Obesity and the Elderly

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Abstract: The prevalence of obesity is rising progressively, even among older age groups. By the year 2030 to 2035 over 20% of the adult US population and over 25% of the Europeans will be aged 65 years or older. The predicted prevalence of obesity in Americans, 60 years and older was 37% in 2010. The predicted prevalence of obesity in Europe in 2015 varies between 20% and 30% dependent on the model used. This means 20.9 million obese 60 years or older people in the United States in 2010 and 32 million obese elders in 2015 in EU. Although cutoff values of body mass index, waist circumference, and percentages of fat mass have not been defined for the elderly, it is clear from several meta-analyses that mortality and morbidity associated with overweight and obesity only increases at a body mass index $>30\,kg/m^2$. Thus, treatment should only be offered to patients who are obese rather than overweight and who have functional impairments, metabolic complications, or obesity-related diseases, that can benefit from weight loss. The weight loss therapy should minimize muscle and bone loss and vigilance as regards the development of sarcopenic obesity—a combination of an unhealthy excess of body fat with a detrimental loss of muscle and fat-free mass including bone—is important. Lifestyle intervention should be the first step and consists of a diet with a 500 kcal energy deficit and an adequate intake of protein of high biological quality, together with calcium and vitamin D, behavioral therapy, and multicomponent exercise. Multicomponent exercise includes flexibility training, balance training, aerobic exercise, and resistance training. The adherence rate in most studies is around 75%. Knowledge of constraints and modulators of physical inactivity should be of help to engage the elderly in physical activity. The role of pharmacotherapy and bariatric surgery in the elderly is largely unknown as in most studies people aged 65 years and older were excluded.

Key Words: obesity, ageing, lifestyle interventions, exercise, diet, sarcopenia, sarcopenic obesity, epidemiology

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In most countries there has been a rapid and continuing increase in life expectancy. By the year 2030, 20% of the adult US population will be older than 65 years.[1] In the 27 member states of the EU, the percentage of people aged 65 years or older will rise from 17.1 in 2008 to 25.4 in 2035 and to 30 in 2060.[2] From 2015 onwards deaths will outnumber births and roughly 2 active people (aged 15 to 65 y) will be caring for 1 inactive older person. This increase in life expectancy does not necessarily mean an increase in healthy life years but in extra years of illness proneness and chronic ill health. These demographics, together with the increased prevalence and severity of obesity, which shows an upward shift into older ages, signifies a double disease burden for the future. Obesity in the elderly (here defined as age 65 y or older unless otherwise stated) is thus an issue of serious concern.[3]

PREVALENCE OF OBESITY IN THE ELDERLY

The prevalence of obesity is rising progressively, even among older age groups. In the United States, it was estimated that the prevalence of obesity [body mass index (BMI) $\geq 30\,kg/m^2$] in elderly Americans, aged 60 years and older, would increase from 23.6% in 1990 and 32.0% in 2000 to 37.4% in 2010 (ranging from 33.6% in the best-case estimate to 39.6% in the worst-case estimate).[4] This signifies an increase in the number of obese older adults from 9.9 (1990) and 14.6 (2000) to 20.9 million in 2010 (range 18.0 to 22.2 million). Whether these projections are borne out is still unknown at present. The Behavioural Risk Factor Surveillance System provided data on 52 921 subjects aged 65 years and older, 20.3% of whom were classified as being obese.[5] In the age group 65 to 74 years, 25% had a BMI of $\geq 30\,kg/m^2$ which was significantly more than the 16.6% prevalence in the 75- to 84-year age group and the 9.9% prevalence in the ≥ 85-year age group.

In Europe, the prevalence of obesity increases with age to peak at about 60 years. Thereafter, body weights change little and begin to decline in older age. However, current trends indicate that the prevalence of obesity in this age group will increase. The Scottish Health Survey, for example, has recently shown that in the 10 years between 1998 and 2008, while the overall prevalence of obesity showed little increase, the BMI continued to rise between age 60 and 70, especially in women.[1] In that same period, waist circumference showed a 5 to 10 cm increase in both sexes at ages between 50 and 70 years. This disproportionate increase in waist circumference with a smaller increase in BMI in the Scottish Health Survey may indicate an unfortunate circumstance of gain in visceral fat mass and loss of lean tissue that are both major determining factors of ill health in the obese elderly. In France, the Obésité Epidémiologie survey 1997 to 2006 analyzed the obesity prevalence with age, period, and cohort as explanatory variables.[6] In those aged 65 years or older the prevalence of obesity was 17.9% and similar in both sexes. Morbid obesity (BMI $\geq 40\,kg/m^2$) was present in 1.1%. With older age, the prevalence decreased from 19.5% in those aged 65 to 69 years to 13.2% in those aged 80 years and older. An increased waist circumference, ≥ 102 cm in males and ≥ 88 cm in females, was present in 47.6% of subjects. An alarming finding in the Obésité Epidémiologie study is the acceleration in the prevalence of obesity for individuals born after the mid-1960s. In Spain, 35% of subjects aged 65 years or older suffered from obesity (30.6% of males and 38.3% of females) and 61.6% had an increased waist circumference (50.9% of males ≥ 102 cm and 69.7% of females ≥ 88 cm).[7] Morbid obesity was present in 1.2%. In

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the Netherlands, obesity was present in 18% of men and 20% of women aged 60 years or older, whereas 40% of men and 56% of women had an increased waist circumference ($\geq$ 102 cm for men and $\geq$ 88 cm for women).[8] The European Prospective Investigation on Cancer and Nutrition with participants aged 40 to 65 years in 1996, predicted a prevalence of obesity of about 30% in 2015 in a linear prediction model and of about 20% in a levelling off model.[9]

