Weight, Mortality, Years of Healthy Life, and Active Life Expectancy in Older Adults

Paula Diehr, PhD,† Ellen S. O'Meara, PhD,* Annette Fitzpatrick, PhD,‡ Anne B. Newman, MD, MPH,§|| Lewis Kuller, MD,§|| and Gregory Burke, MD, MS#*

OBJECTIVES: To determine whether weight categories predict subsequent mortality and morbidity in older adults.

DESIGN: Multistate life tables, using data from the Cardiovascular Health Study, a longitudinal population-based cohort of older adults.

SETTING: Data were provided by community-dwelling seniors in four U.S. counties: Forsyth County, North Carolina; Sacramento County, California; Washington County, Maryland; and Allegheny County, Pennsylvania.

PARTICIPANTS: Five thousand eight hundred eighty-eight adults aged 65 and older at baseline.

MEASUREMENTS: The age- and sex-specific probabilities of transition from one health state to another and from one weight category to another were estimated. From these probabilities, future life expectancy, years of healthy life, active life expectancy, and the number of years spent in each weight and health category after age 65 were estimated.

RESULTS: Women who are healthy and of normal weight at age 65 have a life expectancy of 22.1 years. Of that, they spend, on average, 9.6 years as overweight or obese and 5.3 years in fair or poor health. For both men and women, being underweight at age 65 was associated with worse outcomes than being normal weight, whereas being overweight or obese was rarely associated with worse outcomes than being normal weight and was sometimes associated with significantly better outcomes.

CONCLUSION: Similar to middle-aged populations, older adults are likely to be or to become overweight or obese, but higher weight is not associated with worse health in this age group. Thus, the number of older adults at a "healthy" weight may be much higher than currently believed. **J Am Geriatr Soc 2007.**

Key words: self-rated health; equilibrium; activities of daily living; years of healthy life; active life expectancy; multistate life tables; older adults

The prevalence of obesity and overweight in the United States has grown markedly in recent decades, and two thirds of adults are now classified as overweight or obese.[1,2] In middle-aged persons, obesity is linked to important health problems such as early death, diabetes mellitus, and physical disability.[3–6] The relationships between weight and mortality are different for older adults. Obesity is an established risk factor for shortened survival in younger but not older adults,[7,8] and relative risks for mortality typically decline with older age.[9] The importance of overweight and obesity as predictors of health status in adults aged 65 and older has also been questioned. For example, one study of older veterans found that being overweight was associated with better health status and quality of life than normal weight.[10] Weight loss advice is routinely given to patients of all ages, even though the literature does not support the idea that being obese or overweight is a strong risk factor beyond age 65. Understanding the relationship between weight and morbidity and mortality into old age has important implications for clinical decisions and public health policy.[11]

Future years of life (YOL), years of healthy life (YHL), and active life expectancy (ALE) are important outcome measures that can be estimated at the person level from longitudinal data.[12] Longitudinal data can also be used to estimate probabilities of transition between states defined according to health and weight. Multistate life table methods can then be used to estimate the expected number of future years spent in each state. The usual life table (with only 2 states: alive and dead) starts with a hypothetical population of 100,000 living persons and estimates, from age-specific death rates, the number who will be alive in the following year, the number alive in the year after that, and so on. A multistate life table is similar, but the years in

From the Departments of *Biostatistics; †Health Services; ‡Epidemiology, University of Washington, Seattle, Washington; §Department of Medicine, School of Medicine; ||Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania; #Department of Public Health Sciences, School of Medicine, Wake Forest University, Winston-Salem, North Carolina.

Address correspondence to Paula Diehr, PhD, Department of Biostatistics, University of Washington, P.O. Box 3537232, Seattle, WA 98195.
E-mail: pdiehr@u.washington.edu

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which persons are alive are tabulated separately to indicate what health and weight state they are in. For example, for a hypothetical cohort of 100,000 healthy normal-weight 65-year-old women, the number who will be healthy and normal weight 1 year later, at age 66, can be estimated. (This method is explained in more detail in Appendix A.)

