Body Mass Trajectory, Energy Balance, and Weight Loss as Determinants of Health and Mortality in Older Adults

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Key Words

Older adults · Overweight · Obesity · Energy balance · Mortality · Weight loss

Summary

The relationship between body mass (usually measured as BMI in kg/m²) and healthy longevity is a major focus of study in the nutrition and aging field. Over-nutrition now rivals frailty as the major nutritional concern; the number of older adults who are obese has increased dramatically in the past 3 decades. While obesity exacerbates a host of life-threatening, age-related chronic diseases, a somewhat paradoxical finding is that being somewhat overweight in old age appears to be a benefit with regard to longevity. In our recently completed systematic review of randomized controlled weight reduction trials, we found that weight loss interventions in overweight/obese older subjects led to significant benefits for those with osteoarthritis, coronary heart disease, and type 2 diabetes mellitus, while having slightly negative effects on bone mineral density and lean body mass. In contrast to this finding, the preponderance of epidemiological evidence indicates that higher BMIs are associated with increased survival after age 65 years. Because of this contradictory state of the science, there is a critical need for further study of the relationship of weight and weight loss/gain to health in the later years of life.

Introduction

Decades before the advent of the ‘obesity epidemic’, the relationship between body mass (expressed as BMI) and healthy longevity was a major focus of study in the nutrition and aging field. This interest was prompted by two critical observations about the interaction of energy balance and the aging process.

The first was the discovery, first made in the early part of the 20th century by McCay and colleagues [1], that the restriction of ad libitum intake of calories (termed caloric restriction or CR) delayed or prevented many age-related health decrements and produced remarkable increases in lifespan. This was first described in trout [1] and rats [2] and repeatedly confirmed in hundreds of studies in a variety of animal models over the ensuing decades to be due to a reduction of food energy intake (as opposed to increased energy expenditure) [3, 4]. The effect of CR in these non-human models was found to be most robust when initiated early in life. CR initiated after maturity produces more modest – although still beneficial – results in animals [5, 6]. Because of this, it has seemed that CR might never have practical applicability for human health as it would be unethical to study or apply CR during growth and development. Yet, because of its remarkable and seemingly universal effects on the aging process, CR has continued to be intensely studied in an array of non-human organisms [7, 8]. A literature search of the topic indicates close to 100 CR-related research papers published within the last year alone. Now the impact of CR on human health and longevity is being explored in an NIH(National Institutes of Health)-supported, multi-site, randomized controlled trial of 25% CR in normal weight women and men: the trial is ongoing, and some outcomes should be available within about 2 years (<http://calerie.dcri.duke.edu>).

While avoiding excessive body weight and adiposity benefits health during young and middle adulthood, the dramatic loss of body weight that often occurs near the end of life constitutes a second important issue for geriatric nutrition. In this circumstance, a significant loss of appetite occurs in the absence of a detectable change in medical status. A decreased food intake and a precipitous decline in body mass ultimately follow. The downward spiral is sometimes labeled with terms such as ‘failure to thrive’, ‘the dwindles’, or ‘nutritional frailty’ [9], and the process often culminates in death. The prevalence of nutritional frailty in older patients and the fact that it is so

Fig. 1. Trends in the prevalence of obesity among US adults by age and gender from the National Health and Nutrition Examination Surveys, 1960–2002 [26].

intractable to therapy (responses to nutritional support are modest at best [10, 11]) have combined to reinforce concerns about the health effects of weight loss in obese older adults. A number of studies link weight loss with reduced longevity [12–14], even when the weight loss is voluntary (intentional), leading to serious safety concerns about weight reduction intervention for aged individuals who are overweight or obese [15]. To date, weight reduction interventions for these individuals remain controversial and are the focus of active study. In a later section of this paper, we summarize the evidence to date on the efficacy of weight reduction trials in obese older adults.

