BMI, age, and mortality: the slaying of a beautiful hypothesis by an ugly fact[1–3]

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Body mass index (BMI), more properly Quetelet's index, was developed by Lambert Adolphe Jacques Quetelet (1796–1874). Quetelet, a Belgian polymath, made contributions to astronomy, mathematics, sociology, anthropometry, and statistics. BMI first appeared in Quetelet's book, *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale* (On Man and the Development of His Faculties, or Essays on Social Physics) published in 1835 (1).

A metric that adjusts height for weight and is used to estimate obesity, BMI was little used in studies of best weight-for-height, and the studies raised little controversy until the late 1970s. At that time, Reubin Andres, Clinical Director of the National Institute on Aging, was asked to discuss best weight-for-height at a conference in Vichy, France (Amelia Andres, personal communication, October 2013). In the 1970s, the "definitive" works on best weight-for-height were tables published by the Metropolitan Life Insurance Company: 1941 Metropolitan Life Ideal Weight Men (2), 1942 Metropolitan Life Ideal Weight Women (3), and 1959 Metropolitan Desirable Weight Table (4). The tables provided weights by 1-inch increments in height for 3 frame sizes, small, medium, and large, for adults aged ≥25 y and indicated that weight should be unchanged through adult life. No guidance was given for determining a person's frame size. The tables' endorsed weights were based on the weights of insured lives ages 20–29 y. Subsequently, Metropolitan Life published additional weight-for-height tables. The tables, including the 1959 table, contained separate recommendations for men and women. The ages covered by the tables changed from ≥25 y to 25–59 y, and the recommended weights were slightly higher than those from 1940 and 1941. The tables did not call for an increase in weight with increasing age.

During preparation for his Vichy presentation, Andres reviewed the handful of articles that examined weight-for-height, 15 moderate-to-small populations (review of R Andres' laboratory books). He was subsequently invited to speak at the October 1980 Association of Life Insurance Medical Directors Annual Meeting at the Waldorf Astoria Hotel in New York City (5). Before speaking at the October meeting, Andres reviewed the Society of Actuaries' 1979 Build Study (6), which reported data from 25 US and Canadian life insurance companies. The data included heights and weights obtained at the time of issuance of ~4,200,000 life insurance policies along with mortality ratios (106,000 policies were terminated by the policy holders' deaths) for policies issued between 1950 and 1971. Converting height and weight to BMI,

Andres came to 5 conclusions (5, 7, 8): *1*) the association between BMI and mortality is U- or J-shaped, minimal mortality is toward the middle of the distribution of BMI values, and there is increased risk for mortality in subjects with lower and higher BMI values; *2*) the BMI associated with minimal mortality increases with age, ie, the best weight-for-height increases with age; *3*) accounting for smoking, preexisting disease, or early mortality had little effect on BMI at minimal mortality; *4*) the best BMI for a given age is the same in men and women, ie, there is no need for separate tables for men and women; and *5*) neither frame size nor relative weight are useful metrics, BMI should be used. The first 3 of these conclusions proved controversial because they questioned the "beautiful hypotheses" that *1*) increasing weight is associated with increasing mortality and *2*) weight should remain unchanged through adult life.

The article in the current issue of the Journal by Winter et al (9) is an important addition to the literature and an extension and update to the work of Andres. The study uses data that are considerably newer than those used by Andres. The study is large (197,940 subjects and 72,469 deaths), and the analytic method used (restricted cubic splines) requires a weaker a priori assumption about the shape of the relation between BMI and mortality than the quadratic regression performed by Andres. The authors show that in adults aged ≥65 y the relation between BMI and mortality is U-shaped. The BMIs (in kg/m^2) at minimal mortality in the analyses (ranging from ~26 to 28.9) are higher than currently endorsed values (10, 11) and do not differ by sex. Criticisms of earlier studies are addressed. The authors show that failure to account for smoking, or preexisting illness, excluding early deaths, with the use of measured compared with self-reported height and weight, or adjusting for intermediary factors, has little effect on the BMI at minimal mortality. Interestingly, although we do not know the mean age of the subjects

included in the article (all were aged $\geq$65 y), the findings in the current article are in almost perfect agreement with the findings reported by Andres ~35 y ago. The BMIs at minimal mortality for subjects 65–69 y of age, the oldest subjects reported by Andres, ranged from 26.3 to 28.