A related approach was used to estimate the risk of developing obesity from age 35 to 65.[13] That analysis, using data from the Framingham Study, found that the long-term risk of a normal-weight person becoming overweight was 50% and that the risk of becoming obese was 25%. The authors concluded that the future burden of obesity-associated diseases might thus be substantial, although they did not estimate this burden, and their results may not apply to persons aged 65 and older. A similar study found that persons who were obese at age 70 had lower active life expectancy than nonobese persons.[14] That study did not examine transitions between weight categories.

The work presented here uses transition probabilities and multistate life tables to examine concurrent changes in weight and health status over time in older adults. The objective is to further examine the relationship between weight and health after age 65. The question of whether "normal" weight, which is defined without reference to age, is indeed associated with the best health in older adults, as measured according to total, healthy, and active life expectancy, is addressed.

METHODS

Study Design

The Cardiovascular Health Study

The Cardiovascular Health Study (CHS) is a population-based longitudinal study of risk factors for heart disease and stroke in 5,888 adults aged 65 and older at baseline.[15] Participants were recruited from a random sample of people eligible for Medicare in four U.S. communities, and extensive data were collected during annual clinic visits and telephone calls. Members of the original cohort of 5,201 participants, recruited in 1989/90, had up to 10 annual clinic examinations. A supplemental cohort of 687 African Americans, recruited in 1992/93, had up to seven annual examinations. Follow-up for cardiovascular events was virtually complete for surviving participants.[16]

Body Mass Index

Weight was measured every year, and height was measured up to three times during follow-up. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. A report from the National Heart, Lung, and Blood Institute classified normal weight, without reference to age, as a BMI of 18.5 to 24.9, overweight as 25.0 to 29.9, and obesity as 30.0 or higher.[17] Underweight was defined in the current study as a BMI less than 20.0 instead of 18.5, because a BMI of 18.5 to 20.0 was associated with higher mortality and fewer years of healthy life in an earlier analysis of CHS data.[12] This choice also increased the number of underweight persons for analysis.

YOL, YHL, and ALE

YOL was defined as life expectancy from age 65 to death. YHL was defined on the basis of self-rated health, a simple but well-known measure[18,19] that has been found in many studies to predict health events in older adults.[20] At annual clinic visits, participants were asked to rate their health as excellent, very good, good, fair, or poor. YHL was defined as the expected number of years in which a person was healthy (in excellent, very good, or good health) versus sick (in fair or poor health). ALE was defined as the expected number of years of future life spent with no difficulties in activities of daily living (ADLs).[21] Participants were asked every year whether, because of health or physical problems, they had any difficulty walking around at home, getting out of bed or a chair, eating, bathing or showering, or using the toilet. A person with a positive response to any of these items was considered to have an ADL difficulty at that time. Linear interpolation was used to impute missing data when values were known at clinic visits before and after the missing value. This approach has been shown to perform well in the CHS.[22]

After imputation, data completeness increased from approximately 93% to 95%.

Analysis

This section describes the analysis of YHL; ALE analyses were performed in the same manner. At each year of follow-up, each CHS participant was classified into one of four BMI states (underweight, normal, overweight, or obese) and one of two health states (healthy or sick; with or without ADL difficulties for the analysis of ALE). Eight BMI-by-health states are possible, ranging from sick and underweight to healthy and obese. Because subjects were followed over time, a ninth state was added for death. The longitudinal data allowed approximately 40,000 "transition pairs" to be created, from age 65 to 95. A transition pair is an observation of two BMI and health states for the same person, 1 year apart. The age- and sex-specific probability of transition from one BMI-by-health state to another was estimated using linear discriminant analysis to predict the state the next year as a function of the current state and the logarithm of age. The transition probabilities were estimated separately for each initial BMI-by-health state and sex. A spreadsheet was programmed to perform multistate life table calculations, and the program was applied to eight hypothetical cohorts of 100,000 women, one for each BMI-by-health state at age 65. The program calculated the expected number of women in each BMI-by-health state at age 66, at age 67, and so on. Estimates were summed and divided by 100,000 to calculate expected YOL, YHL (or ALE), and years spent in each BMI category for each hypothetical cohort. These steps were repeated for men. More detail is provided in Appendix A.