The obesity prevalence in nursing homes is also already a common problem.[5] A multistate study of newly admitted nursing home residents found an alarming 30% of adults aged 65 and older to have a BMI of $\geq$ 35.[6] Almost 30% of US nursing homes reported that 15% to 20% of the residents within the nursing homes were obese. Evidence suggests that obesity and weight gain increase the relative risk (RR) of nursing home admission for community-dwelling older adults. For those aged 65 to 74 years the risk of admission increased by 31%.[7] Those who were overweight and experienced a significant weight gain were 2 times as likely to be admitted to a nursing home.[8]

PATHOPHYSIOLOGY OF OBESITY IN THE ELDERLY

Ageing is associated with important changes in body composition and metabolism.[10–13] Between age 20 and 70, there is a progressive decrease of fat-free mass (mainly muscle) of 40% with a relatively greater decrease in peripheral fat-free mass than in central fat-free mass, whereas fat mass rises with age. After age 70, fat-free mass and fat mass decrease in parallel. The fat distribution changes with age such that there is an increase in visceral fat that is more marked in women than in men. Also, fat is increasingly deposited in skeletal muscle and in the liver. The higher visceral fat is the main determinant of impaired glucose tolerance in the elderly. Increased intramuscular and intrahepatic fat contribute to impaired insulin action through locally released free fatty acids. Increased pancreatic fat with declining β-cell function also plays a role.[14]

Because of the loss of skeletal muscle, the basal metabolic rate declines with 2% to 3% per decade after age 20, with 4% per decade after age 50, corresponding to approximately 150 kcal/d (630 kJ/d), and overall with 30% between age 20 and 70.[15] This, together with a decreased intensity and duration of physical activity as well as decreased postprandial energy expenditure due to a decreased fat oxidation, accounts for the decreased energy expenditure with ageing.

Both obesity and ageing are characterized by a low-grade inflammatory state and by endocrine changes. Central and visceral obesity is more proinflammatory than global obesity.[16] The low-grade inflammatory state is associated with decreased lean body mass, reduced immune function, cognitive decline, insulin resistance, and several correlates of metabolic control and insulin resistance such as increased levels of tumor necrosis factor (TNF)-α, interleukin (IL)-6, and C-reactive protein (CRP). TNF-α and IL-6 have catabolic effects on muscle mass and are involved in sarcopenia, a steady and involuntary loss of skeletal muscle mass with ageing resulting in decreased physical performance, mobility disability, and frailty.[10,11,17–19]

Endocrine changes related to obesity in the elderly include changes in gonadal steroids and thyroid hormones.[10,20] Decreased growth hormone and insulin-like growth factor-1 (IGF-1), leptin and insulin resistance, and downregulation of ghrelin are also present. The changes in hormones that occur with normal ageing seem to be exaggerated in the presence of abdominal obesity and insulin resistance.[10]

HEALTH CONSEQUENCES OF OBESITY IN THE ELDERLY

It is far from clear that which measure of adiposity best predicts the impact of obesity on health outcomes in the elderly. BMI, which correlates with body fat in the young and middle-aged, can either underestimate the degree of fatness in older people because of changes in body composition or overestimate it because of loss of height from vertebral compression and kyphosis. So, the relationship between BMI and disease risk is less close in the elderly than in younger people. Moreover, the effect of ageing on body fat distribution (increased omental and mesenteric fat and intramuscular and intrahepatic fat deposition) increases risks of insulin resistance. Waist circumference, which correlates highly with total fat and intra-abdominal fat might better predict adverse health effects of obesity in the elderly but there are insufficient data to define appropriate cutoff values for the elderly.

The National Institute of Health (NIH) guidelines, published in 1998, suggested that a 70-year-old person with a weight of 64 kg and a height of 1.6 m (BMI 25 kg/m^2) and one of the mentioned risk factors (such as established coronary heart disease, hypertension, impaired glucose tolerance, dyslipidemia, etc.) would be a candidate for weight loss.[21] This was questioned by Heiat et al[22] in 2001 and by Janssen and Mark in 2007.[23] Heiat et al[22] reviewed 13 articles that reported the association between BMI and all-cause and cardiovascular mortality in nonhospitalized subjects older than 65 years with a follow-up of more than 3 years. They did not find support for overweight conferring an excess mortality risk and found a small relative mortality risk in higher BMI ranges (RR of 1.15 to 1.34 with BMI 28 to 29 kg/m^2 and a RR of 1.31 to 2.0 with BMI 30 to 35 kg/m^2). The relation between BMI and all-cause mortality was described as a U-shaped curve with a large flat bottom and a right curve that started to rise from a BMI > 31 to 32 kg/m^2. Janssen and Mark[23] performed a meta-analysis of 28 articles on the association of BMI and all-cause mortality in subjects 65 years and older with a follow-up of at least 1 year. They found that a BMI in the overweight range was not associated with an increased risk and that a BMI in the moderately obese range carried a modest increased risk [risk estimate 1.10 (1.06/1.13)], which was marginally higher for women [risk estimate 1.18 (1.13/1.24) vs. 1.10 (1.02/1.18) in men]. So, the threshold value at which BMI confers mortality risk is higher in the elderly than for younger adults. Longitudinal studies published after these meta-analyses have confirmed this.[24–28]