Overweight and Obesity: A New Challenge in Geriatrics

Until recent decades, the overriding concern in geriatric nutrition has been underweight and frailty – not obesity. But as heavier cohorts of adults continue to move into old age there are many health concerns related to positive energy balance and increased adiposity. Underweight, including its nutritional component, has been extensively explored in other literature [9, 16–19]. Thus, the remainder of this review will focus on the newer, less understood issue of obesity in older adults. As already noted, there is some uncertainty about the BMI level at which detrimental health effects begin to occur in older adults; it is likely higher than for younger individuals [20]. However, as we present the literature on this topic, we will of necessity

use the accepted nomenclature that defines overweight as a BMI in the range of 25.0–29.99 kg/m² and obesity as a BMI ≥ 30 kg/m².

The effects of the global epidemic of obesity are being seen in all age groups, including older adults [21–25]. In the USA, representative surveys show that the number of older (≥55 years) adults who are obese has increased dramatically since 1976 (fig. 1) [26]. Rates are highest in the 55- to 64-year-old group, but the prevalence in the 65- to 74-year-old age group follows closely. Even the cohort ≥75 years of age has shown a recent spike in prevalence [26]. Rates of increase are similar for men and women, but the prevalence is higher in women. There are large racial/ethnic differences in the prevalence of obesity in the USA, especially among women. However, the rate of the recent increase in prevalence has been similar across racial/ethnic groups. The prevalence in 2003–2004 among those ≥60 years of age was highest among black women (50.3 vs. 33.7% for white women). In contrast, the prevalence of obesity among Asian Americans was only 5% [26].

Trends toward increased obesity in the older population are not limited to the USA but are also being reported in Europe [27, 28] and Asia [29]. The Survey of Health, Ageing and Retirement in Europe (SHARE) collected data on Europeans >50 years from 10 countries in 2004. The overall prevalences of moderate obesity (BMI 30–34.9 kg/m²) and severe obesity (BMI ≥ 35 kg/m²) were 13.3 and 2.9% in men and 13.5 and 4.3% in women, respectively [30]. The prevalence of moderate and severe obesity varies by country but we are seeing a

Fig. 2. Prevalence of obesity among adults >50 years old from 10 European countries by gender from the Survey of Health, Ageing and Retirement in Europe, 2004 [30].

global shift from concerns about threats to health from undernutrition to the challenges of obesity-related chronic disease (fig. 2). Even in countries with emerging economies and substantial income and health disparities, we see a ‘dual burden’ to health of undernutrition *and* obesity. In fact, in many of the developing countries studied by Mendez et al. [31] (women in 36 countries in Africa, Latin America, the Caribbean, Asia, and the Middle East), overweight is exceeding underweight as a nutritional problem. Additionally, the problem of obesity in the oldest old is recognized as a growing problem in nursing homes/long-term care residences [32]. In the USA, the proportion of obese nursing home residents has rapidly increased from <15% in 1992 to >25% in 2002 [33].

BMI as a Determinant of Mortality

For reasons already mentioned, the interaction of body mass with longevity has been extensively explored via numerous ep-

idemiological surveys. Studies of the overall adult population have yielded the now well-known U- or J-shaped relationship [34]. As illustrated in the findings of Calle et al. [35] in figure 3, individuals with the highest or lowest relative weight have shorter life spans than those with more intermediate BMI levels. However, this relationship shifts somewhat with age, becoming more U-shaped [36] and with an increase in the BMI level that is associated with the lowest rates of mortality [37, 38]. In fact, many of the studies focusing on older subjects have found little effect on mortality risk due to overweight/obesity [39–41] or even an inverse relationship [42, 43], raising questions about the nature of the BMI influence in later life [44]. This is true even when studies carefully exclude smokers and those who are ill or who become ill soon after the weight assessment – i.e. those who are suspected to have unintentional weight loss. Thus, while both thinness and overweight are detrimental to longevity, there seems to be a decline in the importance of obesity with aging. In fact, it has been suggested that in the older population obesity-related death may be less of a threat than obesity-related disability [39, 45].