Bootstrap Standard Errors

To estimate the standard error of YOL, YHL, and ALE, the 5,888 persons were resampled 100 times (with replacement), and the entire set of calculations was performed for each new dataset. The standard deviations among the 100 sample estimates of the various quantities were used in the final analysis to calculate approximate t statistics.

Table 1. Transition Pairs: Body Mass Index and Health States (Row Percentages for Men and Women, Aged 65–100)

	State 1 Year Later (row %)									
		Sick and				Healthy and				
Initial State	Dead	Underweight	Normal	Overweight	Obese	Underweight	Normal	Overweight	Obese	Total (n)
Sick underweight	13.1	53.0	9.6	0.2	0.2	18.1	5.3	0.3	0.2	581
Sick normal	9.0	4.2	51.7	5.7	0.1	1.2	25.0	3.2	0.0	2,759
Sick overweight	5.1	0.1	7.3	51.7	4.1	0.0	2.7	27.3	1.6	3,352
Sick obese	3.6	0.0	0.1	7.6	59.4	0.0	0.1	2.8	26.3	2,228
Healthy underweight	3.7	11.9	2.0	0.1	0.0	67.8	14.4	0.1	0.1	1,288
Healthy normal	1.8	0.7	8.4	0.8	0.0	2.4	77.0	8.9	0.0	10,221
Healthy overweight	1.3	0.0	1.5	8.0	0.6	0.0	6.9	77.9	3.9	13,432
Healthy obese	1.2	0.0	0.0	1.5	11.4	0.0	0.1	8.6	77.2	5,856
Total, n	1,051	647	2,812	3,304	2,211	1,262	9,794	12,947	5,689	39,717

FINDINGS

Information about the 39,717 transitions between states defined according to BMI and self-rated health is shown in Table 1. For example, the first row shows that there were 581 transition pairs in which the person was sick and underweight in the first year. In 53% (308) of these pairs, the person remained sick and underweight 1 year later. For 13.1% (76) of the pairs, the person was dead 1 year later. Examination of this and the other rows shows that, although persons were most likely to remain in the same state, there was substantial movement between states as well. Persons moved from healthy to sick and from sick to healthy in the following year. Persons gained and lost weight, although they rarely moved more than one BMI category in a single year.

Table 1 does not account for age or sex and should not be overinterpreted. (Age and sex are completely accounted for in all of the following analyses.) The mean age of the cohort was 75.7 and decreased monotonically with BMI; underweight persons were approximately 3 years older than obese persons on average (data not shown). Women constituted 59% of the transition pairs. Men who were initially sick and underweight constituted fewer than 200 transition pairs for self-rated health and fewer than 100 pairs for ADLs (not shown). Therefore, calculations for initially sick underweight men may be compromised, especially for ADLs. The great majority of transition pairs were for healthy normal or healthy overweight persons.

Although it is not possible to comment on all 72 transition probabilities here, two trends for healthy, normal-weight persons will be mentioned here. The proportion of healthy and normal-weight men who were sick or dead 1 year later rose from approximately 9% at age 65 to 69 to 27% at age 90 to 94. For women, this probability increased from 4% to 28%. These probabilities were worse (higher) for the other initial BMI-by-health states except for healthy overweight, which was similar to healthy normal. The probability of becoming overweight or obese in the following year is also of interest. For healthy normal-weight men, this probability declined from approximately 16% at age 65 to 69 to 11% at age 90 to 94; for women the decline was from 13% to 3%. Being sick rather than healthy had little effect on the probability of a normal-weight person becoming overweight or obese.

