases such as cardiovascular disease, stroke (in younger obese men), diabetes and asthma, and also common, high-cost and high-morbidity conditions, such as osteoarthritis, diverticular disease, dorsopathy, gallbladder disease, sleep apnoea and uterine prolapse. Although we also found above-normal BMI is associated with a reduced risk of hernia and fracture, particularly in the older age group, the sum total of the relationship between BMI and hospitalisation is adverse. While the association between obesity and most of these conditions is fairly well established^{4,23-31} their investigation in a single population-based dataset is relatively novel and allows both a general perspective on the conditions associated with both obesity and overweight, as well as insights into the diagnoses underlying the observed elevation in overall hospitalisation rates.

The 45 and Up Study is an order of magnitude larger than previous studies investigating the relationship of BMI to hospitalisation, enabling the risks associated with small incremental changes in BMI to be examined. This is particularly useful as dose-response relationships can provide a good indication of the magnitude of risk and likely causality. The inclusion of individuals aged over 80 also meant that we had the power to examine variations in risk in the very old, an increasingly important group as the population ages, yet one which is often excluded (or at best aggregated) in population health studies. Another advantage of the study was the ability to link to administrative records, allowing virtually complete, and objective, ascertainment of outcomes over time. Use of hospitalisation records meant we could capture the risks of both fatal and non-fatal serious diseases associated with BMI. The ability to link

these records to survey data meant that we were able to adjust for a range of factors other than BMI that might influence hospitalisation.

A limitation of our study is that BMI was the only anthropometric measure available and this measurement was based on self-reported weight and height at recruitment. It is well established that people tend to underestimate their weight and overestimate their height (and hence their BMI).³² However, consistent with other studies, a validation study involving participants in the 45 and Up Study revealed that the mean difference between self-reported and measured BMI was not large (on average -0.74kg/m^2) and correlations between self-reported and measured height and weight were 0.95 and 0.99, respectively.³³ This means that self-reported data are useful for research investigating the relative risks of disease and other health outcomes comparing incremental changes in BMI, and although bias in the relative risk estimates cannot be ruled out, a recent study using NHANES data showed that mortality relative risks based on self-reported BMI data were for the most part not significantly different from those based on measured BMI.³⁴ Further, BMI was only measured at one point in time, which does not take into account duration of obesity—this may enhance risk estimates over and above BMI level alone.³⁵ Another limitation is that, like most population-based cohort studies, response rates were relatively low and the potential for a ‘healthy cohort effect’ means that the estimates of relative risks shown here are likely to be conservative. We estimated the age-adjusted total hospitalisation rates (excluding day-admissions) in the 45 and Up cohort (233 and 217 per 1,000 person years for males and females respectively) and found these were only 11–12% lower than for the rates in the Australian population of the same age (respectively, 263 and 246 per 1,000 person years).³⁶ Moreover, it is important to note that relative risks, comparing groups *within* the cohort, remain valid and can be generalised more broadly.^{37,38}

It is evident from this and previous research that overweight and obesity is associated with an increase in the risk of hospitalisation across a large range of diagnoses. While it is reasonable to attribute at least part of the increased risk to increased adiposity, some caution should be applied. First, BMI is an imperfect measurement of adiposity and in different populations such as the young fit men with high muscle mass or the elderly, BMI alone may not be a good measure of adiposity. Second, although longitudinal in design, we cannot totally disentangle the effects of complex disease pathways, and in particular reverse causality. The effect of disease on subsequent weight loss is especially an issue for cancer-related diagnoses, although the relationship between BMI and hospitalisation remained even when those with a diagnosis of cancer and other serious illness prior to entry into the study were excluded, and also when the first year of follow-up was excluded. Any such reverse causality may lead to an underestimate of the effect of above-normal weight on hospitalisation. It can also lead to an overestimate of the effect of underweight and these effects are observed in studies with longer follow-up.^{2,3} In some cases, reverse causality may also work in the opposite direction, leading to an overestimation of effects. For example, with sleep apnoea not only has obesity been linked to an increased risk of developing this condition, but sleep apnoea can also lead to an increase in obesity.²⁸ Even the relationship between obesity and cardiovascular disease is complex and not limited to the standard risk factors such as hypertension, dyslipidemia and diabetes.¹⁰ Some studies on BMI and hospitalisation adjust for pre-existing disease (such as cardiovascular disease and diabetes) to limit the possibility of reverse causality, but as pre-existing disease may lie on the causal pathway between above-normal BMI and hospitalisation, adjusting for these diseases could constitute over-adjustment and inappropriately attenuate risks.