The analyses described by Winter et al (9) do not address optimally the question, Is the BMI at minimal mortality higher in older adults than in younger adults? The authors answer the question by comparing BMI values at minimal mortality in their subjects (all of whom were aged $\geq$65 y) with the BMI recommendations of the WHO (10). Because the BMI values associated with minimal mortality in subjects aged $\geq$65 y were higher than those recommended by the WHO, the authors believe they show that the BMI at minimal mortality is higher in older than in younger adults. A more direct approach to the question would have been to include adults of all ages in their analyses and to directly compare the nadir of the U-shaped curves in younger and older adults.

Given the findings of Winter et al, and the earlier work by Andres, it behooves us to reconsider current weight-for-height guidelines (10, 11). We must be open to the possibility that the hypotheses that *1*) increasing weight is uniformly associated with increasing mortality and *2*) that best weight-for-height in older adults is the same as that seen in younger adults may be wrong. We need to remember the aphorism of Thomas Huxley (12): "The great tragedy of science: the slaying of a beautiful hypothesis by an ugly fact."

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REFERENCES

1. Adolphe Quetelet. Wikipedia, the free encyclopedia; Available from: http://en.wikipedia.org/wiki/Adolphe_Quetelet (cited 2 January 2014).
2. Metropolitan Life Insurance Company. Ideal weights for men. Statistical Bulletin-Metropolitan Life Insurance Company 1942;23:6–8.
3. Metropolitan Life Insurance Company. Ideal weights for women. Statistical Bulletin-Metropolitan Life Insurance Company 1943;24:6–8.
4. Metropolitan Life Insurance Company. New weight standards for men and women. Statistical Bulletin-Metropolitan Life Insurance Company 1959;40:1–10.4.
5. Andres R. The obesity-mortality association: where is the nadir of the U-shaped curve? Trans Assoc Life Insur Med Dir Am 1980;64: 185–97.
6. Build study 1979. Chicago, IL: Society of Actuaries and Association of Life Insurance Medical Directors of America, 1980.
7. Andres R. Effect of obesity on total mortality. Int J Obes 1980;4:381–6.
8. Andres R. Mortality and obesity: the rationale for age-specific height-weight tables. In: Andres R, Bierman EL, Hazzard WR, eds. Principles of geriatric medicine. New York, NY: McGraw-Hill, 1985: 311–8.
9. Winter JE, MacInnis RJ, Wattanapenpaiboon N, Nowson CA. BMI and all-cause mortality in older adults: a meta-analysis. Am J Clin Nutr 2014;99:875–90.
10. Obésité: prévention et prise en charge de l'épidémie mondiale: rapport d'une consultation de l'OMS. [Obesity: preventing and managing the global epidemic. Report of a WHO Consultation (WHO Technical Report Series 894).] OMS. Ser Rapp Tech 1997:894 (in French).
11. National Heart, Lung, and Blood Institute; National Institute of Diabetes and Digestive and Kidney Diseases. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. NIH publication no. 98-4083. Bethesda, MD: National Institutes of Health; National Heart, Lung, and Blood Institute, 1998.
12. Presidential Address at the British Association. Biogenesis and abiogenesis, 1870. Available from: http://aleph0.clarku.edu/huxley/CE8/B-Ab.html. Later published in Huxley TH. Biogenesis and abiogenesis (The Presidential Address to the British Association for the Advancement of Science for 1870). In Discourses: biological and geological essays. Vol. VIII. New York, NY: D Appleton and Company; 1897;8:229–71 (c.f. p 244).