Multistate life table methods were used to examine these complex relationships further. The estimated health trajectory for a hypothetical cohort of 100,000 women who were healthy and of normal weight at age 65 is shown in Figure 1. All were healthy at age 65, and the number of healthy persons decreased regularly over time, whereas the number dead increased, and the number of sick persons waxed and then waned. These patterns are similar for men (available from the authors). The sum of column heights in the lowest category (healthy), divided by 100,000, is the expected years of healthy life (16.8 years); the sum of areas in the middle category (sick) represents years of sick life (YSL; 5.3 years); and the sum of these two represents YOL or life expectancy at age 65 (22.1 years). Estimated YOL, YHL, and YSL for men and women in each of the eight possible BMI-by-health states at age 65 are shown in the first 3 columns of Table 2. Healthy overweight women and

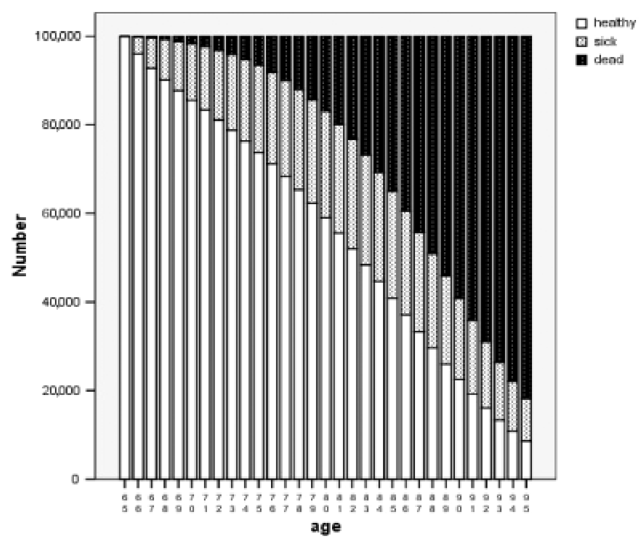

Figure 1. Projected health trajectory over time. Number of people in hypothetical cohort of 100,000 65-year-old healthy normal-weight women, with future health status estimated from multistate life tables.

Table 2. Years Spent in Various Health States According to State at Age 65

Initial Health State	Initial Body Mass Index State	YOL	YHL	Years of Sick Life*	Years Underweight	Years Normal	Years Overweight	Years Obese
Women								
Sick	Underweight	20.2	13.3	6.9	6.1	8.6	4.3	1.2
	Normal	**20.9**	**14.0**	**7.0**	**1.7**	**10.0**	**6.9**	**2.3**
	Overweight	21.6†	14.4	7.2	1.0	5.8	10.2	4.5
	Obese	21.6	13.9	7.7	0.6	3.4	6.3	11.4
Healthy	Underweight	21.2‡	15.9‡	5.3	6.2	9.0	4.6	1.3
	Normal	**22.1**	**16.8**	**5.3**	**1.7**	**10.7**	**7.2**	**2.4**
	Overweight	22.3	16.6	5.7	1.0	5.8	10.6	4.9
	Obese	22.1	15.8‡	6.3	0.6	3.3	6.2	11.9
Men								
Sick	Underweight	13.7	8.6	5.0	3.7	4.5	4.1	1.4
	Normal	**16.1**	**11.1**	**5.0**	**0.6**	**7.3**	**6.7**	**1.6**
	Overweight	17.8†	12.4†	5.3	0.4	4.0	10.4	3.0
	Obese	18.4†	12.3	6.0	0.3	2.8	6.9	8.4
Healthy	Underweight	17.3	13.2	4.1	3.8	6.6	5.5	1.4
	Normal	**18.3**	**14.3**	**4.0**	**0.6**	**8.1**	**8.0**	**1.7**
	Overweight	18.8	14.7	4.1	0.4	4.3	11.3	2.9
	Obese	19.3†	14.6	4.7	0.3	2.9	7.1	9.0

* In fair or poor health.
Significant difference from the normal-weight group (2-tailed $P<.05$), based on bootstrap standard errors:
† Significantly more years of life (YOL; life expectancy at age 65) or years of healthy life (YHL; in excellent, very good, or good health, according to self-report) than in the respective (healthy or sick) normal-weight group.
‡ Significantly fewer YOL or YHL than in the respective (healthy or sick) normal-weight group.

healthy obese men had the longest estimated life expectancy, whereas healthy normal-weight women and healthy overweight men had the most years of healthy life.