While previous studies have adjusted for smoking, there are concerns that because smoking is so strongly associated with illness, and also BMI, and the amount of smoking may be imperfectly measured, that simple adjustment for smoking is insufficient. By stratifying our

results according to smoking, we were able to show clearly the risks of hospitalisation associated with BMI independently from smoking status. Similarly, the relationship between physical activity, BMI and hospitalisation is complex, and by stratifying by physical activity we were able to show the effect of BMI on hospitalisation was evident regardless of physical activity level. That this finding was shown to hold even in the inactive population is important, as BMI as a measure of adiposity is most valid in this population.³⁹

It is unclear why the strength of the association between BMI and hospitalisation declines with increasing age; there are a number of possible explanations. First, in elderly people, BMI may not be a good measure of adiposity because as one ages, height decreases, and lean body mass decreases and adipose tissue increases without weight gain, with the possible development of sarcopenic obesity.⁴⁰ There is also a greater probability of reverse causality because older people have a greater number of health conditions that result in weight loss. Second, a likely contribution to the decline in the association between BMI and hospitalisation with age is the survival effect, as those with higher BMIs and/or those most susceptible to the effects of BMI on health may have already died. Third, it may be possible that being overweight in later life confers a genuine health benefit, as frailty and underweight become increasingly important contributors to ill health. Finally, the number of people in the oldest age group, particularly those with high BMIs, is limited, resulting in reduced power in the elderly. Importantly it should be kept in mind that while relative risks were lower in older than younger people, this may not necessarily translate to a lower absolute burden of hospitalisation attributable to overweight/obesity in older people than younger people; burden must also take into account the age-specific prevalence of overweight and obesity in the population (which is lowest in those age 80+) and the absolute rates of hospitalisation (which are highest amongst those aged 80+).

There has been some uncertainty about the relationship between BMI and risk of disease and hospitalisation, in particular regarding the level of BMI at which risk starts to increase in the population, and whether the risk associated with obesity persists in the elderly. The incremental nature of the increasing risk of hospitalisation above the normal range of BMI found in this study shows that at the population level, even mild overweight increases risk, especially amongst those aged below 80 years of age. That a dose-response relationship was found after adjustment for a range of important confounders gives strength to the argument that above-normal BMI is causally linked to many diseases. The findings suggest that, all else being equal, populations with even a minor difference in the BMI distribution toward lower values could have substantially lower hospitalisation rates.

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Conflicts of interests: None to declare.

Supplementary Material: Supplementary information is available at International Journal of Obesity's website.

Data sharing: The 45 and Up Study is an accessible data resource for approved research projects; see www.45andUp.org.au for details.

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Figure Legends

Figure 1. Age-standardised incident hospitalisation rates by body mass index (BMI)

Figure 2. Age-standardised incident hospitalisation rates (with 95% CI) by body mass index (BMI), stratified by sex and age group

Figure 3. Age-standardised hospitalisation rates by body mass index (BMI), stratified by (a) prior history of serious illness; (b) smoking status and (c) tertile of physical activity

Table 1. Characteristics of the study population (%)¹ by category of body mass index (BMI)

	BMI Category									Total sample	
	Under-weight	Normal weight				Overweight		Obese			
	15-<18.5	18.5-<20	20-<22.5	22.5-<25	25-<27.5	27.5-<30	30-<32.5	32.5-<35	35-50		
n	3 107	6 834	30 180	53 756	55 694	41 740	25 544	13 773	15 733	246 361	
% of total	1.3	2.8	12.3	21.8	22.6	16.9	10.4	5.6	6.4	100	
Male	24.9	22.2	32.0	45.5	55.1	56.9	51.3	46.0	35.1	47.0	
45-64 yrs	49.6	60.1	61.9	59.3	59.8	61.8	64.6	66.9	72.9	61.9	
65-79 yrs	26.0	23.0	24.4	28.5	30.4	30.7	29.0	28.2	23.8	28.3	
80 yrs	24.4	16.9	13.7	12.2	9.9	7.6	6.4	4.9	3.3	9.8	
Lives in major city	48.1	50.6	48.9	47.7	45.3	43.5	42.4	40.5	39.4	45.2	
Income >=\$70K ²	17.2	28.2	30.7	31.9	32.5	31.5	29.2	27.9	25.0	30.6	
University degree	21.1	27.1	28.5	27.3	24.9	22.2	19.9	17.7	16.3	24.0	
Health insurance ³	56.2	62.6	66.4	67.7	67.9	66.6	64.2	61.2	56.5	65.7	
High PA ⁴	37.6	38.3	40.2	38.5	36.2	33.1	29.6	26.7	22.6	34.7	
Current smoker	16.6	11.0	9.1	7.2	6.3	6.3	6.7	7.1	7.3	7.2	
Alcohol 15+ p/w ⁵	9.0	8.6	10.5	13.6	16.6	17.5	16.5	15.2	10.8	14.6	

