# *What is a healthy body mass index for women in their seventies? Results from the Australian Longitudinal Study on Women's Health*

# What is a Healthy Body Mass Index for Women in their Seventies? Results from the Australian Longitudinal Study on Women's Health

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## ABSTRACT

**Background:** This study examines the relevance of the World Health Organization (WHO) optimal range for body mass index (BMI) of 18.5-25 kg/m$^2$ to morbidity in older women.

**Methods:** Data were from 11,553 women who completed five mailed surveys at three year intervals between 1996 (age 70-75 years) and 2008 (age 82-87 years). Incidence and prevalence of diabetes mellitus (DM), hypertension, heart disease and osteoporosis; hospital admissions and mortality were assessed. The association between BMI in 1996 and each outcome was examined using logistic regression models with repeated measures and a proportional hazards model for survival.

**Results:** There were consistent associations between increasing BMI and increasing incidence and prevalence of DM, hypertension and heart disease, and between increasing BMI and decreasing risk of osteoporosis. The association with hospital admission was J-shaped and lowest for BMI of 22-24 kg/m$^2$ while the association with mortality was U-shaped, being lowest for BMI of 25-27 kg/m$^2$. These associations were not affected by excluding women with cancer, or excluding the first five years of follow up.

**Conclusion:** These results illustrate the complexity of determining the optimal BMI range for women who survived to age 70 to 75 years. Although the WHO recommendation is appropriate for DM, hypertension, heart disease and hospitalization, a slightly higher BMI range may be optimal for osteoporosis and mortality.

## INTRODUCTION

Current World Health Organization (WHO) recommendations advise a body mass index (BMI) range of 18.5 to 25 $kg/m^2$ for optimal health in adults aged 18+ years (1). While the WHO separately addresses the health consequences of overweight and obesity in childhood and adolescence and in adults, there are no distinctions for young, mid-aged or older adults. As older adults have already survived to a greater age, the optimal BMI-range for adults aged 18+ years may be less relevant for older people, for example as a result of survival effects (2;3). Several papers and systematic reviews have recently shown that, in older people, BMI in the range of 25-30 $kg/m^2$ is not associated with higher mortality risk compared with ‘normal BMI’ (18.5-25 $kg/m^2$) and may even have a protective effect (4-8). However, in other studies, BMI in the ‘overweight’ (25-30 $kg/m^2$) and ‘obese’ (>30 $kg/m^2$) range has been shown to be associated with *increased* risk of frailty and chronic conditions, disability and health complaints in older people (3;9-13). Therefore, in older adults (defined in this paper as 70+ years) the patterns of association between BMI and several outcomes that are of importance for health may not be as clear as in younger populations.

The Australian Longitudinal Study on Women's Health (ALSWH) is one of few studies worldwide that includes a large population based sample of women who were aged 70 to 75 years at the start of the study in 1996. This paper examines the relationships between BMI in 1996 and incidence and prevalence over a twelve year follow-up period of four chronic conditions that are common in older women: DM, hypertension, heart disease and osteoporosis. The aim of this study was to examine the relevance of the World Health Organization (WHO) optimal body mass index (BMI) range of 18.5-25 $kg/m^2$ to morbidity in this sample. The associations between BMI and hospital admission and BMI and mortality are also examined, in order to provide a broad view of associations between BMI and health outcomes.

## METHODS

### Setting

The Australian Longitudinal Study on Women's Health (ALSWH) is a prospective study of factors affecting health and wellbeing in three cohorts of Australian women. The women were randomly selected from the national Medicare health insurance database, which includes all citizens and permanent residents of Australia. There was intentional over-sampling of women living in rural and remote areas. Three cohorts were first surveyed in 1996: their ages were 18-23 (women born in 1973-1978), 45-50 years (women born in 1946-1951) and 70-75 years (women born in 1921-1926). Subsequently, the three cohorts have been resurveyed by mail every three years. Details of the study design, recruitment methods and response rates have been described elsewhere (14;15) and more details about the study can be found at www.alswh.org.au. The study was approved by the ethics committees of the University of Newcastle and the University of Queensland and informed consent was received from all respondents. The focus of this study is on older women, who were surveyed in 1996 (survey 1, number of respondents=12432), 1999 (survey 2, n=10434), 2002 (survey 3, n=8646), 2005 (survey 4, n=7158), and 2008 (survey 5, n=5559). Only women who reported height and weight in survey 1 were included in the analysis (n=11553). A summary of attrition at each survey is provided in Table 1. Sociodemographic factors, health related behavioral factors and indicators of health status of this population have been described elsewhere (14).