These findings suggesting that a higher BMI value predicts a lower relative mortality in older adults (the obesity paradox) should not mask the harm from obesity to the elderly. Although the RR of mortality and decreased survival seem to decrease at ages above 59, the absolute mortality risk increases with increasing BMI till age 75.[12,13,29] Additional confounding factors contribute to underestimating the health risks of obesity in the elderly and the obesity paradox.[11] These include the survival effect (the presence of "resistant" survivors in whom the relation between BMI and mortality is lost), competing mortalities,

relatively shortened life expectancy in the old age, and the importance of age of onset and duration of obesity, as those who became obese in old age may die before the adverse effects of obesity become apparent. Also, smoking, weight change (weight gain and weight loss may be more detrimental than stable weight), and unintentional weight loss may confound the estimation of health risks. The underlying disease (reverse causation), physical activity and cardiorespiratory fitness (a lean unfit may have a higher mortality than an obese fit subject), fat distribution (unknown in many studies), and length of follow-up (as with shorter duration no association between obesity and mortality is evident) also play a role.[11,27] Thus, the inverse relation between BMI and mortality (the obesity paradox) observed in a recent study of US veterans aged 40 to 70 years at entry could be explained by some of the abovementioned factors: reverse causation, veteran effect (becoming obese after discharge from the service), survival effect, and being a healthy obese.[28] Furthermore, the high fitness state despite a high BMI may have biased the generalizability of these findings.[27,28,30]

Medical complications of obesity in the elderly are mainly concentrated around the metabolic syndrome (with glucose intolerance, hypertension, dyslipidemia, and cardiovascular disease). The metabolic syndrome peaks at age 50 to 70 in men and age 60 to 80 in women with an odds ratio (OR) of 5.8 in 65-year-old men and 4.9 in 65-year-old women compared to 20- to 34-year-old subjects.[31] The metabolic syndrome is a recognized risk factor for stroke, but is also related to subclinical ischemic brain lesions, placing the subjects at risk for future cognitive impairment.[32] A recent meta-analysis suggests the existence of a significant U-shaped association between BMI and Alzheimer disease and vascular dementia.[33,34] Obesity also increases the risk of heart failure, and estimates suggest that having a BMI $\geq 30\,kg/m^2$ doubles the risk.[35] Waist circumference and percentage body fat also predicted this risk.[36] Other obesity-related disorders are (osteo)arthritis (with an OR of 4.8 for men and 4.0 for women), pulmonary dysfunction including the obesity hypoventilation syndrome and obstructive sleep apnea syndrome, certain cancer types, reduced cognitive skills, sexual dysfunction, and urinary incontinence.[1,13,29,37–39] Obesity may also contribute to cataract formation and the progression of age-related macular degeneration.

The obese elderly are also likely to have functional limitations because of decreased muscle mass and strength and increased joint dysfunction, disabilities of activities of daily living, frailty, chronic pain, and impaired quality of life.[1,13,40,41] Unintentional injuries such as sprains and strains occur more often.[42] Obesity is an important risk for frailty either through increased levels of inflammatory markers or through sarcopenia (OR 3.5 in 70- to 79-y-old women).[43]

Obesity can have beneficial effects (through endocrine effects of insulin, leptin, and oestrogens on stimulating bone growth and inhibiting bone remodeling) that can result in preserved or higher bone mineral density, a lower risk of osteoporosis and hip fractures, and a cushioning effect of fat around the trochanter that can provide protection against hip fracture during a fall.

WHO SHOULD LOSE WEIGHT AND WHAT ARE THE CONCERNS?

The considerations above do not directly inform about the risks or benefit of intentional, therapeutic weight loss. Few data (outside of bariatric surgery) provide long-term prospective outcome data even in the young and middle-aged; there are very few data in the elderly. In 2005, the American Society of Nutrition and the North American Association for the Study of Obesity revised the NIH guidelines of 1998 and recommended weight loss in the elderly only in case of obesity (BMI $\geq 30\,kg/m^2$) combined with weight-related comorbidities or functional limitations.[12,13,21]

Adverse effects of intentional weight loss (such as the loss of bone mineral density and loss of fat-free tissue) should be taken into account (Table 1).[44] At least in the nonoverweight elderly, weight loss and a decrease in fat mass may be associated with an increased risk of hip fractures.[45,46] In young adults 75% of diet-induced weight loss is composed of fat tissue and 25% is composed of fat-free tissue. The relative amount of diet-induced weight loss as fat-free mass, and fat mass in older men and women is similar to that observed in younger adults.[47,48] Therefore, diet-induced weight loss does not produce a proportionally greater loss of lean tissue in older patients. This moderate loss of lean body mass is not relevant in obese subjects who not only have more fat mass but also more muscle mass to support the body and to enable movements and physical exercise with a heavier body weight. However, a specific condition in the elderly has been described that may contradict this reassurance. The term sarcopenic obesity was coined in 2004 by Roubenoff used to characterize the confluence of excess fat coexisting with low lean body mass including both muscle and bone.[18,49,50] In sarcopenic obesity, the proportion of muscle mass is low relative to the total weight. There is a loss of muscle quantity and quality with a decreased number and size of muscle fibers, with a reduced mitochondrial function, and a decreased synthesis of muscle protein. These changes result in a decreased functional capacity and quality of life; increased risk of disability, morbidity, and mortality; and increased risk of frailty and falls and loss of independency. The proinflammatory cytokines TNF-α and IL-6 produced in adipose