Note. 1. Percentage of sample within BMI category unless indicated otherwise; participants with missing values are not included in the percentages (% missing: area=0.1%; income=20.9%; education=1.4%; physical activity=1.9%; smoking=0.3%; alcohol=1.9%; other variables=0 missing); percentages may not total 100 due to rounding. 2.

Annual pre-tax household income in Australian dollars. 3. Includes private health insurance or Department of Veterans Affairs health card. 4. Top tertile of physical activity.

5. 15 or more alcoholic drinks per week.

Table 2. Adjusted relative risks (RR)¹ of hospitalisation by body mass index (BMI), stratified by sex and age group

BMI	45-64 years					65-79 years					80 years or older				
	n ⁽²⁾	py	RR	95% CI	p	n ⁽²⁾	py	RR	95% CI	p	n ⁽²⁾	py	RR	95% CI	p
Males															
15-<18.5	77	693	1.26	0.99–1.59	.056	90	346	1.36	1.10–1.69	.005	140	299	1.34	1.10–1.64	.003
18.5-<20	140	1510	1.19	0.99–1.42	.063	161	762	1.14	0.96–1.35	.125	204	555	1.10	0.94–1.29	.238
20-<22.5	740	9916	1.00	–	–	990	5490	1.00	–	–	1056	3175	1.00	–	–
22.5-<25	2045	26905	1.04	0.96–1.14	.322	2587	14817	0.99	0.92–1.06	.688	1885	6002	0.97	0.90–1.06	.507
25-<27.5	3024	36149	1.13	1.05–1.23	.002	3405	18463	1.05	0.98–1.13	.163	1642	5138	1.01	0.93–1.10	.814
27.5-<30	2673	29218	1.21	1.12–1.32	<.001	2671	13762	1.10	1.02–1.19	.009	949	2791	1.05	0.96–1.16	.279
30-<32.5	1776	16578	1.38	1.27–1.50	<.001	1529	6947	1.26	1.17–1.37	<.001	458	1243	1.13	1.00–1.27	.048
32.5-<35	960	8132	1.49	1.35–1.64	<.001	733	3278	1.28	1.16–1.41	<.001	172	424	1.29	1.08–1.53	.004
35-50	1088	7288	1.86	1.69–2.05	<.001	639	2464	1.48	1.34–1.64	<.001	93	249	1.17	0.94–1.46	.157
Trend ³			1.04	1.03–1.04	<.001			1.03	1.02–1.03	<.001			1.01	1.00–1.01	.033
Females															
15-<18.5	178	2564	1.06	0.91–1.24	.434	200	1100	1.22	1.05–1.42	.010	280	781	1.13	0.99–1.29	.072
18.5-<20	433	7120	0.99	0.89–1.10	.868	320	2172	1.04	0.92–1.18	.519	396	1212	1.08	0.96–1.21	.209
20-<22.5	1802	29685	1.00	–	–	1208	8540	1.00	–	–	997	3315	1.00	–	–
22.5-<25	2649	40384	1.05	0.99–1.12	.087	1985	14276	1.00	0.93–1.07	.991	1283	4484	0.99	0.91–1.07	.789
25-<27.5	2490	33162	1.18	1.11–1.25	<.001	1906	13081	1.04	0.97–1.12	.279	1019	3572	0.99	0.91–1.08	.812
27.5-<30	2063	23178	1.38	1.30–1.47	<.001	1559	9661	1.16	1.08–1.25	<.001	664	2108	1.11	1.00–1.22	.046
30-<32.5	1673	16459	1.55	1.45–1.65	<.001	1073	6245	1.22	1.13–1.33	<.001	388	1221	1.11	0.99–1.25	.078
32.5-<35	1159	9939	1.76	1.63–1.90	<.001	683	3505	1.39	1.27–1.53	<.001	181	590	1.06	0.91–1.25	.458
35-50	2021	14432	2.09	1.96–2.23	<.001	864	3896	1.61	1.47–1.76	<.001	182	493	1.31	1.12–1.54	.001
Trend ³			1.04	1.04–1.05	<.001			1.03	1.03–1.04	<.001			1.01	1.01–1.02	.001

Notes. 1. Adjusted for age, region of residence, household income, smoking, alcohol intake and private health insurance status. 2. n refers to number of incident hospitalisations; py=person years. 3. Trend: Test for trend where BMI>20kg/m²; RR refers to the increase in rate per 1kg/m² increase in BMI.