**BMI, smoking, chronic conditions, hospital admission and mortality**

BMI ($kg/m^2$) was calculated using self-reported weight and height. Self-reported smoking status was categorized as never smoker, ex-smoker, or current smoker.

At survey 1, women were asked 'Have you ever been told by a doctor that you have: diabetes (high blood sugar)/…hypertension (high blood pressure)/…heart disease/…osteoporosis?' At subsequent surveys, women were asked if they had been diagnosed with or treated for any of these conditions in the last 3 years. At surveys 3, 4 and 5 women were asked if they had angina/ heart attack/ other heart problems. For the present analysis these conditions were grouped as 'heart disease'. Incidence of each condition was defined as reporting the condition at surveys 2, 3, 4 or 5 by women who did not have the condition at any previous survey. For analysis of prevalence, each condition was defined as occurring only once and remaining until the end of the study (or death, withdrawal, or non-participation). Women who reported chronic conditions at survey 1 were included in the analyses of prevalence but not incidence. Data from women with multiple conditions were included in the analyses for each condition they reported.

At each survey women were asked to report how many times they had been admitted to hospital in the last 12 months. At each survey, the outcome was dichotomized as hospital stay of one day or longer vs. no hospital stay.

The ALSWH data are linked to Australian National Death Index (NDI) to identify all deaths on an annual basis, NDI data were available from 1996 to October 2006, with the main underlying and additional causes of death coded using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) (16). The sensitivity of the NDI for identifying known deaths between 1996 and 1998 in this ALSWH cohort was 95% (17). Cause of death data were used to supplement self-reported data on chronic conditions from 1997 onwards. For example, if a study participant died of a myocardial infarction, or had heart disease recorded among the causes of death between surveys 2 and 3, but did not report having any heart problem at or before survey 2, then ‘heart disease’ was imputed at survey 2. The following ICD-10 codes were used for each condition: a) diabetes mellitus: E10-14; b) hypertension: I10-15; c) heart disease: I20-25 (ischaemic heart disease); I30-52 (other forms of heart disease); and d) osteoporosis: M80-82.

**Statistical analysis**

The analyses were conducted using SAS software, Version 9. Logistic regression models (with the generalized estimating equation procedure for repeated measures) were used to model the association between baseline BMI in 1996 and incidence and prevalence of each chronic condition, and between baseline BMI and hospital admission. For analysis of incidence, the outcome was the proportion of newly reported cases by women who had not previously reported the condition. Data from surveys 2, 3, 4 and 5 were analyzed together using repeated measures models. For analysis of prevalence, the outcome at each survey was the proportion of respondents who had ever reported the condition and data from all five surveys were the repeated measures. For the analysis of hospital admissions, the outcome at each survey was the proportion of respondents who reported a hospital stay of at least one day in the last 12 months and data from all five surveys were the repeated measures. Baseline BMI and age at each survey were included in the model, as well as the square and cube of these variables. Smoking status in 1996 was also included. Model covariates were selected in a stepwise fashion using backward elimination: covariates statistically significant at $p<0.05$ were retained in the adjusted multivariable model. To obtain estimates of incidence and prevalence rates, fitted values were calculated using the coefficients from the logistic regression models with BMI values in the range 18 to 35, age equal to 78.5 years, and smoking status (if smoking status was statistically significant in the multivariable model). The fitted values, which were on the logit scale, were back transformed and scaled to give estimated annual rates for each BMI value. These rates were plotted against BMI, with separate curves for each smoking category if smoking status was statistically significant.