TABLE 1. Potential Benefits and Risks Related to Weight Loss in the Elderly[44]

Benefits	Risks
Reduced risk for developing type 2 diabetes in subjects with impaired glucose tolerance	Potentially increased mortality risk with unintentional weight loss and less with intentional weight loss
Improved glycaemic, lipid, and blood pressure control Reduced cardiovascular risk	Loss of muscle mass (sarcopenia) if not combined with regular exercise
Potentially reduced mortality risk from cardiovascular disease with intentional weight loss	Loss of mineral bone density, osteoporosis, and increased risk of fractures
Improved respiratory function and obstructive sleep apnea control	Increased risk of specific protein and vitamin deficiencies
Improved functional capacity and ability of activities of daily living, reduced musculoskeletal comorbidities	Increased risk of gallstone attacks (only in rapid weight loss)
Improved depressive symptoms, sense of well-being, and quality of life	

tissue stimulate the degradation of protein and induce muscle wasting and additionally, both sarcopenia and obesity are associated with a decrease in anabolic hormones such as testosterone and IGF-1.[10,18,20,50]

Obesity and sarcopenia in the elderly may potentiate each other, maximizing their effects on disability and morbidity. Baumgartner et al[51] demonstrated that obesity and sarcopenia were each strongly associated with disability (OR of obesity 1.34 in men and 2.15 in women; OR of sarcopenia 3.78 in men and 2.96 in women) but both combined were more strongly associated than either alone (OR 8.72 in men and OR 11.98 in women). The hazard ratio of a drop in 2 instrumental activities of daily living (IADL) over a 7-year follow-up period in the presence of sarcopenic obesity was 2.5 to 3.0 and this drop of 2 IADLs was associated with a more than 5 times higher mortality (28.6% vs. 5.6%) in the short term (1.5 vs. 2.3 y). These measures of physical capacity were self-reported. Bouchard et al[52] measured objectively the physical capacity in almost 900 subjects 68 to 82 years old. Obesity per se appeared to contribute more to a lower physical capacity than sarcopenia.

Identification of elderly subjects with sarcopenic obesity is clinically relevant but difficult. Muscle strength is more important than muscle mass as a determinant of functional limitation and poor health. Measuring muscle strength (handgrip dynamometry) is easier, cheaper, and clinically more relevant than measuring muscle mass (by dual-energy x-ray absorptiometry, computed tomography scan, or bioelectrical impedance analysis). In studies using muscle mass as an indicator of sarcopenia, the prevalence of sarcopenia ranges from 4% to 12%.[53,54] On the basis of BMI and handgrip strength, sarcopenic obesity can be roughly estimated between 4% and 9%.

So, weight loss recommendations are restricted to elderly patients who are obese and who have functional limitations or metabolic complications that may benefit from weight loss by a weight loss therapy that minimizes muscle and bone loss.[10,12,13] Assessment of body composition is particularly important in determining if an older individual will benefit from intentional weight loss. It may also safeguard against excessive lean body mass loss.

TREATMENT OPTIONS IN THE ELDERLY

Obesity-related complications such as diabetes, hyperlipidemia, and hypertension should be treated. This treatment should be adapted to age. The current therapeutic tools available for weight management in the elderly are not different to those for weight management in general and include[12,13]:

1. lifestyle intervention involving diet, physical activity, and behavioral modification;
2. pharmacotherapy;
3. endoscopic interventions;
4. surgery.

Lifestyle Intervention

Lifestyle intervention should consist of a 500 kcal (2.1 MJ) deficit diet (range 500 to 1000 kcal (2.1 to 4.2 MJ)) with a sufficient amount of high-quality protein (1.0 g/kg), and adequate supplementation of calcium (1000 mg/d), vitamin D (10 to 20 mcg/d), multivitamins and minerals, combined with exercise and behavioral therapy.[12,13] Increased physical activity and regular exercise are not essential for achieving initial weight loss but help to preserve lean body mass, maintain weight loss, and prevent weight regain. Elements of aerobic exercise, resistance training, balance, and flexibility training may be of particular benefit in older persons because it improves physical function and frailty. Behavioral therapy includes self-monitoring, goal setting, social support, stimulus control, and relapse prevention.

The combination of a moderate energy-deficit diet, increased physical activity, and behavioral modification results in moderate weight loss of 0.4 to 0.9 kg/wk or 8% to 10% after 6 months, improved obesity-related medical complications and physical dysfunction with a small risk of treatment-associated complications.[12,13]

Evaluating the efficacy of lifestyle interventions must come from studies that specifically include only or at least a large number of elderly subjects. In the Diabetes Prevention Program obese men and women up to the age of 84 years were included to follow a program of moderate physical activity of at least 2.5 hours a week, a reduction in total dietary fat to $<25\%$ of total energy, coupled with sessions with a lifestyle counselor.[55] Every kilogram of weight loss through diet and exercise reduced the incidence of diabetes type 2 with 16% over a period of 3.2 years and with 3.3 cases per 100 patient-years in the 60- to 85-year age group, half of that obtained in the younger age group of 25 to 44 years of age. Systematic reviews of weight loss interventions in people aged over 60 years revealed significant changes such as improved glucose tolerance and physical functioning, a reduced incidence of newly developed diabetes, and significant benefits for those with osteoarthritis, diabetes, and coronary heart disease (Table 1).[38,44,56] Negative outcomes included slightly decreased bone mineral density and lean body mass. Research has tended to focus excessively on cardiovascular risks but insufficiently on the multiple effects of obesity on mobility, bladder function, sexual health, mood, and quality of life that determine the everyday life of the elderly.[1]

Lifestyle Intervention: Feasible in the Frail Elderly?

