Smoking kills, obesity disables.
A multistate approach of the U.S. Health and Retirement Survey

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Abstract

Objectives

To estimate the effect of obesity, smoking and levels of education on duration of ADL disability among middle and old aged adults.

Design

Prospective longitudinal study of a weighted stratified sample of the unselected US population, the Health and Retirement Survey (HRS).

Setting

United States

Population

16,167 non-Hispanic white adults, aged 55 and over between 1995 and 2004.

Main outcome measures

Years to live with and without ADL disability at age 55 by self-reported BMI, smoking status and levels of education.

Results

The life expectancy (LE) of men at age 55, free of ADL disability and with ADL disability, was 19.1 [18.6;19.6] years and 5.5 [5;5.9] years. For women this was 20.8 [20.2;21.4] years and 7.9 [7.4;8.4]. Among men, BMI 30-34.9 compared to BMI 23-24.9 decreased disability free LE with 2.7 [1.2;3.2] year but increased LE with disability with 2.0 [0.6-3.4] years. Among women, BMI 30-34.9 decreased disability free LE with 3.6 [2.1;5.1] year but increased LE with disability with 3.2 [1.6-4.8] years. Among women, BMI 25-29.9 compared to BMI 23-24.9 increased life expectancy with disability with 2.0 [0.8-3.2] years. A low education decreased disability free life, but did not change life expectancy with ADL disability. Smokers lived shorter both with and without ADL disability.

Conclusions

Obesity expands ADL disability by increasing incidence but not mortality. Smoking decreases both disability free and disabled life expectancy by being highly fatal. High education expands disability free life without expanding ADL disability. Increasing prevalence of obesity may considerably increase care dependence.

Introduction

In 2001-2004, 30% of men and 34% of women in the US 20-74 year of age were obese (BMI 30 and over).[1] Many countries follow the US lead.[2] Several studies suggest that obesity could overtake smoking as actual cause of death.[3 4] However, more recent studies suggest otherwise, demonstrating that at middle and old age, overweight lowers mortality, especially for men.[5-7] The so called obesity epidemic is put into question.[8 9] Even mild obesity does not increase the hazard to die among the 65 and older.[10] The major obesity related cause of death, cardiovascular mortality, has been spectacularly declining, partially by improved therapies and cardiovascular risk management.[11-14] However, if disability is increased but not mortality, numbers of obese survivors expand morbidity, increasing life years lived with disability, care dependence and health care costs.[15 16] Obesity is related to increased blood pressure, dyslipidemia and diabetes. These can now be controlled, but at a cost.[12-14] High weight increases the mechanical stress on joints, particularly knee and back, increasing back pain and osteoarthritis and limiting mobility.[17 18]

We describe the disability free life expectancy and expected duration of disability at age 55, conditional on BMI class, smoking and education in a recent large US prospective study of the middle aged and the elderly,[19] using multi state life tables. The life table translates hazard rates and ratios as age and risk factor dependent transition probabilities, calculating life expectancies with or without disability, conditioned by risk factors.

Population and methods

We used the RAND Health and Retirement Survey (HRS) data file containing the HRS and the Asset and Health Dynamics Among the Oldest Old (AHEAD) which began in 1992 and 1993, respectively, and were merged in 1998.[19] More information is available elsewhere (http://hrsonline.isr.umich.edu/). The HRS and AHEAD surveys include a nationally representative sample of initially non-institutionalized persons born in 1931–1941 (HRS, aged 51–61 in 1992) and in 1923 or earlier (AHEAD, aged 70 and older in 1993). Sampled persons were re-interviewed biannually. Response was on average 86% (HRS) and 90% (AHEAD). We selected white non-Hispanic men and women of whom date of birth, gender, level of education, Body Mass Index (BMI), smoking status, and ADL score was available. Data on vital status and month and year of death are obtained through the mortality register (the National Death Index)

and exit interviews. 1.0 percent of the population (166/16167 individuals) experienced recovery. Ignoring recovery simplified the multi state life tables without changing the results. Our sample covers survey rounds from 1992 to 2004.