Table 3. Adjusted relative risks of diagnosis-specific hospitalisation by BMI category, by age group, males and females combined

	45–64 years			65–79 years			80 years or older		
	No. events norm/ow/ob ²	Relative Risks ¹ (95% CI)		No. events norm/ow/ob ²	Relative Risks ¹ (95% CI)		No. events norm/ow/ob ²	Relative Risks ¹ (95% CI)	
		Overweight	Obese		Overweight	Obese		Overweight	Obese
Diabetes (E10–E14)	49/77/191	1.27 0.89–1.82	4.35 3.16–5.98	83/180/196	1.72 1.32–2.23	3.76 2.90–4.88	93/103/43	1.45 1.09–1.92	1.94 1.34–2.80
Circulatory diseases									
Ischaemic heart disease (I20–I25)	340/715/609	1.54 ⁸ 1.35–1.75	2.12 ⁸ 1.85–2.43	688/1071/603	1.19 1.08–1.31	1.45 1.30–1.62	564/469/157	1.10 0.97–1.24	1.23 1.03–1.47
Atrial fibrillation (I48)	121/215/174	1.37 1.09–1.72	1.84 1.45–2.33	271/344/206	1.07 0.91–1.26	1.33 1.11–1.60	275/203/71	1.04 0.87–1.25	1.15 0.88–1.50
Cerebrovascular disease (I60–I69, G45, G46)	149/185/153	1.00 0.80–1.25	1.31 1.04–1.66	381/428/210	0.91 0.79–1.05	0.96 0.81–1.15	464/329/98	0.99 0.86–1.14	0.97 0.78–1.21
Chest pain (R07, excl. R07.0)	363/594/542	1.48 1.29–1.69	1.99 1.74–2.28	345/537/337	1.26 1.10–1.45	1.52 1.31–1.77	231/198/70	1.13 0.93–1.36	1.23 0.94–1.62
Respiratory diseases									
Coronary obstructive pulmonary disease (J41–J44)	84/89/105	0.94 0.70–1.27	1.31 0.98–1.76	245/189/178	0.60 0.49–0.72	1.05 0.86–1.28	230/177/64	0.98 0.81–1.20	1.13 0.85–1.49
Asthma (J45–J46)	24/52/70	2.30 1.41–3.75	3.97 2.48–6.36	30/28/32	0.84 0.50–1.41	1.64 0.98–2.73	13/15/11	1.69 0.80–3.56	3.06 1.35–6.94
Pneumonia (incl. influenza) (J09–J18)	153/205/191	1.12 0.90–1.39	1.49 1.19–1.85	275/315/195	0.89 0.76–1.05	1.11 0.92–1.34	418/250/95	0.83 0.71–0.97	1.04 0.83–1.30
Digestive diseases									
Diverticular disease (K57)	77/118/126	1.42 1.06–1.90	2.18 1.63–2.91	87/124/105	1.20 0.91–1.58	1.97 1.47–2.63	71/71/26	1.40 1.01–1.95	1.57 1.00–2.48
Gallbladder disease ³ (K80)	219/350/375	1.71 1.44–2.03	2.87 2.42–3.40	134/257/137	1.67 1.35–2.06	1.84 1.45–2.35	89/89/30	1.41 1.05–1.90	1.43 0.94–2.17
Hernia	327/380/134	0.71	0.48	354/396/74	0.76	0.34	187/113/15	0.72	0.36