Changes in the lifestyle of older persons present special challenges. An increased burden of disease, adverse quality of life, cognitive dysfunction and depression, isolation, loneliness, widowhood, dependency from others, and institutionalization may make it difficult to change the lifestyle.[12,13] Chronic disability, reduced physical and exercise capacity may interfere with the desired increase in physical activity. Also, obstacles such as impaired vision and hearing and limited financial resources are faced by older adults. In several small clinical trials, the group of Villareal and colleagues from Washington randomized obese and frail subjects to a control group and a group receiving lifestyle intervention. Lifestyle intervention consisted of a 750 kcal (3.15 MJ) deficit energy-restricted diet, behavioral modification, and a multicomponent exercise program, 3 times 90 min/wk. These studies were of short, 6 months', duration. In subjects with coronary heart disease and the metabolic syndrome, the intervention group achieved a greater weight loss and fat mass loss with significant improvements in all the components of the metabolic syndrome, and in CRP and IL-6 blood levels.[57] In frail subjects the intervention reversed frailty, increased muscle strength and quality, and improved static and dynamic balance tests.[58] Lifestyle intervention improved the pancreatic β-cell and α-cell function, increased the insulin clearance, and doubled the insulin sensitivity.[59] The only adverse effect consisted of

an increased bone turnover and a 2% to 3% decrease of hip bone mass.[60]

Very recently, Villareal et al[61] reported the results of a larger group of 107 frail obese elderly subjects followed for 1 year. Patients were randomized into a control group, a diet group with a 500 to 750 kcal (2.1 to 3.15 MJ) deficit diet with 1 g protein/kg/day, a multicomponent exercise group, and a combined diet plus exercise group. All subjects received a supplement of 1500 mg calcium and 10 mcg vitamin D. Compared to the control group, the diet group and exercise group reversed their state of frailty, but the combination of diet and exercise was more effective than either individual intervention alone. The best physical performance, functional status, and aerobic endurance capacity were achieved by the combined group. The loss of body weight and fat mass was similar in the diet group and the diet plus exercise group. The quality of life improved and the only potential adverse effect was a small reduction in lean body mass and bone mineral density in the diet group (-5% and -2.6%, respectively) and in the diet plus exercise group (-3% and -1.1%, respectively).

In the Arthritis, Diet, and Activity Promotion Trial 316 patients older than 60 years of age with osteoarthritis of the knee were randomized into 4 groups of healthy lifestyle, diet only, multicomponent exercise only, and a diet plus exercise group.[62] Weight loss was significantly greater in the diet only and the combined diet-exercise group. Measures of physical function improved but the improvements were the greatest in the diet plus exercise group. Pain scores were 6% less in the exercise group, 16% less in the diet group, and 30% less in the diet plus exercise group. These beneficial results became already apparent after 6 months and persisted during the 18 months of the study. Follow-up after 8 years demonstrated no increased mortality.[63] In fact, the groups randomized to diet or diet plus exercise had a 50% lower mortality than the groups just receiving advice on healthy lifestyle or exercise.

Nutrition and Diet

Diet-induced weight loss results in both a decrease in fat mass and fat-free mass and thus may exacerbate the age-related loss of muscle mass and further impair physical function. On the basis of intensive research concerning sarcopenia (age-related reduction in skeletal muscle mass in the elderly) and sarcopenic obesity, dietary guidelines were adjusted to prevent sarcopenic obesity and to guide the medical profession in their support of weight loss in the presence of sarcopenic obesity.[12,13,18,19,64,65]

In healthy muscle, proteins and amino acids constantly turn over with equilibrium between protein synthesis and protein breakdown. Sarcopenia may be the result of increased rates of protein breakdown under the influences of cytokines produced in adipose tissue in a chronic state of low-grade inflammation. It may also be the consequence of diminished protein synthesis, which is partly due to the anorexia of ageing. Early satiety secondary to a decreased relaxation of the gastric fundus, an increased cholecystokinin release in response to fat intake, and increased leptin levels and declining testosterone levels in men may account for the anorexia of ageing and result in decreased food and nutrient intake.[66–68]

In the treatment of subjects with or being at risk of sarcopenic obesity, the energy deficit should be more moderate than usual [range of 200 to 750 kcal (840 to 3150 kJ)] with emphasis on a higher intake of proteins (up to 1.5 g/kg) of high biological quality. When restricting the energy intake, protein intake has to be maintained or increased as dietary protein and amino acids are the most effective means to slow or prevent muscle protein catabolism. To optimize the anabolic response to ingested high-quality proteins certain peculiarities of the old age have to be taken into account.[64,65,67,69] In contrast to youngsters, the elderly has a diminished anabolic response to proteins when they are coingested with carbohydrates. There is no evidence that coingestion of protein and fat affects protein anabolism. So, ageing in itself does not reduce the anabolic response to sufficient amounts of high-quality protein but it is the presence of carbohydrates that blunts this response, explained by the effects of insulin resistance on muscle protein synthesis. Exercise is important as even a modest bout of physical activity such as 45 minutes of treadmill walking is sufficient to restore the ability of insulin to stimulate protein synthesis.