Exposures are BMI, smoking and levels of education. Self-reported weight and height at baseline are used to calculate BMI (kg/m^2), classified as low normal weight (18.5-22.9), high normal weight (23-24.9), overweight (25-29.9), mildly obese (30-34.9) and severely obese (35+). We split normal weight in two classes, defined by BMI 23, because previous analyses suggested important heterogeneity at middle age. We excluded underweight (BMI < 18.5), not being part of our study of normal and excess weight. We use the first length and weight reported. We start counting exposures and events after three years follow up. Smoking status is included as 'never smoked', 'stopped smoking' and 'currently smoking' based on the first reported information on smoking status. We distinguish three groups of educational attainment: Less than high-school or General Educational Development (GED), High-School graduate, and College graduate and above.

Outcomes are all-cause mortality and disability. Disability is defined by the Katz basic activities of daily living (ADL): Walking, Bathing, Dressing, Toileting and Feeding .[20] We classify as ADL disabled the person who answers "with difficulty" on at least one of the ADL.

We estimated the hazard rates of transitions to death and disability by age for each determinant of interest and for males and females. We estimated Cox proportional hazard ratios by BMI, smoking and education. Age is used as the timescale for the baseline hazard instead of time, accounting for left truncation and right censoring. Schoenfeld residuals with significance level set at 5% tested the proportionality assumption. The transition rates are smoothed using Poisson regression assuming Gompertz baseline hazard. To include covariates in estimating the rates we used both univariate models, stratified by one risk factor of interest, and multivariate models correcting for all risk factors. In order to describe the burden of mortality and disability of BMI, smoking and education we defined multistate life tables by the estimated transition rates. To translate the rates in annual probabilities we assume the rates to be constant in the 1- year intervals. The main outcomes are life expectancy measures at age $x \geq 55$ total life expectancy, active life expectancy or years to live free from ADL disabilities and disabled life expectancy or years to live with ADL disabilities. Confidence intervals for the life expectancies and differences in life expectancies were calculated using bootstrapping with 250 replicates.

Results

The selection of non-Hispanic white individuals aged 55 and over, that participated at least 3 years and reported BMI, smoking, education and ADL resulted in a sample of 16167 individuals, 94177 personyears, 3206 deaths and 5363 transitions to disability between 1995 and 2004. The distribution by sex, age-groups and covariates is shown in table 1.

Table 1: Population, exposure and deaths by sex, age and risk factor status at baseline

	Number of individuals			Person Years			Deaths		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
Total	7195	8972	16167	41920	52257	94177	1603	1603	3206
BMI 18.5-22.9	881	2522	3403	4926	14557	19483	302	526	828
BMI 23-24.9	1337	1668	3005	7878	9822	17700	316	312	628
BMI 25-29.9	3596	3034	6630	21130	17759	38889	732	505	1237
BMI 30-34.9	1089	1213	2302	6348	7127	13474	200	174	374
BMI 35+	292	535	827	1637	2992	4630	53	86	139
never smoked	1873	4629	6502	11164	26848	38011	293	882	1175
stopped smoking	3826	2716	6542	22168	15682	37850	919	446	1365
currently smoking	1496	1627	3123	8588	9727	18315	391	275	666
low education	1963	2319	4282	11068	13180	24248	636	658	1294
middle education	2106	3426	5532	12476	20526	33002	457	534	991
high education	3126	3227	6353	18376	18550	36927	510	411	921
55-64 *)	3961	4716	8677	18168	22142	40309	237	161	398
65-74 *)	1349	1504	2853	12889	12916	25805	364	210	574
75-84 *)	1562	2110	3672	8431	12318	20749	586	554	1140
85+ *)	323	642	965	2433	4882	7314	416	678	1094

**) For number of individuals, the age at entry into observation is used (baseline + 3 year)*

Relative risks

A Cox hazard regression model shows the proportional hazards for transitions to death and to disability (failing at least one ADL) by BMI, smoking status and levels of education. (table 2)

Table 2: Proportional hazard ratios (PHR) of BMI, smoking and education on transitions from healthy to death, healthy to ADL disabled and from ADL disabled to death, adjusting for age, smoking and education. 95% Confidence intervals.

