

# Changes in the Relationships Between Body Mass Index and Health Outcomes Across Middle Age and Older Adulthood

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## Abstract

**Objective:** To examine patterns of the incidence of diabetes, hypertension, and mortality by single units of body mass index (BMI) and 5-year age groups using longitudinal data from middle-aged and older women.

**Patients and Methods:** Middle-aged (born between 1946 and 1951; N=13,715) and older (born between 1921 and 1926; N=12,432) participants in the Australian Longitudinal Study on Women's Health completed surveys in 1996 and at approximately 3-year intervals thereafter until 2011. Proportions of women with diabetes, hypertension, and mortality over 3-year intervals were estimated for each unit of BMI and 5-year age group (45 to <50, 50 to <55, 55 to <60, 70 to <75, 75 to <80, and 80 to <85 years) using generalized additive modeling with adjustment for time-varying covariates.

**Results:** Three-year incidence of diabetes (1.2%-3.6%), hypertension (5.2%-17.8%), and death (0.4%-9.5%) increased with age. For both diabetes and hypertension, the associations with BMI were curvilinear in middle-aged women and became almost linear in older women. With increasing age, the slope became steeper, and the increase started at lower BMI values. For hypertension, there was a marked increase in intercept from 75 years onward. In contrast, mortality risks were highest for low BMI ( $\leq 20$ ) in all age groups. A clear U-shaped curve was observed only in the oldest age group.

**Conclusion:** The shapes of the relationships between BMI and incidence of diabetes, hypertension, and mortality change with age, suggesting that weight management interventions should be tailored for different age groups.

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In the general population, overweight and obesity are associated with a wide range of health problems that may lead to increased risk of premature mortality in adults.<sup>1</sup> In older adults, however, the relationships between body mass index (BMI) and health outcomes may become weaker, and at older ages, excess weight may serve as a buffer against mortality.<sup>2</sup> Studying whether the associations between BMI and health outcomes change with age may therefore provide valuable information about high-risk groups and potential interventions.

Data from the 1988-1994 National Health and Nutrition Examination Survey have revealed that the associations between BMI and cardiovascular disease, dyslipidemia, and hypertension in women attenuate with increasing age, but this modifying effect of age was not found for the association between BMI and diabetes.<sup>2</sup> This study

used 4 age categories (18-39, 40-64, 65-75, and 75 years or older) and examined the prevalence rather than the incidence of these conditions. The wide age ranges precluded detailed examination of how age affects the nature of the associations.

In 1980, Andres<sup>3</sup> reported that the relationship between BMI and mortality was U- or J-shaped and suggested that age had little influence on this relationship. More recent studies of the BMI-mortality relationship have yielded conflicting results. A large study of adults aged 30 to 74 years found that higher BMI was associated with higher mortality but that the relative risk declined with age.<sup>4</sup> In contrast, a study of adults aged 53 years and older found an L-shaped association, with underweight (but not overweight) being associated with higher mortality.<sup>5</sup> This pattern



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**TABLE 1. Response Rates and Baseline (1996) Characteristics of the Middle-aged and Older Participants<sup>a,b</sup>**

Variable	Middle-aged women (born 1946-1951)	Older women (born 1921-1926)
Survey 1 (1996)	13,715	12,432
Survey 2 (1998/1999)	12,338 (90.0)	10,434 (83.9)
Survey 3 (2001/2002)	11,226 (81.9)	8647 (69.6)
Survey 4 (2004/2005)	10,905 (79.5)	7158 (57.6)
Survey 5 (2007/2008)	10,628 (77.5)	5560 (44.7)
Survey 6 (2010/2011)	10,011 (73.0)	4055 (32.6)
Age (y)		
Range	45-50	70-75
Mean (SD)	47.6 (1.5)	72.6 (1.5)
Living in rural/remote areas	8726 (63.6)	7392 (59.5)
Post-high school diploma	4491 (33.1)	1742 (14.8)
Married/de facto relationship	11,311 (82.9)	6934 (56.8)
≥1 Chronic conditions	4376 (32.1)	5244 (42.7)
BMI		
Underweight (<18.5)	230 (7.1)	360 (3.2)
Normal weight (18.5 to <25)	6706 (45.8)	5575 (50.1)
Overweight (25 to <30)	3750 (28.8)	3698 (33.3)
Obesity (>30)	2404 (18.4)	1486 (13.4)
Mean (SD)	25.9 (5.2)	25.3 (4.4)
Current smoker	2382 (18.0)	873 (7.5)
Physical activity level		
Inactive	1723 (12.6)	2360 (19.2)
Low	9725 (71.5)	8414 (68.5)
Moderate	1830 (13.4)	1149 (9.4)
High	410 (3.0)	358 (2.9)

<sup>a</sup>BMI = body mass index.

<sup>b</sup>Data are presented as No. (percentage of responders relative to number of responders to the baseline survey) unless indicated otherwise. Percentages may not total 100 because of rounding.

was consistent across the age ranges studied (53-64, 65-74, 75-84, and 85 years or older). Another study also found an L-shaped association, but only in those aged 85 years or older.<sup>6</sup> In the same study, there was a U-shaped association in those aged 75 to 84 years, with both underweight and obesity being associated with higher mortality. Limitations of these studies were the wide or open-ended (eg, 75 years or older) age ranges and the use of BMI in categories rather than as a continuous variable.<sup>4-6</sup> Two of these studies examined relationships separately for women and men and found similar results in both sexes.<sup>2,3</sup>

The aim of this study was to explore the shape of the relationship between BMI and incidence of hypertension, diabetes, and mortality in women aged 45 to less than 85 years. The associations were studied for women in 5-year age groups to examine changes in the shape of

the associations during middle age and older adulthood.

## PATIENTS AND METHODS

### Study Participants

We used data from the Australian Longitudinal Study on Women's Health, a large population-based study of factors affecting the health and well-being of 3 generations of women.<sup>7</sup> Samples were randomly drawn from the national Medicare health insurance database, which includes all Australian citizens and permanent residents, with oversampling of women from rural and remote areas. The study methods were approved by the human research ethics committees of the University of Newcastle and University of Queensland, and all participants provided informed consent. Detailed information on design, recruitment, and attrition have been reported elsewhere.<sup>7,8</sup> This study used data from 2 cohorts, those who were born between 1946 and 1951 (middle-aged) and those born between 1921 and 1926 (older). The first surveys in 1996 included 13,715 middle-aged and 12,432 older women. Since then, the middle-aged cohort completed follow-up surveys in 1998, 2001, 2004, 2007, and 2010, and the older cohort completed follow-up surveys in 1999, 2002, 2005, 2008, and 2011. At the last survey, the main reasons for attrition were "did not do survey" (1151 of 13,715 [8.4%]), "withdrawn" (1143 of 13,715 [8.3%]), and "could not be contacted" (905 of 13,715 [6.6%]) in the middle-aged women and "death" (3672 of 12,432 [29.5%]), "withdrawal" (2112 of 12,432 [17.0%]), and "frailty" (1616 of 12,432 [13.0%]) in the older women (Table 1).

### Health Outcomes

At the 1996 survey, participants were asked, "Have you ever been told by a doctor that you have: (1) diabetes, (2) hypertension?" At each follow-up survey, participants were asked if, since the last survey, they had been diagnosed as having or been treated for: (1) diabetes or (2) hypertension. For each survey interval, incident diabetes and incident hypertension were defined as reporting the condition at the follow-up survey but not at any of the preceding surveys. Type 1 and type 2 diabetes mellitus were differentiated in some, but not all, of the surveys in the

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