Also, protein intake should be strategically timed at each meal to overcome other consequences of ageing such as the blunting of the anabolic response due to changes in digestion, gastric emptying rate, splanchnic uptake, and peripheral utilization. Moreover, in contrast to the young, skeletal muscle in the old requires greater amounts of protein and amino acids to stimulate protein synthesis to a similar extent as that of the young.[64] Protein supplementation increases satiety which is a beneficial side effect to reduce hunger to comply with an energy-deficient diet. Excessive protein intake should be avoided in renal function disturbances.[44]

Another potential strategy to enhance protein synthesis is the supplementation of essential amino acids and mixtures of arginine and glutamine or arginine and lysine have been tried.[70,71] Also, optimalisation of the leucine intake from a minimum requirement of 2 g/d to an optimum of 6 to 8 g/d is an option as leucine increases protein anabolism and decreases protein breakdown.[64,72] Leucine-rich foods are legumes (soybeans) and animal products (fish, beef). The addition of leucine to a mixed nutrient meal in older subjects resulted in an increase in muscle protein synthesis of 56%.[73] Also, supplementation of β-hydroxy-β-methylbutyrate (a leucine metabolite, 2 to 3 g daily) resulted in increased total body protein synthesis.[70,71]

Specific micronutrients that should be addressed are vitamin D, involved in protein synthesis and muscle health,[74,75] magnesium—hypomagnesemia is associated with insulin resistance—and vitamin B_6, vitamin B_{12}, and selenium that are associated with functional decline.[12,13] Pharmacological attempts to increase muscle mass by IGF, growth hormone, or testosterone posed significant potential side effects without consistent effects on muscle.[76] Also, the addition of recombinant growth hormone or nandrolone to a program consisting of an energy-restricted diet and exercise did not result in benefits in body composition or muscle performance.[77]

In obese older adults with a low muscle mass relative to body weight (relative sarcopenia), a 6-month intervention with a 440 kcal (1850 kJ) deficit diet and weekly behavioral therapy without physical exercise resulted in a 10% body weight loss and a 16.3% decrease in fat mass and a 5.6% decrease in fat-free mass.[78] The endurance capacity and exercise tolerance increased as did the cardiovascular and pulmonary efficiency. If these effects can be achieved just by a diet and behavioral therapy, why should one than add exercise to a diet?

Why Add Exercise to a Diet?

Several studies examined groups receiving an energy-restricted diet with or without exercise. Both treatments resulted in similar weight loss and loss of body fat and visceral fat. There were several reasons to add exercise to a diet:

- With added exercise higher basal and stimulated lipolysis was observed in abdominal and gluteal regions and serum levels of CRP and IL-6, indicative of chronic inflammation, decreased.[79]
- In frail old adults exercise added to the diet reduced the loss of fat-free mass and lean tissue mass and increased muscle strength, suggesting an improved muscle quality by a decreased muscle fat infiltration and a reduced inflammation.[80]
- The addition of exercise in elderly obese patients with impaired glucose tolerance or diabetes type 2 resulted in an attenuated loss of fat-free mass and muscle mass and prevented the loss of type 1 high-oxidative muscle fibers and type 2 aerobic or glycolytic muscle fibers.[81]
- In the diet plus exercise group improvements in endurance capacity, muscle strength, plasma triglycerides, and low density lipoprotein cholesterol and diastolic blood pressure were seen. The intrahepatic fat content decreased to a similar extent in both the groups, which was accompanied by a comparable improvement of insulin sensitivity.[82]

Finally, a systematic review and meta-analysis of interventions to achieve long-term weight loss in obese older people (aged 60 y or older, BMI $> 30\,kg/m^2$, follow-up > 1 y), reported that combined dietary advice and physical activity achieved the highest weight loss as well as a greater decrease in serum total cholesterol.[83] Weinheimer et al[84] performed a systematic review of the separate and combined effects of energy restriction and exercise on fat-free mass in middle-aged and older adults which is important for combating sarcopenic obesity. The addition of exercise to energy restriction clearly attenuated the loss of fat-free mass which went down from 24% to 11%. They confirmed (in the elderly) the findings of a 1995 meta-analysis in young adults where exercise added to energy restriction reduced the loss of fat-free mass from 25% to 12%.[85]

Physical Exercise

The American College of Sports Medicine recommends a multicomponent training exercise program (strength, endurance, balance, flexibility) to improve and maintain physical function in older adults.[86] Resistance training has been investigated as an approach to counteract sarcopenia in older adults by stimulating protein synthesis and causing muscle hypertrophy with increased muscle mass and muscle strength and with improved physical functioning and performance of simple and complex activities in older people.[87] Endurance training improves aerobic capacity. Most of the studies have a multicomponent program of 3 times/wk 90-minute sessions, consisting of 15 minutes of balance training, 15 minutes of flexibility, 30 minutes aerobic exercise, and 30 minutes of high-intensity resistance training.

To study the impact of each exercise modality more into detail, Davidson et al[88] randomized 136 (60- to 80-y-old) obese subjects into 4 groups: a control group, a group that had progressive resistance training, a group that performed aerobic exercise, and a group that combined progressive resistance training with aerobic exercise. After 6 months, body weight decreased by 0.6 kg in the resistance, by 2.8 kg in the aerobic, and 2.3 kg in the combined exercise group. Abdominal fat and visceral fat decreased and endurance capacity improved significantly in the aerobic and combined exercise group. Skeletal mass increased in the resistance and combined exercise groups only and also muscle strength improved. Insulin resistance improved by 31% in the aerobic group and by 45% in the combined exercise group, whereas it did not change in the resistance training group. The fear of a negative interference of endurance and resistance training was not substantiated.[89,90] The combination of progressive resistance training and aerobic exercise is the optimal exercise strategy for simultaneous improvement of insulin resistance and functional limitations in the elderly. Aerobic exercise only is a second best choice.