	Males									Females								
	Healthy to Death	CI		Healthy to ADL disabled	CI		ADL disabled to Death	CI		Healthy to Death	CI		Healthy to ADL disabled	CI		ADL disabled to Death	CI	
BMI 18.5-22.9	**1.25**	1.04	1.51	1.11	0.89	1.39	**1.42**	1.12	1.79	1.05	0.88	1.26	0.98	0.83	1.15	1.13	0.94	1.34
BMI 23-24.9	1.00			1.00			1.00			1.00			1.00			1.00		
BMI 25-29.9	0.95	0.82	1.11	1.04	0.87	1.24	0.98	0.80	1.20	0.99	0.83	1.20	**1.25**	1.07	1.46	**0.75**	0.63	0.90
BMI 30-34.9	1.17	0.94	1.45	**1.69**	1.37	2.09	1.01	0.78	1.31	1.07	0.83	1.39	**1.66**	1.37	2.00	**0.79**	0.62	1.00
BMI 35+	**1.62**	1.11	2.36	**2.54**	1.84	3.52	0.91	0.61	1.36	**1.86**	1.31	2.62	**2.81**	2.22	3.56	1.07	0.79	1.44
Never smoked	1.00			1.00			1.00			1.00			1.00			1.00		
Stopped smoking	**1.50**	1.28	1.76	1.06	0.91	1.23	1.12	0.93	1.34	1.09	0.94	1.27	1.01	0.90	1.15	1.13	0.97	1.31
Currently smoking	**2.95**	2.45	3.56	**1.43**	1.18	1.74	**1.34**	1.06	1.69	**2.31**	1.92	2.78	**1.60**	1.38	1.86	**1.69**	1.39	2.05
Low education	**1.46**	1.27	1.68	**1.69**	1.45	1.97	1.18	0.99	1.40	**1.53**	1.30	1.81	**1.49**	1.31	1.71	**1.31**	1.12	1.53
Medium education	**1.26**	1.09	1.45	**1.32**	1.13	1.54	1.09	0.90	1.32	1.11	0.95	1.31	1.04	0.92	1.19	1.11	0.94	1.32
High education	1.00			1.00			1.00						1.00			1.00		

* *Reference category*

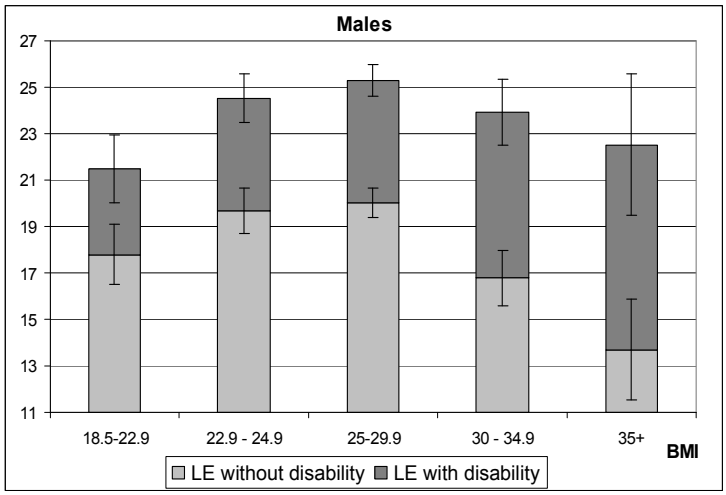
bold *figures are significant at p=0.05*

A higher BMI increases the hazard of ADL disability. For mildly obese men and women the proportional hazard ratio's (PHR) were respectively 1.69 (1.37, 2.09) and 1.66 (1.37, 2.00). There was a clear dose response relationship, with increasing obesity causing increasing hazards of disability. For men, overweight did not increase the risk of disability, but for women it did (PHR 1.22; 1.07-1.46). Females with overweight or mild obesity also face lower hazards of death once disabled, extending life with disability. Smoking and low education both increase risks of ADL disability and death for both men and women. Disability hazards by BMI are similar for smokers and non-smokers; but the increased risk of death at low normal weight was predominantly caused by smoking.