(K40)		0.61–0.82	0.39–0.59		0.66–0.88	0.26–0.44		0.57–0.92	0.21–0.61
Musculoskeletal diseases									
Osteoarthritis	383/745/929	1.67	3.32	563/1124/822	1.69	2.59	307/332/122	1.46	1.67
(M15–M19; M47)		1.47–1.89	2.94–3.75		1.53–1.88	2.32–2.89		1.25–1.71	1.35–2.07
Dorsopathy	286/418/360	1.31	1.73	276/408/232	1.24	1.45	200/189/70	1.36	1.56
(M40–M54)		1.12–1.52	1.47–2.02		1.07–1.45	1.21–1.73		1.11–1.66	1.19–2.06
Soft tissue disorders	290/460/427	1.29	1.90	185/319/192	1.33	1.66	68/61/18	1.19	1.14
(M60–M79)		1.11–1.50	1.63–2.21		1.11–1.59	1.35–2.04		0.84–1.68	0.67–1.93
Cancer									
Any cancer (excl. skin)	823/972/639	1.00	1.03	877/1130/569	0.99	1.07	611/481/143	1.05	1.04
(C00–C97, excl C43–C44)		0.91–1.10	0.93–1.14		0.91–1.09	0.96–1.19		0.93–1.18	0.87–1.25
Any cancer — excl. previous ⁴	610/737/490	1.04	1.10	602/798/428	1.05	1.20	431/325/103	1.03	1.09
		0.93–1.16	0.97–1.24		0.94–1.17	1.06–1.36		0.89–1.20	0.87–1.35
Other									
Sleep Apnoea	134/341/421	2.07	4.62	62/169/175	1.95	4.99	25/40/18	1.98	3.47
(G47.3)		1.69–2.54	3.79–5.62		1.45–2.61	3.71–6.69		1.19–3.28	1.88–6.42
Cellulitis	83/140/189	1.41	2.94	104/158/156	1.23	2.55	144/124/62	1.23	1.94
(L03)		1.07–1.86	2.26–3.82		0.96–1.58	1.98–3.28		0.97–1.57	1.44–2.63
Depression	95/101/105	1.06	1.60	48/46/27	0.80	0.87	33/19/6	0.79	0.72
(F32–F33)		0.80–1.41	1.21–2.12		0.53–1.20	0.54–1.41		0.45–1.39	0.30–1.74
Fracture	424/427/255	0.92	0.85	426/372/191	0.83	0.80	653/302/85	0.69	0.58
(ICD codes – see note ⁵)		0.80–1.05	0.72–0.99		0.72–0.95	0.67–0.95		0.61–0.80	0.46–0.73
Benign prostatic hyperplasia ⁶	99/167/113	0.95	1.24	219/309/135	0.94	1.04	126/97/26	0.95	1.00
(N40)		0.74–1.22	0.94–1.63		0.79–1.12	0.83–1.29		0.73–1.25	0.65–1.54
Prolapse of the uterus ⁷	163/172/118	1.44	1.36	84/112/61	1.50	1.37	20/15/4	1.13	0.74
(N81)		1.16–1.78	1.07–1.74		1.13–2.00	0.98–1.92		0.57–2.22	0.25–2.18

Notes. 1. Adjusted for sex, age, region of residence, household income, smoking, alcohol intake and private health insurance status; reference group is normal weight (20–25 kg/m²). 2. No. events=total diagnosis-specific incident hospitalisations in that age group for normal/overweight/obese. 3. Excludes those who reported at baseline having had their gallbladder removed. 4. Excludes participants with diagnosis of cancer on cancer registry prior to enrolment in study. 5. ICD codes for fracture: S02, S12, S22.0, S22.1, S22.2, S22.3, S22.4, S22.8, S22.9, S32, S42, S52, S62, S72, S82, S92, T02, T08, T10, T12, T14.26. 6. Excludes women and those who reported at baseline having

had a partial or total prostatectomy. 7. Excludes men and those who reported at baseline having had a hysterectomy. 8. Proportional hazards assumption not satisfied, but was when males and females analysed separately, with HRs for overweight and obese in males being 1.50 (95%CI: 1.28–1.76) and 2.08 (1.76–2.46) and for females 1.55 (1.23–1.96) and 2.09 (1.66–2.62).

Figure 1. Age-standardised incident hospitalisation rates by body mass index (BMI)

Notes. 1. Median BMI of each category. 2. Test for trend where BMI>20kg/m², $p < 0.001$ for both males and females .

Figure 2. Age-standardised incident hospitalisation rates (with 95% CI) by body mass index (BMI), stratified by sex and age group

MALES

FEMALES

Notes. 1. Median BMI of each category. 2. Test for trend where BMI>20kg/m². 3. Different scales used across age groups.

Figure 3. Age-standardised hospitalisation rates (with 95% CI) by body mass index (BMI), stratified by (a) prior history of serious illness; (b) smoking status and (c) tertile of physical activity

(a) Stratified by prior history of prior serious illness

(b) Stratified by smoking status

(c) Stratified by physical activity

◆ Tertile 1- low ■ Tertile 2 ▲ Tertile 3 - high

Notes. 1. Median BMI of each category. 2. Prior serious illness includes circulatory disease, diabetes, coronary obstructive pulmonary disease and cancer. 3. Test for trend where BMI>20kg/m², p<0.001 for all strata of illness, smoking and physical activity, in both males and females.