BMI as a Determinant of Health Status

As the debate continues concerning the optimal BMI for longevity, obesity should not be underestimated as a determinant of illness and functional impairment in older individuals. As illustrated in table 1, obesity exacerbates a host of life-threatening age-related conditions including glucose intolerance, cardiovascular disease (CVD), hypertension, and some cancers. In the SHARE 2004 study, obese men and women were significantly more likely to have diabetes, high cholesterol, hypertension, and arthritis when compared to normal weight individuals, irrespective of country [30]. However, in the same analysis, obesity was linked to increased rates of depression only among women [30]. The fact that obesity increases the risk of functional disability is also increasingly recognized and documented [46–48].

Obesity also causes detrimental effects in financial terms, resulting in higher levels of health care spending. In general, obese older adults are more likely to have chronic medical conditions and higher levels of disability. In a simulation analysis using data from the longitudinal cost and use files of the Medicare Current Beneficiary Survey (MCBS) from 1992 to 2001, overweight and obese individuals were found to have higher average lifetime inpatient, outpatient, and prescription drug spending. For women, the overweight and obese cohorts had higher lifetime long-term care spending. In contrast, for men, the average lifetime spending on long-term care was the reverse; overweight and obese individuals had lower lifetime expenditures than underweight and normal weight cohorts [49]. Overall, the average total health care expenditures of the male overweight and obese cohorts was 6 and 12.5% higher, respectively, than the normal weight male cohort [49]. For

Fig. 3. Multivariate relative risk of death from all causes for BMI by gender, smoking status, and disease history. The relationship between body mass index (BMI) and relative risk of death from all causes among men and women by smoking status and disease history is reprinted by permission from the original paper by Calle et al. [35] published in the *New England Journal of Medicine* in October 1999. The reference category was subjects with a BMI of 23.5–24.0 kg/m² and the 4 groups were mutually exclusive. Nonsmokers had never smoked.

females, the differences were 10.7 and 16.8% higher for the overweight and obese cohorts compared to those of normal weight [49]. In another study with somewhat different methodology, the economic cost of overweight and obesity was even greater [50].

Another important cost of obesity comes via its effects on quality of life for older adults. While age-specific studies are limited, surveys in the general population demonstrate a marked effect of obesity on Health Related Quality of Life (HRQOL) [51]. Recently published findings from the Look AHEAD (Action for Health in Diabetes) Trial demonstrated that overweight adults (mean age = 58.7 years) with type 2 diabetes mellitus (DM-2) who enrolled in the program and achieved significant weight loss also had a significant improvement in HRQOL [52]. And in a group of postmenopausal

Table 1. Health risks due to overweight and/or excess visceral adiposity in older adults

CVD, especially in men, with midlife gain [62, 63]
Hypertension [65]
Mobility-related disability [47, 67–69]
Certain cancers, e.g. colon, breast, endometrial, kidney [71–73]
Diabetes mellitus [22, 64]
Sarcopenia, via inflammation [66]
Osteoarthritis [70]

CVD = Cardiovascular disease.

women who lost at least 5 pounds during a diet and physical activity intervention, those who later regained their weight had decrements in mental health and social functioning scores [53].

The positive attributes of overweight/obesity in late life should also be noted. They include a reduction in risk of osteoporosis-related fractures due to superior bone mineral density [54] (attributed, in part, to the bone-stimulating effects of bearing extra body weight) and protection from fracture by literally serving as protective padding, especially for the hip. Excess adiposity in later life may also provide benefit by serving as an energy reserve in times of food deprivation or illness. A survival benefit of obesity has been shown in wasting diseases like end-stage renal failure, heart failure, chronic obstructive pulmonary disease (COPD), and other inflammatory wasting diseases [55, 56]. This ‘reverse epidemiology’ of obesity may occur because of a larger amount of energy stored as fat, slightly larger lean mass stores, and the influence of adiposity on the fuels of choice during negative energy balance. In times of energy deprivation, lean tissue is better preserved in persons with more substantial fat stores [57].