The importance of exercise was investigated in 2 studies. Frail old subjects, randomized to a diet or to exercise showed a weight loss of 7.1% after 12 weeks in the diet group and no weight loss in the exercise group.[91] Fat-free mass decreased by 4.8% as a result of weight loss and increased by 2.7% as a result of exercise. Exercise resulted in a significant decrease in cytokine expression (TNF-α, IL-6) in skeletal muscle and a significant increase of muscle growth factors and anabolism. Similarly, in 65- to 80-year-old, moderately frail, obese older adults exercise had no effect on body weight but caused major changes in body composition such as decreased fat mass and increased fat-free mass.[92] Endurance, muscle strength, and functional mobility increased significantly. Adding multicomponent exercise resulted in a 50% higher basal and postmeal protein synthesis rate.

Three meta-analyses examined the effects of physical activity on health-related quality of life in older adults.[93–95] None of these meta-analyses performed a separate subanalysis with respect to the presence of normal weight, overweight, or obesity.

Schlechtman and Ory[93] examined the Frailty and Injuries: Cooperative Studies of Interventional Techniques, a linked series of randomized trials focussed on the benefits of exercise in the frail elderly. Of the 4 SF-36 subscales, an improved emotional health with a trend toward improved social functioning was associated with physical activity. In a meta-analysis of 36 studies in old subjects without clinical disorders, 4 components of quality of life were examined.[94] Psychological well-being was significantly improved. Self-efficacy, overall well-being, and view-of-self tended to be improved in physically active subjects. A meta-analysis of 11 studies in community-dwelling older adults with all SF-36 scales demonstrated an improvement in the self-reported physical function.[95]

Why Add a Diet to Exercise?

Despite beneficial effects on body composition and insulin resistance only small amounts of weight loss can be obtained by exercise only. Is there additional benefit from adding a diet to exercise interventions?

In older obese adult with the metabolic syndrome, similar improvements of all components of the metabolic syndrome occurred in the exercise and exercise + diet group in the short term of 12 weeks, but the combination resulted in greater weight loss and subcutaneous fat mass loss.[96] In a large study, 288 older, obese adults with poor cardiovascular health were randomized to a successful ageing control arm, a physical activity, and an energy-restricted diet and physical activity arm for 18 months.[97] In the combined diet and physical activity group, subjects were losing more weight, were better able to maintain the lost weight, and had the best physical performance tests.

Barriers and Perceived Constraints to Participate in Physical Exercise

The Screening and Counselling for physical Activity and Mobility in Older People study examined 619 subjects of 75 to 83 years old and a BMI between 20 and 53 kg/m^2.[98] The objective was to examine what they felt as constraints to exercise and whether these perceived constraints explained physical inactivity. Compared to the nonobese elderly (BMI 20 to 29.9 kg/m^2), the moderately obese (BMI 30 to 34.9 kg/m^2) had twice the risk of inactivity and the severely obese (BMI $\geq$ 35 kg/m^2) 4 times the risk of inactivity. Poor health, pain, diseases, and tiredness explained 27% of the increased risk of physical inactivity. Fear and negative experiences such as the fear of falling, the fear of injury, exercise experienced as uncomfortable, and insecurity when exercising outdoors, contributed 23% to the increased risk of inactivity. All these factors entered in the model together with the item of having no interest in exercise explained 42% of the increased risk of physical inactivity. These factors were substantially more frequent among the severely obese.

A meta-analysis of 43 studies in 33,090 (60- to 70-y-old) subjects rejected the hypothesis that interventions to increase physical activity failed to be effective in older adults.[99] Several modulating factors were found that can be used to increase the physical activity amongst elders. One should only target physical activity and not couple this to health education. Also, one should focus on group activity, encourage moderate exercise intensity and activity, incorporate self-monitoring, and encourage centre-based activities with an intense contact with the interventionists at a structured time.

Pharmacotherapy

In most clinical trials older subjects are excluded. The average age of subjects ranged from 34 to 54 in a meta-analysis of pharmacotherapy.[100] Of the many drugs that were developed to treat obesity most have been withdrawn from the market and only Orlistat is currently approved for a longer period in patients with a BMI $\geq$ 30 kg/m^2 and in patients with a BMI of 27 to 29.9 kg/m^2 in the presence of obesity-related comorbidities.[101,102]

Orlistat, a lipase inhibitor, blocks the digestion and absorption of fat up to one third of the ingested amount, thereby causing an energy deficit of approximately 300 kcal/d (1260 kJ). The weight loss by Orlistat is 2 to 3 kg more than with placebo and results in improvement in glucose tolerance and blood pressure dependent on the rate of weight loss.[100,103,104] Moreover, Orlistat has a weight loss independent beneficial effect on dyslipidemia.[105]

Gastrointestinal side effects result from Orlistat's mode of action and consist of flatulence, fecal incontinence, oily spotting, urge, steatorrhoea, and abdominal cramps but are only likely to occur if high-fat meals (> 20 g fat/meal) are consumed. The absorption of fat soluble vitamins are reduced by Orlistat but while they do not fall into the deficiency range, is has been suggested that vitamin supplementation should be given to those on Orlistat for an extended period of time. When fat soluble vitamins are supplied such as vitamin D, they should be ingested 2 hours prior to the ingestion of Orlistat. Although more liquid stools may help the many constipated elders, they can cause fecal incontinence particularly as the elderly are more likely to have impaired internal and external sphincter function. The analysis of an older subpopulation of a 2-year randomized study in the primary care setting found that Orlistat was just as effective in adults aged 65 and more as in younger adults.[106,107] Also, the gastrointestinal side effects were not different in older than in younger subjects.[107]