Also shown in Table 2 are results of approximate *t*-tests comparing normal BMI with each other BMI category with respect to YOL and YHL. (Confidence intervals are not shown because of the complexity of the table but are available from the authors.) Five states that were significantly better than normal weight (in the corresponding health state) are indicated by "+". Three states that were significantly worse than normal weight are indicated by "‡". As expected, the standard errors of the difference between underweight and normal-weight men were large (1.7 for YOL and 2.4 for YHL—not shown); thus the apparently large differences between underweight and normal-weight men were not statistically significant.

Results for ALE are shown in Table 3. For example, underweight women with ADL difficulties at age 65 are expected to have 20.3 YOL and 15.3 years of ALE. In five comparisons, overweight or obese were significantly better than normal weight. In two comparisons, normal weight was significantly better. The overall pattern is similar to that in Table 2.

Estimated BMI trajectories for a hypothetical cohort of 100,000 women who were healthy and of normal weight at age 65 are shown in Figure 2, where the lowest (clear) bars represent the number projected to be obese at each age, the bars with slashes represent normal weight, and so on. Within just 1 year (at age 66), fully 15% of this hypothetical cohort was overweight, and the number overweight increased further over time and then decreased as the number dead increased. Findings were similar for men (available from the authors). The sum of the heights of the lowest bars represents expected years of future life spent in the obese state (2.4 years), and the sum of the next higher set of bar areas represents expected years of overweight life (7.2 years); similarly, an average of 10.7 years of normal-weight life and 1.7 years of underweight life were estimated for this cohort. These four numbers sum to the YOL (life expectancy) at age 65 (22.1 years).

Estimated years of future life spent in each BMI category for men and women in the eight initial BMI-by-health states at age 65 are shown in the last four columns of Table 2. On average, persons will spend the majority of their remaining life in the BMI state they were in at 65. The exception is that persons who are underweight at age 65 are expected to spend most of their future years at a normal weight. Underweight is a somewhat transient state, in part because of its higher death rate. The BMI patterns for ALE, shown in Table 3, are similar to those for YHL. Approximate standard errors for these quantities are available from the authors.

SUMMARY AND DISCUSSION

In this section, the results are summarized, and then the findings are discussed separately for underweight, obese, and overweight. The sex differences are reviewed, and the results for YOL, YHL and ALE are compared. Finally, the potential role of confounding in the analysis is discussed, and why older adults may be different from middle-aged and younger persons is considered.

Our findings have extended the results of a previous study[13] by showing that persons of normal weight at age 65 are likely to be overweight or obese in the future, although the further finding that older adults who are overweight (or, in some cases, obese) have no worse and sometimes better outcomes than those of normal weight at 65 may mitigate

Table 3. Years Spent in Various Activity of Daily Living (ADL) States According to State at Age 65

Initial ADL State	Initial Body Mass Index State	YOL	ALE	DLE	Years Underweight	Years Normal	Years Overweight	Years Obese
Women								
ADL difficulty	Underweight	20.3	15.3	5.0	5.4	8.9	4.7	1.4
	Normal	**21.3**	**15.5**	**5.8**	**1.6**	**9.8**	**7.3**	**2.6**
	Overweight	21.9	15.6	6.3	1.0	5.7	10.6	4.6
	Obese	21.9	14.6	7.3	0.6	3.3	6.0	11.9
No difficulty	Underweight	21.0*	16.9	4.1	6.2	9.0	4.6	1.3
	Normal	**21.8**	**17.1**	**4.7**	**1.7**	**10.6**	**7.1**	**2.4**
	Overweight	22.1†	16.8*	5.3	1.0	5.8	10.5	4.9
	Obese	22.0	15.9	6.1	0.6	3.4	6.3	11.7
Men								
ADL difficulty	Underweight	14.7	11.9	2.7	4.1	5.8	4.0	0.7
	Normal	**15.3**	**12.0**	**3.3**	**0.5**	**6.5**	**6.8**	**1.5**
	Overweight	18.0†	13.9†	4.1	0.3	3.9	10.2	3.6
	Obese	18.4†	13.8	4.6	0.3	2.9	7.2	8.1
No difficulty	Underweight	15.2	13.2	2.0	4.3	6.0	4.1	0.7
	Normal	**17.9**	**15.4**	**2.5**	**0.6**	**8.0**	**7.7**	**1.6**
	Overweight	18.5	15.7	2.8	0.3	4.2	11.1	2.9
	Obese	19.2†	15.7	3.5	0.2	2.8	6.9	9.2