For women who died during the study, lifespan was calculated as the difference between year of death and year of birth. For other women, data were right-censored at the end of the study period (or at the date of withdrawal or non-participation for those women still alive in January 2009). A proportional hazards model was used to estimate hazard ratios of death in relation to age, BMI and smoking at baseline.

To take into account a possible confounding effect of cancer on the association between BMI and outcome measures, all analyses were repeated excluding women who (at any survey) reported having been told by a doctor that they had cancer (other than skin cancer) and women who died and had ‘malignant neoplasm’ listed in their causes of death. In total 9315 women were included in the analysis of women without cancer. Furthermore, to account for pre-existing disease at the start of the study, the mortality analysis was repeated excluding the first five years of follow-up (only 2001-2008 data were included).

## RESULTS

The distribution of BMI in all survey 1 respondents (1996) is shown in Figure 1. Median BMI (25–75 percentiles) was 24.8 (22.3 – 27.7) kg/m$^2$. Prevalence and incidence of the four chronic conditions per three years over the twelve year follow-up period are reported in Table 2. The number of incident cases over 12 years was 790 for DM, 1981 for hypertension, 2278 for heart disease and 1813 for osteoporosis. Of the 11553 women included in this study, 56% never smoked, 27% were ex-smokers, 7% were current smokers and data about smoking status were missing for 10% of the women.

Incidence and prevalence rates for the four conditions, as a function of BMI in 1996, are shown in Figure 2. Higher BMI was associated with higher incidence and prevalence for DM and hypertension. While the incidence and prevalence of hypertension flattened out for BMI ≥30 $kg/m^2$, incidence and prevalence of DM increased markedly in women with a BMI ≥30 $kg/m^2$; for example, DM prevalence ranged from 6% to 13% in women in the healthy BMI-range, whereas it ranged from 20% to more than 30% in women with a BMI of 30 $kg/m^2$ and higher. Remarkably, although prevalence of hypertension was higher for smokers than for ex-smokers, the highest prevalence was reported by women who never smoked. The rates for heart disease also increased with increasing BMI, but less sharply, and there were marked differences in rates according to smoking status, with the lowest incidence and prevalence in never smokers.

There was an inverse association between BMI and osteoporosis, with the lowest risk of osteoporosis in women with a BMI ≥30 $kg/m^2$. For example, the incidence of osteoporosis for women with a BMI of 30 $kg/m^2$ was 27/1000 women/year, compared with 44 to 31/1000 women/year for women with a BMI between 18.5 and 25 $kg/m^2$. Prevalence of osteoporosis was lower in women who never smoked than in smokers and ex-smokers.

The association between BMI and hospital admission in the last 12 months was J-shaped, with lowest rates in the BMI range 22 to 24 $kg/m^2$ (Figure 3). The risk of hospital admission was lowest in women who never smoked. Regardless of smoking status, hospital stay increased markedly for women with BMI≥25 $kg/m^2$.

During the 12 year follow-up 3143 of the 11553 women included in this study died, representing 31.6 deaths/1000 person-years. The association between BMI and mortality was U-shaped, with the lowest risk of mortality for BMI between 25 and 27 kg/m$^2$ **(Figure 4)**. Smokers were at much higher risk of death than ex-smokers or women who had never smoked.

Excluding women with cancer did not result in changes in the association between BMI and incidence and prevalence of chronic disease, or BMI and mortality, but the higher risk of hospital admission in women in the BMI-range of 18.5 to 22 leveled out. Excluding the first five years of follow-up did not affect the BMI range associated with lowest mortality.

## DISCUSSION

It is predicted that there will be marked increases in burden of disease and demands on health care systems as a result of the growing percentage of overweight and obese older women in the population (2;18-20). If this increase is to be prevented, it is important to understand the associations between BMI and health in this population group, and to be clear about the advice given to older women about reducing risk of ill health. The results of this study illustrate that this is not an easy task in the case of BMI. The risks of DM, hypertension and heart disease increased with increasing BMI, with the lowest risk in women with lowest BMI. In contrast, osteoporosis risk was lowest in women with high

BMI, and the relationship between BMI and hospitalization was J-shaped, with the lowest risk at BMI around 22-24 $kg/m^2$. The situation is complicated further by the fact that this study confirmed that, in older women, a BMI in the ‘overweight’ range had a protective effect on mortality.