Life expectancy

Translating age, sex and risk factor-specific transition rates (univariate) into life expectancies at age 55 shows the stratified life expectancy with and without disability for each risk group. The actual life expectancy of the total unselected white American population in 1997 was 23.6 for men and 27.7 for women at age 55.[21]. The comparable life expectancy of our study population was respectively 24.0 and 28.2 years (excluding underweight individuals). A BMI between 18.5 and 29.9 showed the longest life expectancy free from disability (figure 1). Mild obesity (BMI 30-34.9) did not shorten total life expectancy but, at age 55, mild obesity shortened disability free life with 2.8 [1.2 to 4.5] years for males and 4.2 [2.6 to 5.8] for females compared to normal weight. Severely obese men live on average 5.8 [3.8 to 7.8] years shorter free from ADL disability and women 8.4 [6.4,10.4] years. For men, low normal weight lowers both total and disability free life expectancy.

Figure 1: Life expectancy with and without ADL disability at age 55 (univariate analysis). Error bars represent 95% confidence intervals of disability free and total life expectancy.



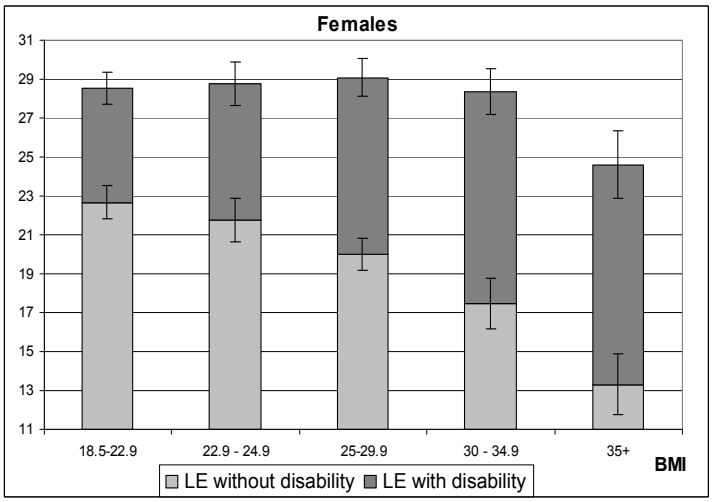


Table 3 shows the gains or losses in disabled and disability-free life expectancy in the multivariately adjusted multistate life table compared to the reference risk category. Among men, a BMI 30-34.9 compared to BMI 23-24.9 decreased disability free LE with 2.7 [1.2;4.2] year and increased LE with disability with 2.0 [0.6-3.4] years. Among women, a BMI 30-34.9 compared to BMI 23-24.9 decreased disability free LE with 3.6 [2.1;5.2] year and increased LE with disability with 3.2 [1.6-4.8] years. Among women, overweight (BMI 25-29.9) compared to BMI 23-24.9 increased life expectancy with disability with 2.1 [0.8-3.3] years. Negligible differences in total life expectancy hid large and significant decreases in disability free life expectancy and increases in life expectancy with ADL disability.

The effect of smoking is very different. Smoking shortens both life expectancy free of disability (6.4 years [5.2-7.6] among men and 5.2[3.4-6.3] years among women) and years lived with disability (1.3 years [0.5-2.5] and 1.4 years [0.3-2.6]). These results add to previous life course analyses showing decreased health care costs and cardiovascular morbidity as a consequence of the high mortality of smoking.[22 23] A lower level of education decreases total life expectancy, but does not change life expectancy with disability.

Table 3: Gains or losses(-) of disabled and non-disabled lifespan at age 55 by risk factor compared to reference category using multivariate modeling with 95% confidence intervals