Significant difference from the normal-weight group (2-tailed $P<.05$), based on bootstrap standard errors:
* Significantly fewer years of life (YOL; life expectancy at age 65) or active life expectancy (ALE; years without ADL difficulties) than in the respective (healthy or sick) normal-weight group.
† Significantly more YOL or ALE than in the respective (healthy or sick) normal-weight group.

the potentially harmful consequences of this finding. The results did not support a previous finding that obesity was associated with lower ALE.[14]

Underweight was associated with worse outcomes than normal weight in 16 of 16 comparisons in Tables 2 and 3. Only three of the individual comparisons reached statistical significance, due in part to the small number of underweight persons in this study. Risks associated with underweight have been reported in several studies of mortality and other health outcomes.[23–25] The association between low weight and previous unexplained weight loss may explain the higher mortality.[23] Underweight was defined in the current

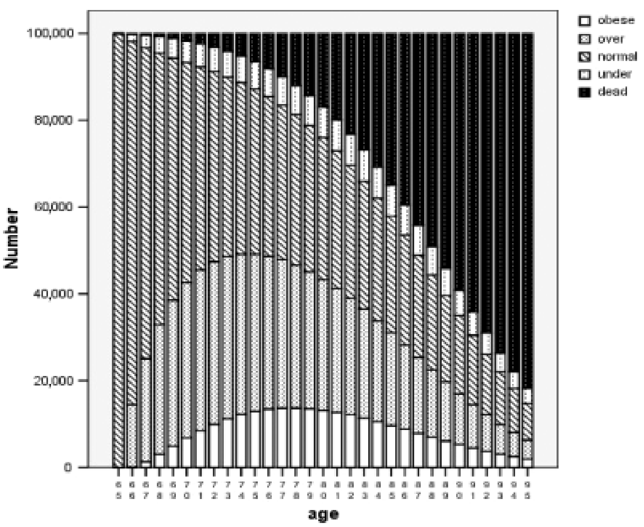

Figure 2. Projected body mass index (BMI) trajectory over time. Number of people in hypothetical cohort of 100,000 65-year-old healthy normal-weight women, with future BMI states estimated from multistate life tables.

study as a BMI less than 20.0, instead of the usual cutpoint of 18.5. If the standard definition had been used, the normal and underweight groups would have had worse outcomes than shown here, because the healthiest underweight people would have become the sickest normal-weight people. Thus, these findings are robust to the definition of underweight.

Obesity was associated with better outcomes than normal weight in 11 of the 16 comparisons, and two of those comparisons were statistically significant. Obesity was the same or worse in the remaining five comparisons (1 statistically significant). It is unclear whether obesity is better or worse than normal weight for older adults.

Perhaps the most interesting finding is that being overweight at age 65 was associated with better outcomes than being of normal weight in 14 of 16 comparisons, and six of these differences were statistically significant. One study mentioned above found slightly better ALE for overweight than normal-weight older adults.[14] In another recent study based on data from half a million volunteers from the AARP[26] overweight older adults had favourable mortality, similar to the findings of the current study, although this was not emphasized. A meta-analysis of the association between weight and mortality in 26 observational studies also noted that the overweight classification had favorable mortality, although the results were age-adjusted rather than age-specific.[27] A recent study following 697 80-year-old Japanese persons documented lower all-cause mortality in overweight and obese persons and higher mortality in underweight persons than in those of normal weight.[28] The previously mentioned study of older veterans found that overweight was associated with lower mortality and with better health status and quality of life than normal weight.[10] Until recently, the overweight category has been neglected in the literature, which has tended to focus on the extremes of obesity and underweight. Given the consistency of findings, perhaps new weight standards for older adults should define both normal weight and overweight to be healthy weight. According to the current definition, only 37% of Americans aged 65 to 74 and 48% of those aged 75 and older are at a healthy weight.[29] If overweight was included, then 78% of those aged 65 to 74 and 82% of those aged 75 and older would be at a healthy weight, a major change from current perceptions.