A strength of this study is that it is one of few studies to examine the association between BMI and several different specific health outcomes, as well as hospital stay and mortality. The study involved a large nationally representative sample of community-dwelling older women, aged 70 to 75 years at the start of the study in 1996. They were surveyed five times from 1996 to 2008 and longitudinal analyses were performed using data from these five surveys. Another strength is that cause of death data from the national death index were used to supplement self-report data on chronic conditions, and additional analyses were performed to take account of the potential confounding effects of cancer.

This study also has several limitations. We examined the association between BMI, calculated using self-report weight and height data, and self-reported chronic conditions. Estimates of biases due to use of self-reported data vary. Studies in older people have shown that self-report of chronic disease is accurate when compared with information from their general practitioners (kappa [95% CI] = 0.69 [0.65-0.73] for cardiac disease and 0.85 [0.81-0.89] for DM) (21). There is also good agreement between self-report hospital stay and insurance claims for hospital stay in people aged 70+ years (kappa = 0.77) (22). Several studies have shown that objective measures of weight and height give BMI estimates that are higher than those calculated using self-reported data (23). For example, in US women (aged 60+ years) the difference was 1.05 $kg/m^2$ (95% confidence interval 0.96; 1.15) (24), and in Swedish women aged 70+ years it was 1.4 $kg/m^2$ (25). It is therefore expected that the curves in the graphs in this paper would have shifted one to one-and-a-half BMI units to the right if height and weight had been objectively assessed. This shift would mean, for example, that the optimal BMI range for hospitalization and mortality rates would be slightly higher, at 23-25 and 26-28 $kg/m^2$ respectively, but this shift does not change the interpretation of the morbidity graphs. Other factors such as the age of onset of obesity, number of years of obesity and weight development over the last decades, may be important in determining the association between BMI and morbidity and mortality (2;3). However, these data were not available in ALSWH, as data collection only began when the women were 70-75 years old. Finally, estimates of incidence of disease in older people are by definition limited to those who reached old age without ever having experienced the condition.

We used BMI as a measure of obesity. The validity of BMI as a measure of general obesity in older adults has been questioned, as fat distribution changes with age (3;26;27). However, even though the correlation between BMI and body fat decreases with age, this correlation remains reasonably strong in elderly people (28). Studies comparing different anthropometric measures of body fat have reported similar results for the association between BMI, waist circumference, and waist-hip ratio with incident DM and hypertension (29;30) and heart disease (28). Studies have shown, however, that the positive association between high BMI and mortality observed in older adults is diminished (31;32), or disappears, in very old age (5;6), possibly reflecting the fact that

BMI may not be a good measure of body fat in this population. Other researchers have suggested that waist-hip ratio alone (33), or in combination with BMI (34) is a better predictor of mortality in older people than BMI alone.

The morbidity results are in line with other studies in women, which have shown positive associations between BMI and incidence of DM, hypertension and heart disease (29;35;36) and negative associations between BMI and osteoporosis (28;29). These associations with particular conditions are potentially affected by confounding due to smoking. Risk of cardiovascular disease and several cancers is higher in current smokers and ex-smokers than among lifelong never smokers (37), but current smokers are also likely to weigh less, and ex-smokers to weigh more, than those who never smoked (38). Therefore it is possible that smoking might account for the left end of the J-shaped and U-shaped curves for composite outcomes of hospitalization and all-cause mortality. The higher prevalence of hypertension observed in women who never smoked was not expected. This finding may be due to a ‘healthy behavior’ bias: women who pursue a healthy lifestyle, such as not smoking, may be more likely to have their blood pressure checked regularly. As a result, there may be greater awareness of hypertension among non-smokers, even though the actual prevalence of hypertension may be greater among smokers.