Health Impact of Weight Reduction in Obese Older Adults

Because of this uncertainty surrounding the net effect of weight loss on the health of overweight and obese older adults, we recently conducted a systematic review of studies examining the impact of intentional weight loss in adult subjects aged ≥60 years with a baseline BMI of ≥27 kg/m² [58]. We included only randomized controlled trials, excluding observational and non-randomized studies since, without random allocation, the apparent effect of weight loss can be distorted in either direction. We included only studies of ≥6 months duration that produced a weight loss from baseline of ≥3% and/or ≥2 kg. We used a baseline BMI cutoff for overweight or obesity of ≥27 kg/m² because of evidence that in older adults detrimental effects of excess body weight begin to be seen at this higher BMI level [20, 59]. We did not include mortality as an end-point since it cannot be practically studied in a randomized controlled trial but rather examined randomized controlled

Table 2. Findings of a systematic review of weight loss intervention trials in overweight and obese older adults [58]

Targeted medical condition	Main findings
Arthritis	<p>The ADAPT trial randomized 316 sedentary overweight and obese older adults (mean BMI $34.5 \pm 5.4 \text{ kg/m}^2$) with symptomatic knee osteoarthritis to dietary weight loss, exercise, combined diet and exercise, or control groups. The combined diet and exercise intervention resulted in significant improvement in physical function and knee pain [74, 75]. There was no improvement on the SF-36 mental health composite scale, but the 3 intervention groups resulted in significant improvement in their satisfaction with body appearance [74].</p> <p>The Physical Activity, Inflammation, and Body Composition Trial randomized 87 obese older adults (mean BMI 34.6 kg/m^2) with symptomatic knee osteoarthritis to diet and exercise or control groups and showed improved self-reported physical function, 6-minute walk time, and stair climb time [76]. The intervention group resulted in a reduction in both body fat and lean body mass [76, 77].</p>
Physical function	A study of 27 obese older adults (mean BMI 39 kg/m^2) with some baseline difficulty with physical function showed improvement in physical function with diet and exercise [78]. The intervention group had an improvement in fat mass, but no change in fat-free mass [78, 79].
Metabolic syndrome	Among 27 obese older adults (mean BMI 39 kg/m^2), the number with metabolic syndrome decreased 59% with a diet and exercise intervention and was unchanged in the control group [79].
Hypertension	The TONE trial randomized 585 overweight or obese (mean BMI 31.2 kg/m^2) adults to a reduced sodium diet, a weight loss and reduced sodium diet, a weight loss diet, or a control group. After 30 months there was statistically significant difference in the composite endpoint of high blood pressure, treatment with an anti-hypertensive medication, or a cardiovascular event in all of the intervention groups, but these results may not be clinically significant as there were no significant differences among the groups in the rate of cardiovascular events [80].
DM-2	29 overweight or obese (mean BMI 31.9 kg/m^2), sedentary older adults with DM-2 completed a randomized controlled trial in which they were randomized to a weight loss diet plus either high-intensity resistance training or flexibility exercises. The HbA1C improved $1.2 \pm 1.0\%$ in the resistance training group but did not change in the flexibility exercise group [81]. Lean-body mass increased in the resistance training group [81].

ADAPT = Arthritis, Diet, and Activity Promotion Trial; TONE = Trial of Non-pharmacological Intervention in the Elderly.

trials using medical diseases/conditions associated with obesity or with metabolic abnormalities as endpoints, namely CVD and inflammation, hypertension, DM-2, osteoarthritis and physical function, and osteoporosis.

We searched the PubMed database for English language articles containing each of 4 search domains: obesity (MeSH term or text word obese), weight loss (MeSH term), weight loss interventions (MeSH terms anti-obesity agents, bariatric surgery, exercise, or diet), and comorbidities (MeSH terms diabetes mellitus, osteoporosis, osteoarthritis, or CVD) and found 16 papers meeting the inclusion criteria. These trials employed diet and exercise to achieve weight loss and ranged in duration from 6 to 30 months. There were no trials on bariatric surgery or pharmaceutical agents that met our criteria. We found that the 16 articles we identified actually represented only 5 distinct trials, since some trials led to several published papers. The detailed findings of these trials are listed in table 2. Overall, our review findings showed that weight reduction in older subjects led to clinically significant benefits for arthritis, physical function, DM-2, and metabolic syndrome, while having slightly negative effects on bone mineral density and lean body mass.