Results sometimes differed according to sex. For men, better outcomes were always seen in those who were overweight and obese than in those who were normal weight. Findings were mixed for women. This may represent a true sex difference in health and activity limitations; alternatively, men and women may rate themselves differently on these items. Obese women's preference for thinness might lead them to downgrade their health status, and underweight women may mistakenly rate their health more favorably, because they are thin. Such misclassification could help to explain the results for healthy thin and sick obese women who fare worse and better, respectively, than might have been expected.

The findings were fairly consistent for all three outcomes: YOL, YHL, and ALE. Associations between weight and YOL had been expected to differ from associations with YHL and ALE because of the high prevalence of nonfatal conditions such as osteoarthritis in obese elderly people. That higher prevalence seemed to suggest that overweight and obesity would be more strongly associated with YHL and ALE than with mortality, but this was not the case. The results for ALE and YHL had also been expected to differ from one another, because ADL and self-rated health do not classify the same persons as impaired. Only 53% of those with ADL difficulties rated themselves as sick, and only 11% of the sick reported an ADL difficulty. Nevertheless, results for YHL and ALE were substantively similar. There were more persons in fair or poor health than persons with ADL disabilities, suggesting that the transition probabilities were estimated more accurately for YHL than for ALE.

These analyses did not control for smoking or chronic disease except indirectly, through their effect on self-rated health or ADLs. In separate analyses, it was found that higher BMI was significantly associated at baseline with more heart disease, hypertension, diabetes mellitus, arthritis, and depression and less exercise (data not shown). Despite these negative associations, the overweight and obese categories had favorable results. The only positive association was that low BMI was associated with smoking. Earlier analyses in the CHS that were restricted to nonsmokers and adjusted for a large number of important covariates resulted in similar conclusions to those of the present analysis.[12,23] Studies of the health effects of weight often approach confounding by restricting the analysis to healthy nonsmokers. Such studies estimate the effect of BMI in persons with no other health problems. In the CHS, only 14% of the men and 23% of the women were never-smokers without a history of cancer, heart disease, stroke, respiratory disease, or recent loss of 10 pounds at baseline (the exclusions used by a previous study[30]), suggesting that results from such restricted studies may not apply to most older adults. The analysis reported here examines whether BMI predicts mortality and morbidity in the general population of older adults. The current study found that overweight and even obesity are not, on average, risk factors for shortened YOL, YHL, and ALE, although it may be advisable for persons with certain health problems to modify their weight.

Relationships between BMI and future health and mortality in older adults are different from the relationships found in younger populations. There are several possible explanations for these differences. The first is a putative "survivor" effect in which middle-aged individuals whose health is sensitive to their weight—perhaps due to genetic or environmental factors or to poor access to medical care for hypertension or dyslipidemia—are less likely to survive into old age. The resulting cohort of survivors would be less susceptible to the health problems of overweight and obesity than a younger cohort.

Another possibility is that, in old age, the protective aspects of obesity may outweigh the negative effects. Obesity provides a nutritional reserve to the individual in times of stress such as illness or trauma, and persons with a higher BMI are more likely to survive acute illness.[31–33] Obesity also protects against acute injury from traumatic events such as falls. Heavier persons have lower rates of osteoporosis, probably as a result of fatty tissue synthesis of estrogens and greater weight-bearing-related bone formation.[34,35]