A meta-analysis by the Prospective Studies Collaboration (PSC) published in 2009, which pooled mortality data from 57 prospective studies, reported that the lowest overall mortality risk in adults (both sexes and all ages) was in the BMI range of 22.5-25 $kg/m^2$

(31). The lowest mortality rate in women aged 70 to 79 years was, however, around a BMI of 26 kg/m$^2$ (31), which is within the ‘optimal BMI’ for mortality in our study.

Although we found lower risk of three conditions with low BMI, and it is accepted that intentional weight loss may benefit functional status and reduce risk of conditions such as cardiovascular disorders, diabetes and osteoarthritis (28;39), unintentional weight loss is not a good sign and warrants further examination (3;7). It has been suggested that, if weight loss advice is warranted, it should be accompanied by treatment for prevention of bone loss (28). Potential benefits of weight loss should be considered for each patient separately, taking their medical history into account (39-41). Future research in this area is needed and should focus on developing a knowledge base addressing the efficacy and safety of weight loss strategies in older people (26).

In conclusion, relationships between BMI and health in older women are complex. While the WHO recommendation is appropriate for DM, hypertension, heart disease and hospitalization, a slightly higher BMI range may be optimal for osteoporosis and mortality.

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**TABLE 1. Attrition between 1996 and 2008: numbers and percentages of women at each survey.**[a]

| Survey (year) | Ages (years) | Number of respondents (%)[b] | | Number of non respondents (%)[b] | | | |
|---|---|---|---|---|---|---|---|
| | | | | Deceased | Frail | Withdrawn | Did not do survey/ no contact |
| 1 (1996) | 70-75 | 11553 (100%) | | | | | |
| 2 (1999) | 73-78 | 9336 (84%) | | 494 (4%) | 92 (1%) | 523 (5%) | 1108 (10%) |
| 3 (2002) | 76-81 | 7986 (72%) | | 935 (8%) | 288 (3%) | 983 (9%) | 1361 (12%) |
| 4 (2005) | 79-84 | 6668 (60%) | | 1596 (14%) | 599 (5%) | 1334 (12%) | 1356 (12%) |
| 5 (2008) | 82-87 | 5208 (47%) | | 2358 (21%) | 882 (8%) | 1538 (14%) | 1567 (14%) |

[a] Only women who reported their height and weight at survey 1 are included; [b] Percentage of number of respondents in 1996

**TABLE 2. Prevalence of chronic conditions in 1996 and incidence per 3 years over a 12 year period.**[a]

| | | Diabetes mellitus Number[b] (%) | | Hypertension number[b] (%) | | Heart disease Number[b](%) | | Osteoporosis number[b] (%) | |
|---|---|---|---|---|---|---|---|---|---|
| Survey 1 (1996) | Condition reported | 962 | (9) | 5233 | (47) | 1952 | (18) | 2183 | (20) |
| | Condition not reported | 10117 | (91) | 5831 | (53) | 9082 | (82) | 8868 | (80) |
| Survey 2 (1999) | Condition newly reported | 228 | (2) | 464 | (5) | 540 | (6) | 437 | (5) |
| | Condition already existed | 754 | (8) | 4484 | (47) | 1568 | (16) | 1857 | (20) |
| | Condition not reported | 8555 | (90) | 4554 | (48) | 7413 | (78) | 7220 | (76) |
| Survey 3 (2002) | Condition newly reported | 252 | (3) | 729 | (9) | 794 | (10) | 563 | (7) |
| | Condition already existed | 780 | (9) | 4219 | (52) | 1669 | (20) | 1935 | (24) |
| | Condition not reported | 7179 | (87) | 3217 | (39) | 5728 | (70) | 5678 | (69) |
| Survey 4 (2005) | Condition newly reported | 210 | (3) | 494 | (7) | 564 | (8) | 472 | (7) |
| | Condition already existed | 797 | (12) | 4052 | (60) | 1841 | (27) | 2031 | (30) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Condition not reported | 5802 | (85) | 2243 | (33) | 4389 | (65) | 4289 | (63) |
| Survey 5 (2008) | Condition newly reported | 100 | (2) | 294 | (6) | 380 | (7) | 341 | (7) |
| | Condition already existed | 700 | (14) | 3385 | (66) | 1623 | (32) | 1838 | (36) |
| | Condition not reported | 4319 | (84) | 1440 | (28) | 3116 | (61) | 2940 | (57) |
| Number of incident cases between 1996 and 2008 | | 790 | | 1981 | | 2278 | | 1813 | |

[a] At each survey, for each condition, the number of existing cases and newly reported cases are given; only women who participated in the survey (or for whom data were imputed based on cause of death data) are included.