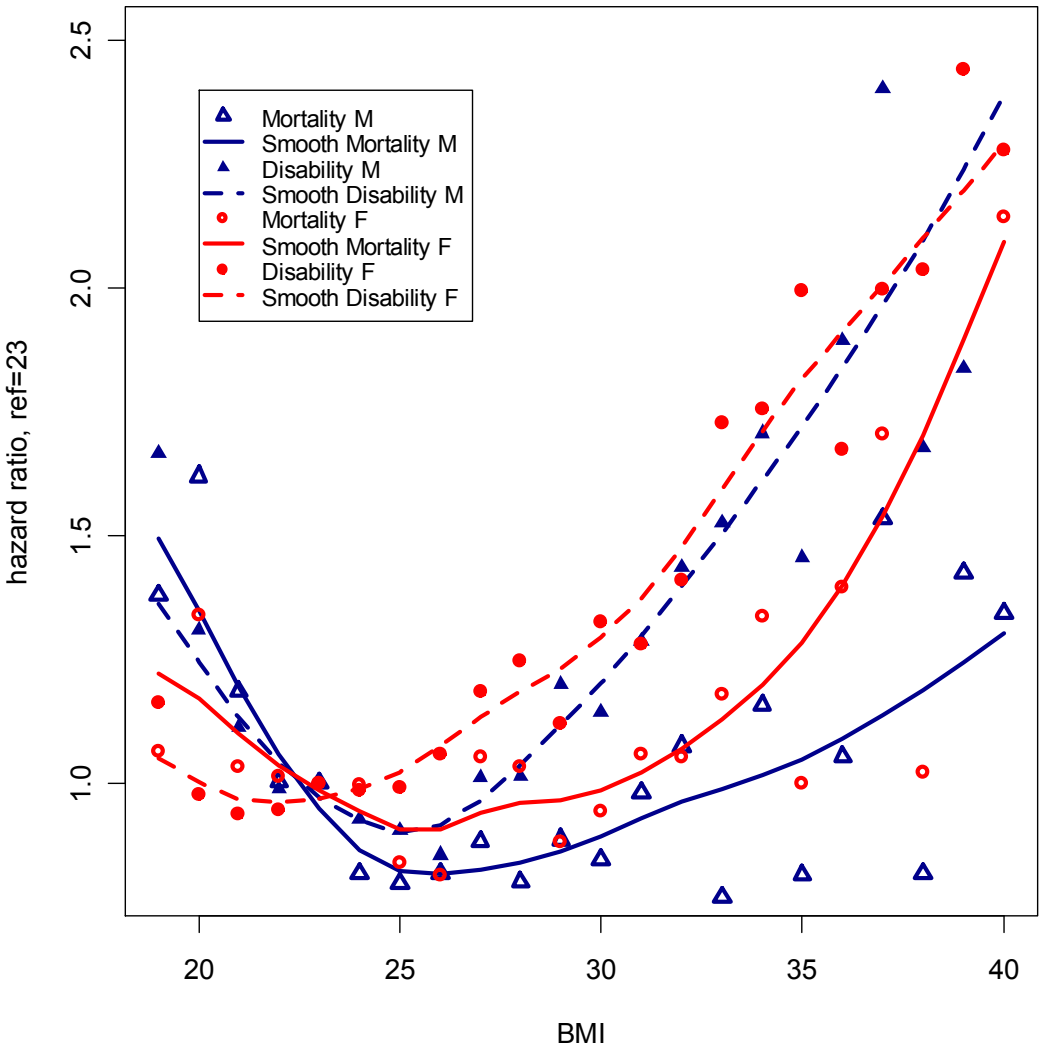
	Males						Females					
	Non-disabled Life			Disabled Life			Non-disabled Life			Disabled Life		
BMI 18.5-22.9	-1.1	-2.5	0.2	-0.7	-1.8	0.5	0.1	-1.3	1.5	-0.5	-1.6	0.6
BMI 23-24.9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BMI 25-29.9	0.2	-0.9	1.3	0.4	-0.6	1.4	**-1.5**	-2.9	-0.1	**2.1**	0.8	3.3
BMI 30-34.9	**-2.7**	-4.2	-1.2	**2.0**	0.6	3.4	**-3.6**	-5.2	-2.1	**3.2**	1.6	4.8
Never smoked *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stopped smoking	**-1.9**	-3.0	-0.8	-0.9	-1.8	0.3	-0.7	-1.9	0.4	-0.9	-2.0	0.1
Currently smoking	**-6.4**	-7.6	-5.2	**-1.3**	-2.5	-0.5	**-5.2**	-6.3	-4.1	**-1.4**	-2.6	-0.3
Low education	**-3.6**	-4.6	-2.5	0.7	-0.1	1.5	**-3.3**	-4.4	-2.1	0.0	-1.0	1.0
Medium education	**-2.1**	-3.2	-1.0	0.4	-0.5	1.2	-0.4	-1.5	0.6	-0.6	-1.5	0.4
High education *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