A third explanation for differing relationships between BMI and health in older and younger adults may be that disease processes and treatments change with age. The relative excess of chronic disease in the higher weight categories tends to decrease at older ages, because lighter-weight persons eventually contract these diseases.[36] The increased disease burden with age leads to different interactions with the healthcare system, more hospitalizations, and changes in medication use and lifestyle. Other health risks associated with aging may also mask health hazards of being overweight in later life.[34] Finally, overweight and obesity in middle-aged and younger persons are usually associated with long-term sequelae, which may be less important in older adults, because "forevermore is shorter than before."[37]

LIMITATIONS

Persons who enrolled in the CHS were relatively healthy for their age at baseline. Even though most of the data used here were collected long after baseline, the results may be overly favorable when compared with the general population. The data were collected before the current obesity epidemic, suggesting that today's overweight and obese elderly people may be different from their counterparts measured in the 1990s. Nearly 40,000 transition pairs were available for estimating the transition probabilities, and a simple life table calculation yields a life expectancy close to the national average.[38] However, for the multistate life tables in this article, 72 probabilities needed to be estimated for each year of age according to sex (5,320 probabilities in all), and YOL, YHL, and ALE may be poorly estimated in the smallest cells. The standard errors for YHL and YOL in the initially sick and underweight category were large. Repeating these analyses with different and larger datasets would be valuable. Many differences between states were small and may not be clinically important. Finally, in the bootstrap procedure used to estimate the standard errors, it was not possible to duplicate the complex calculations exactly, and the *t*-statistics used in Table 2 and Table 3 are only approximate. Despite these limitations, the evidence is strong that higher weight does not not reflect greater risk for poor outcomes in older adults.

CONCLUSION

This article supports the idea that guidelines for weight should be age-appropriate, not "one size fits all." Older adults who are overweight (or, for men, even obese) may be at a healthy weight for their age. If further research confirms this, this message should be emphasized. The current BMI and weight standards would seem to detract from appropriate concern for underweight, which has been shown to be a more-important concern for older adults.[23]

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APPENDIX A

Calculations for Multistate Life Tables

Multistate life tables are similar to the usual two-state life tables except that the "alive" state is divided into separate states, such as the states listed in Table 1 (healthy and overweight, sick and underweight, and so on). The life table calculations apply the transition probabilities from Table 1 to a hypothetical population of 100,000 persons in a specified state at age 65 to determine how many will be in each state in the following year. (For simplicity in this example, the transition probabilities in Table 1 were used, even though they are not age- and sex-specific.)

For example, considering 100,000 persons who are healthy and normal weight at age 65, the sixth row of Table 1 indicates that 1 year later (at age 66), 77%, or 77,000 will still be healthy and normal weight, 8,900 will be healthy and overweight, 8,400 will be sick and normal weight, 1,800 will have died, and smaller numbers (calculated in the same way) will be in the other states. One year after that (at age 67), 77% of the 77,000 or 59,290 of the healthy normal persons will still be healthy and normal weight. In addition, using the seventh row of Table 1, it can be seen that 6.9% of the 8,900 healthy overweight people (614) will return to being healthy and normal weight, as will 25% of the 8,400 who are sick and normal weight (from line 2, n = 2,100) and smaller numbers returning from the other states. The number who are healthy and normal weight at age 67 will thus be 59,290 + 614 + 2,100 + the smaller numbers returning from the other states.

These calculations can then be repeated to determine the number in each state at age 68 and up to age 95, by which time most will have died. The number of person-years spent in a particular state over all the ages for a given starting state is then added up and the sum divided by 100,000 to yield the expected number of years spent in that state. (Actually, the values at age 65 and age 95 are weighted by 0.5, which is a feature of the trapezoidal approximation for the area under the curve.)[39] This simple but tedious bookkeeping is most easily accomplished using a spreadsheet, which was programmed for this purpose. The probabilities in Table 1, which includes men and women of all ages, were not actually used. Transition probabilities are different for each age and sex.[38] A version of Table 1 thus had to be created for each age and sex to make it possible to perform the calculations in the table.

This process assumes only that valid estimates of the average transition probability for each age and sex state are available. Because the Cardiovascular Health Study is a sample of the general population, the estimates used here should be appropriate except perhaps in the smallest cells, as noted in the article.