[b] Survey data are supplemented with cause of death data**.**

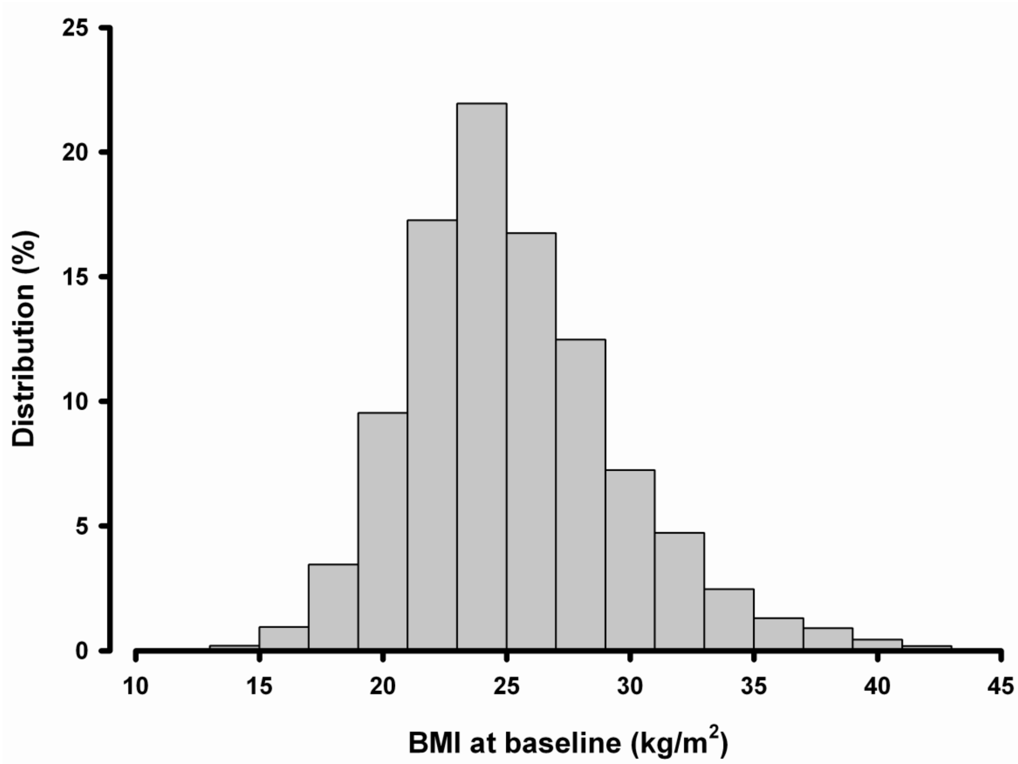


**FIGURE 1.** Distribution of body mass index in 1996.

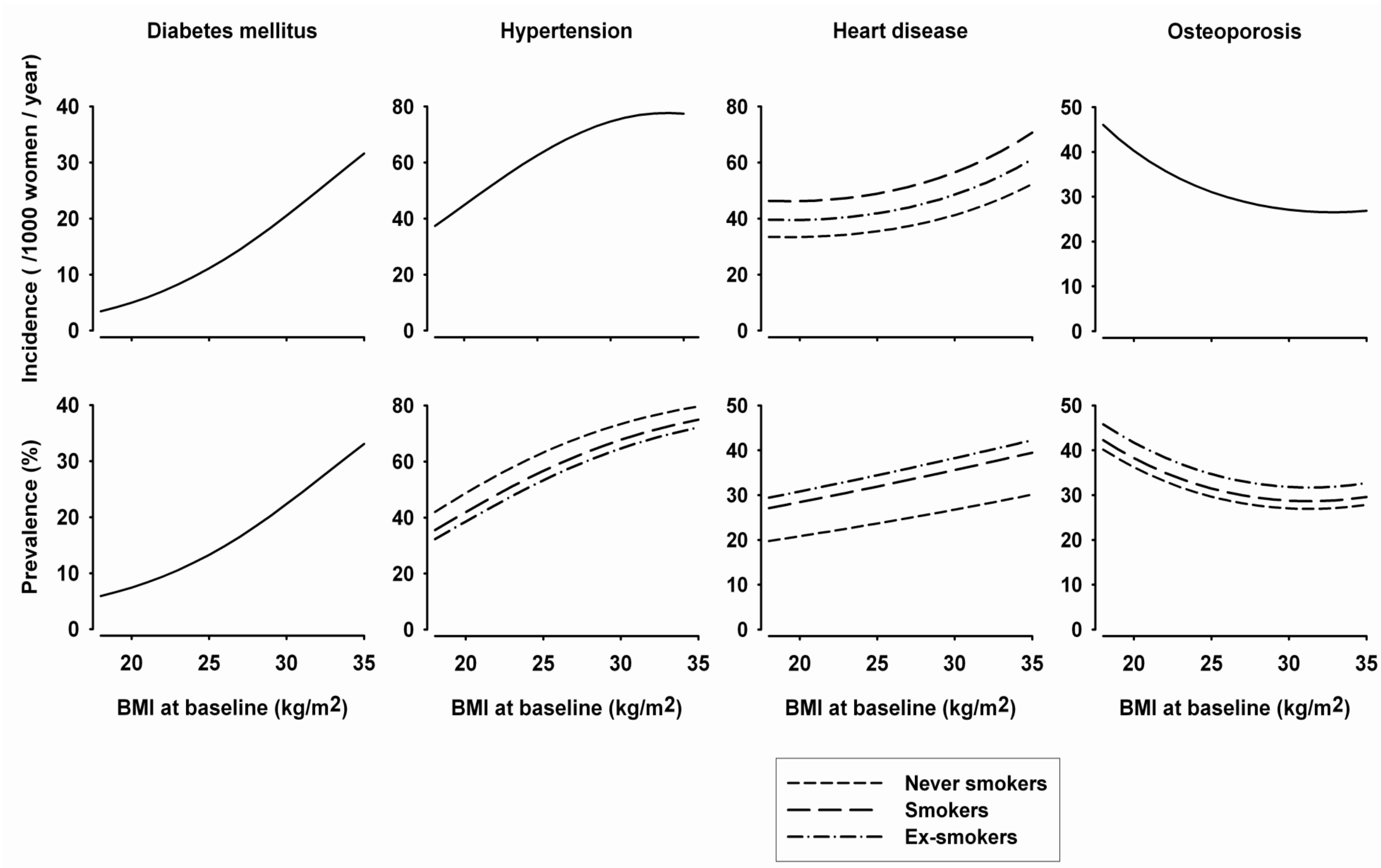


**FIGURE 2.** Estimated incidence and prevalence rates per year, at age 78.5 years, of chronic conditions in relation to baseline body mass index in women, Australian Longitudinal Study on Women's Health, 1996-2008.