Based on our review, considerable evidence supports the conclusion that weight loss can improve metabolic and functional status in older adults who are obese. While diet and

exercise are the intervention methods of first choice, in some cases other avenues (e.g. drug treatment, surgery) have been needed to achieve weight loss success in young and middle-aged adults. Unfortunately, systematic study of these interventions in obese older adults is lacking. For example, bariatric surgery has not been studied in randomized controlled trials in older adults. Available data come from retrospective cohort studies using Medicare claims or hospital discharge data [60, 61]. As an exemplar, one study showed that 2 years after surgery the mortality was 8.0% in the surgical group and 12.2% in the nonsurgical group for patients aged ≥ 65 . This improved mortality was despite a 1.55% 30-day mortality rate for those ≥ 65 years old compared with 0.53% in the nonsurgical group. Though the surgical mortality was higher for those over the age of 65 (1.55 vs. 1.27%), by 11 months the surgical group >65 years overcame the initial higher mortality. Specific positive outcomes in the surgical group included the decreased comorbidities of DM-2, hypertension, hyperlipidemia, and coronary artery disease at 2 years [61]. It should be underscored that this observational data is not sufficient to establish guidelines and recommendations for the use of bariatric surgery in older adults; rather, well-controlled interventional studies are needed to establish an evidence-based protocol for surgical treatment of obesity in older adults.

Recommendations for Future Research

There are many challenges ahead as we seek to better understand energy balance in aged individuals and cope with imbalances that can lead to obesity as well as frailty. Among these, we would highlight these important topics:

- *The fundamental impact of body mass on health and mortality*: Clearly, the current state of the science is ambivalent concerning the relationship of body mass to health over the life course. While being underweight is associated with increased mortality in older adults, the health impact of a higher than normal BMI in later life is not well defined. Optimal body mass may vary in the same person over time and/or between individuals according to gender, body composition, ethnicity, and medical status. The reverse epidemiology of the BMI relationship to mortality during illness must be recognized in this population, well known to be very prone to life-threatening chronic diseases. More studies are needed to better understand this phenomenon before recommendations can be made. In fact, a call for increased study of associations between body mass and health in old age was recently issued (November, 2008) by an international working group [36], and we concur with that recommendation. In particular, we agree that research should go beyond BMI and consider the specific effects and interactions of age-related changes in body composition, e.g. fat and muscle mass. It may also be important to examine disease-specific relationships of BMI and survival.
- *Clinical interventions to reduce adiposity and achieve a healthy body composition in older adults*: It has been suggested that the most common phenotype of frailty in the future may be the disabled, obese older individual [36]. With obesity in older adults being associated with greater risk of disability but not necessarily greater mortality, the future could hold an increasing burden of caring for large numbers of disabled individuals [39] unless new interven-

tions can change these trends. While the interventional studies summarized in table 2 provide a valuable preliminary foundation of evidence, further study is needed regarding the safety, feasibility, effectiveness, and health outcomes of weight loss interventions in older obese adults. In addition to studies of diet and exercise interventions, pharmaceutical and surgical approaches should be examined as successful ones become available for younger cohorts. For example, the newer, minimally invasive laparoscopic procedures for bariatric surgery are likely to further enhance surgical interventions for obesity in older adults. We recommend that these interventions be carefully and systematically studied so that they can eventually be incorporated into evidence-based guidelines that are individualized to match the medical history and health priorities of older obese subjects [58].

- *Health services research on care delivery for obese older patients*: Even with strong interventional initiatives, we need to anticipate that large numbers of obese older adults will need medical care and long-term care in the decades ahead. The burden will be felt in many components of the health care delivery system, but probably nowhere more profoundly than in the long-term care/nursing home setting. A detailed discussion of many of the important information gaps, which include information about best clinical practices, considerations for health care staff, environmental adaptations, equipment needs, and psycho-social issues, is provided in a recent review [32]. In addition, we need surveys to help capture the numbers, demographic characteristics, and most prevalent medical diagnoses of future obese hospital and nursing home patients so that these facilities can be better prepared to provide care for these individuals.

Disclosure

The authors declared no conflict of interest.

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