***** *Reference category*

bold *figures are significant at p<0.05*

Figure 2 illustrates the differences in hazard ratios between both sexes, disability and mortality that generated the increased life expectancies with ADL disability. The shape of mortality and disability by BMI is remarkably different, disability being far more BMI dependent than mortality. Among men, mortality is a broad plain with increases at the extremes, while disability is a sharp V. A BMI with lower disability risks would be between 22 and 28. Among women, mortality increases earlier (at around BMI 33) and higher, while a BMI with lower disability would be between 20 and 26, two points lower than men. The BMI effect on disability was not different between smokers and non-smokers. Among individuals reporting poor or fair health, BMI had little effect on disability and mortality, among individuals reporting good or excellent health, the correlation was higher.

Figure 2 Mortality and disability hazard ratios for males and females, reference is BMI=23. Lines are discrete splines weighted by personyears (lambda=10^4 and d=2)


Mortality M
Smooth Mortality M
Disability M
Smooth Disability M
Mortality F
Smooth Mortality F
Disability F
Smooth Disability F
hazard ratio, ref=23
1.0
1.5
2.0
2.5
20
25
30
35
40
BMI

Discussion

The debate about compression and expansion of morbidity suggested generic processes of the consequences of life extension and healthy life, expanding morbidity by increasing the numbers of frail elderly; compressing morbidity by increasing the numbers of healthy aged or a dynamic equilibrium between both.[5 24-26] The population of the HRS shows that such scenario's are risk factor specific. Comparable to previous analyses,[22 23] smoking shortens both disability free life and life with disability, the latter with 1.3 to 1.4 year. The hazard of disability of obesity is far higher than the hazard of mortality. Obesity in the HRS population shortened life free from ADL disability with 2.7 year (men) and 3.6 year (women), but increased the duration of ADL disability with 2.0 years (men) and 3.2 years (women). Total life expectancy changed little, but disability free life years were traded off for life years with disability. Education then showed a third scenario, where higher levels of education were correlated to higher life expectancy free of disability, not extending disability.

EPESE and the same HRS study documented loss of ADL disability free life expectancy among the obese.[10 16] We had the advantage of more data and longer follow-up, allowing for a more refined analysis. The EPESE study described people of 65 and older, [10] where we started at age 55. The HRS results disagree with earlier studies from the Framingham Heart Study cohort using the same methodology.[3 27] The most likely reason is the profoundly changed cardiovascular mortality, partly by successful risk management.[11 12] Obesity is associated with several potential disabling, but non-fatal conditions, such as osteoarthritis of the weight-bearing joints and chronic back pain.[28 29] Muscle strength declines with increasing adiposity.[10] The male/female differences may be explained by the higher prevalence of osteoarthritis, lower back pain and smaller muscle mass among women than for men.[30]

We used self-reported BMI, which tend to be underreported by 1 BMI point.[31 32] For epidemiological studies, this is sufficient.[33]
BMI is but a fair measure of adiposity and it does not reflect fat distribution. [31 34] However, it is easy to measure and widely used in health policy. Like many other studies we used the BMI reported at entry into the survey.[10 16]. The follow up of the HRS survey is too short to assess the effect of duration and change by age and cohort, which might be important.[35] Self reported

limitations on ADL compared to medical evaluation of activity performance have shown good correlations (r=0.88).[36] Defining disability as 2 ADL instead of 1 did not result in relative changes in the effect of obesity on disability.

The primary aim of this paper is observational and descriptive. We did not try to disentangle the intimate relationships of physical activity and obesity. Fatal or debilitating disease causing weight loss instead of the reverse, can never be fully excluded in observational studies. We assessed potential reverse causation by various sensitive analyses. None of these altered the results materially. Longer term weight loss, was associated with an increased, not a decreased life expectancy.

Several studies show that healthier people at baseline show lower mortality risks at lower BMI than less healthy people: among women, non-smokers, or those free from disease, BMI related to lowest mortality are lower.[37-40] As increased mortality among low normal weight is likely caused by smoking related disorders, lowered mortality among non-smokers and women of normal weight may be caused by a more prudent lifestyle, too, with weight control as a common characteristic. There was little interaction between smoking and BMI as cause of disability. There was a stronger correlation between increasing BMI and disability among persons reporting good or excellent health at baseline. Among those who reported poor or fair health (20% of population), BMI ceased to predict disability or mortality.