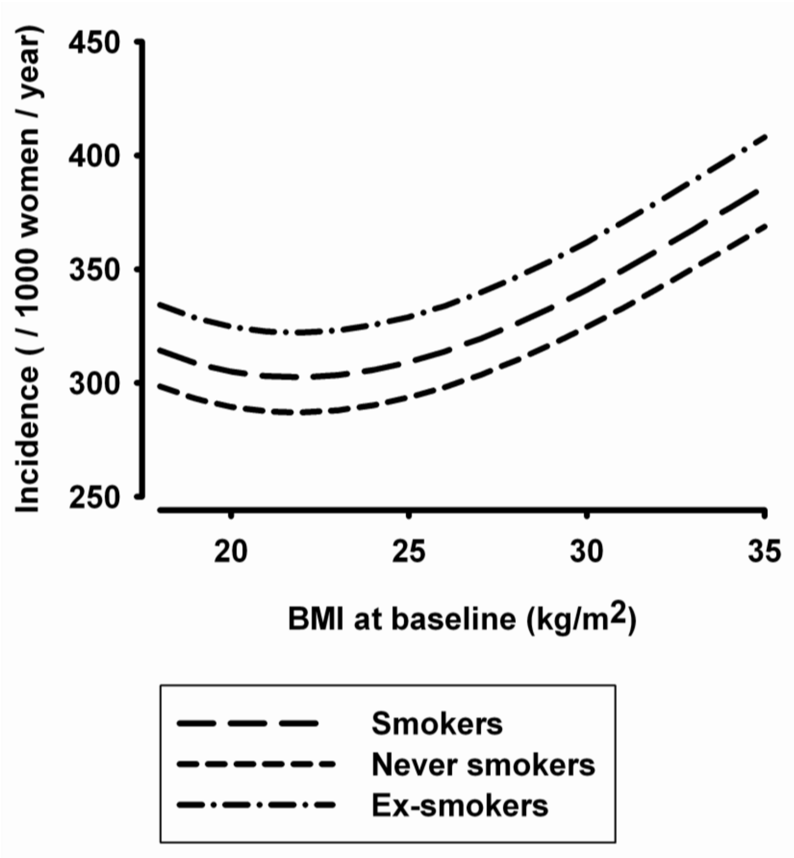


**FIGURE 3.** Estimated hospital admission rates, at age 78.5 years, in relation to baseline body mass index in women, Australian Longitudinal Study on Women's Health, 1996-2008.

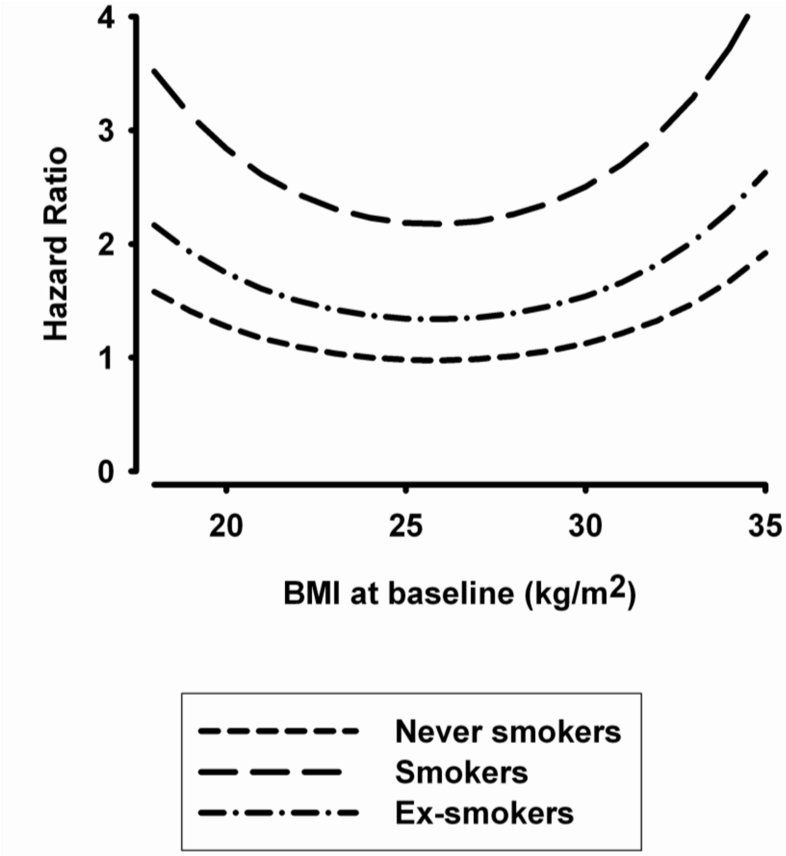


**FIGURE 4.** Hazard ratios for all-cause mortality in relation to baseline body mass index in women, Australian Longitudinal Study on Women's Health, 1996-2008. (Reference: Never smokers, BMI=24)