The obesity epidemic may be both exaggerated and underestimated.[8 9] The burden of spoiled years by obesity is now more important than the burden of lost years. Obesity ceased to be fatal, but a paradoxical consequence of lowered mortality is increased morbidity and care dependence, particularly among women where increased disability goes hand in hand with increased survival, both sharply increasing the numbers of years lived with disability. Fewer smokers and more quitters are another paradoxical source of future disability, adding life years with care dependence. The combination of aging, less smoking and increasing population BMI predicts a gloomy future of increasing disability. However, high levels of education promise a long and a long healthy life. The recent past saw technological innovation decreasing cardiovascular mortality and extending the lives of many obese people. Mortality is unambiguous and easy to measure. But, particularly for elderly, approaching death may be less troubling than survival in care dependence. ADL disability is relatively easy to measure and to interpret: extending disability free life may be a new worthy target.

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1. Centers for Disease Control and Prevention NCfHS. Health, United States, 2006 with chartbook on trends in the health of Americans., 2006.
2. York DA, Rossner S, Caterson I, Chen CM, James WP, Kumanyika S, et al. Prevention Conference VII: Obesity, a worldwide epidemic related to heart disease and stroke: Group I: worldwide demographics of obesity. *Circulation* 2004;110(18):e463-70.
3. Peeters A, Barendregt JJ, Willekens F, Mackenbach JP, Al Mamun A, Bonneux L. Obesity in adulthood and its consequences for life expectancy: a life-table analysis. *Ann Intern Med* 2003;138(1):24-32.
4. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the United States, 2000. *JAMA* 2004;291(10):1238-45.
5. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA* 2005;293(15):1861-7.
6. McGee DL. Body mass index and mortality: a meta-analysis based on person-level data from twenty-six observational studies. *Ann Epidemiol* 2005;15(2):87-97.
7. Bonneux L, Reuser M. Overweight and mortality risk: no connection between overweight in middle and older age groups and increased mortality [in Dutch]. *Ned Tijdschr Geneeskd* 2007;151(50):2764-9.
8. Jeffery RW, Sherwood NE. Is the obesity epidemic exaggerated? No. *BMJ* 2008;336(7638):245-.
9. Basham P, Luik J. Is the obesity epidemic exaggerated? Yes. *BMJ* 2008;336(7638):244-.
10. Al Snih S, Ottenbacher KJ, Markides KS, Kuo Y, Eschbach K, Goodwin JS. The effect of obesity on disability vs mortality in older Americans. *Arch Intern Med* 2007;167(Apr. 23):774-780.
11. CDC. Decline in deaths from heart disease and stroke--United States, 1900-1999. *MMWR Morb Mortal Wkly Rep* 1999;48(30):649-56.
12. Gregg EW, Cheng YJ, Cadwell BL, Imperatore G, Williams DE, Flegal KM, et al. Secular trends in cardiovascular disease risk factors according to body mass index in US adults. *JAMA* 2005;293(15):1868-74.
13. Lawlor DA, Lean M, Sattar N. ABC of obesity: obesity and vascular disease. *Bmj* 2006;333(7577):1060-3.
14. Wild SH, Byrne CD. ABC of obesity. Risk factors for diabetes and coronary heart disease. *Bmj* 2006;333(7576):1009-11.
15. Andreyeva T, Sturm R, Ringel JS. Moderate and severe obesity have large differences in health care costs. *Obes Res* 2004;12(12):1936-43.
16. Reynolds SL, Saito Y, Crimmins EM. The impact of obesity on active life expectancy in older American men and women. *Gerontologist* 2005;45(4):438-44.
17. Sach TH, Barton GR, Doherty M, Muir KR, Jenkinson C, Avery AJ. The relationship between body mass index and health-related quality of life: comparing the EQ-5D, EuroQol VAS and SF-6D. *Int J Obes* 2007;31(1):189-96.
18. Sturmer T, Gunther KP, Brenner H. Obesity, overweight and patterns of osteoarthritis: the Ulm Osteoarthritis Study. *J Clin Epidemiol* 2000;53(3):307-13.
19. Juster FT, Suzman R. An Overview of the Health and Retirement Study. *The Journal of Human Resources* 1995;30(0):7-56.

20. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of Illness in the Aged. the Index of Adl: a Standardized Measure of Biological and Psychosocial Function. *JAMA* 1963;185:914-9.
21. Centers for Disease Control and Prevention NCfHS. National Vital Statistics Reports. 2006;54(14).
22. Barendregt JJ, Bonneux L, van der Maas PJ. The health care costs of smoking. *N Engl J Med* 1997;337(15):1052-7.
23. Mamun AA, Peeters A, Barendregt J, Willekens F, Nusselder W, Bonneux L. Smoking decreases the duration of life lived with and without cardiovascular disease: a life course analysis of the Framingham Heart Study. *Eur Heart J* 2004;25(5):409-15.
24. Gruenberg EM. The Failures of Success. *Milbank Mem Fund Q Health Soc* 1977;55:3-24.
25. Manton KG. Changing concepts of morbidity and mortality in the elderly population. *Milbank Mem Fund Q Health Soc* 1982;60(2):183-244.
26. Olshansky SJ, Rudberg, M.A., Carnes, B.A., Cassel, B.A., Brady, J.A. Trading off longer life for worsening health: the expansion of morbidity hypothesis. *journal of ageing and health* 1991;3:194-216.
27. Peeters A, Bonneux L, Nusselder WJ, De Laet C, Barendregt JJ. Adult obesity and the burden of disability throughout life. *Obes Res* 2004;12(7):1145-51.
28. Must AS, J., Coakley E.H., Field, A.E., Colditz, G., Dietz, W.H. The disease burden associated with overweight and obesity. *JAMA* 1999;282:1523-1529.
29. Naumann Murtagh K, Hubert, H.B. Gender differences in physical disability among an elderly cohort. *American Journal of Public Health* 2004;94(8):1406-1411.
30. Lean ME, Han TS, Seidell JC. Impairment of health and quality of life in people with large waist circumference. *Lancet* 1998;351(9106):853-6.
31. Visscher TL, Viet AL, Kroesbergen IH, Seidell JC. Underreporting of BMI in adults and its effect on obesity prevalence estimations in the period 1998 to 2001. *Obesity (Silver Spring)* 2006;14(11):2054-63.
32. Nawaz H, Chan W, Abdulrahman M, Larson D, Katz D. Self-Reported Weight and Height. Implications for Obesity Research. *American journal of preventive medicine* 2001;20(4):294-298.
33. McAdams MA, van Dam, R.M., Hu, F.B. Comparison of self-reported and measured BMI as correlates of disease markers in U.S. adults. *Obesity* 2007;15:188-196.
34. Visscher TL, Seidell JC, Molarius A, van der Kuip D, Hofman A, Witteman JC. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord* 2001;25(11):1730-5.
35. Peeters A, Bonneux L, Barendregt J, Nusselder W. Methods of estimating years of life lost due to obesity. *Jama* 2003;289(22):2941; author reply 2941-2.
36. Hubert HB, Bloch DA, Oehlert JW, Fries JF. Lifestyle Habits and Compression of Morbidity. *J Gerontol A Biol Sci Med Sci* 2002;57(6):M347-351.
37. Adams KF, Schatzkin A, Harris TB, Kipnis V, Mouw T, Ballard-Barbash R, et al. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *N Engl J Med* 2006;355(8):763-78.

38. Calle EE, Thun MJ, Petrelli JM, Rodriguez C, Heath CW, Jr. Body-mass index and mortality in a prospective cohort of U.S. adults. *N Engl J Med* 1999;341(15):1097-105.
39. Kuriyama S, Ohmori K, Miura C, Suzuki Y, Nakaya N, Fujita K, et al. Body mass index and mortality in Japan: the Miyagi Cohort Study. *J Epidemiol* 2004;14 Suppl 1:S33-8.
40. Manson JE, Willett WC, Stampfer MJ, Colditz GA, Hunter DJ, Hankinson SE, et al. Body weight and mortality among women. *N Engl J Med* 1995;333(11):677-85.