Endoscopic Modalities

Because of a lack of choice of antiobesity drugs and the strict criteria of BMI before being a suitable candidate for surgery, there is large number of patients, that is, those with a BMI between 30 and 40 kg/m^2, without a clear patient-tailored step-wise treatment plan. In this vacuum endoscopic treatment comes into play and several modalities are available. As is true for pharmacotherapy, obese elderly subjects are excluded from most clinical trials. Intragastric balloons have been used in thousands of obese subjects but their ages varied between 31 and 43.3 years.[108] Weight loss and improvement of obesity-associated complications are in between those obtained by pharmacotherapy and surgery.[108–110] Defining successful weight loss by a weight loss of 10% of initial weight in 6 months and successful weight maintenance by the continuation of that weight loss over a period of at least 2 years, Negrin Dastis and colleagues achieved immediate success in 63%, and a 10% weight loss or more was maintained by 24% of patients in the long-term after 2.5 years and by 28% after a mean of 4.8 years.[111,112] Intolerance and gastrooesophageal reflux may be more important in the elderly and the first 3 days of vomiting, nausea, and abdominal cramps may not be tolerated by the elderly with a risk of developing hypokalemia and dehydration. The newly available adjustable balloons[113] might be an alternative. The Endobarrier, an endoscopically delivered duodeno-jejunal bypass device, is a unique concept that starts to ameliorate the symptoms of diabetes type 2 soon after its positioning.[114] Despite sufficient implant training, the positioning is difficult (2.9%) or impossible (5.8%) and the stability of the anchors and the tolerability of the device still leave much to be desired as in 25% of patients the Endobarrier is explanted early, because of dislocation, obstruction, physical symptoms, or gastrointestinal hemorrhage.[114] Intramuscular injections of botulinum toxin A in the gastric wall of the antrum are supposed to work by delayed gastric emptying, reduced compliance of the gastric wall, and increased satiety.[115,116] Studies reporting effective weight loss are mainly of short duration and a recent placebo-controlled double-blind trial showed no differences in weight loss.[117] Finally, new methods of gastric restriction such as the transoral gastroplasty and transoral endoscopic restrictive implant system and a gastroduodenojejunal bypass sleeve (ValenTx) have been abandoned or are still under investigation.[118,119]

Bariatric Surgery

Bariatric surgery is indicated for subjects with severe obesity and most guidelines suggest to include patients with a BMI $\geq$ 40 kg/m^2 or a BMI $\geq$ 35 kg/m^2 with comorbidity such as cardiorespiratory disease, diabetes, sleep apnea, and severe osteoarthritis, which are expected to improve by surgically induced weight loss. A more recent position statement from the International Federation of Diabetes suggests that a lower BMI threshold (> 30 kg/m^2) should be set for those with type 2 diabetes. Age limitations between 18 and 50 by the NIH Consensus Conferences in 1991 were widened over time to age 60.[43,120,121] With the improvement in intraoperative surgical management and optimalisation

of perioperative care, many centers offer bariatric surgery to patients who exceed this age limit. Retrospective data of operations, mainly performed by laparoscopy in the last decade, are shown in Table 2.[122–128] Older obese adults suffered from more comorbidities and required more medications prior to surgery than younger obese subjects. After bariatric surgery the eldery lost a significant amount of weight and this weight loss was associated with an improvement in obesity-related comorbidities and an overall reduction in medication requirements. Compared to older patients, younger adults lost more weight and had a higher level of resolution of obesity-associated diseases. With respect to mortality numbers were low and still in favor of operation when considering the observed-to-expected mortality ratio.[127] Also, the complication rate is low and related to underlying diseases and not to the operative technique or procedure itself. None of the mentioned studies provided data on the number of subjects in whom the surgeons declined to perform the operation because of major life-limiting processes or unacceptable cardiorespiratory risk factors or because surgical risks outweighed the expected benefits. Most of the enrolled subjects were females and according to a very recent study in veterans, sex difference should be taken into account.[129] No benefit in

TABLE 2. Outcome of Retrospective Studies in Bariatric Surgery

References	Age (y)	Elderly, N (%)	Non-elderly, N	Operation	BMI	Weight Loss	Follow-up	30-d Morbidity	30-d Mortality	Length of Stay	Remarks
Abu Abeid et al[125]	60 or older	18 (4.5%)	380	LAGB	44.4	13.7 BMI units	21.9 mo	0	0	1.2 d	4 late complications band slippage and dilation (reoperation)
Sosa et al[123]	60 or older	23 (4.2%)	527	L-GBP	48.5	65% EWL 16.5 BMI units	12 mo	4.3%	4.3%	2.0 d	Death due to cardiovascular collapse (1), complication rhabdomyolysis (1)
Sugerman et al[122]	60 or order	80 (2.8%)	2843	HGP,VGB, GBP, L-GBP	49.0	57% EWL 14 BMI units 50% EWL 14 BMI units	12 mo 60 mo	8.8%	0	ND	Complications: 4 infections, 2 leaks, 1 pulmonary embolus 44 late complications: 10 marginal ulcers, 5 stomal stenoses, 3 bowel obstruction, 26 incisional hernias
Quebbemann et al[126]	65 or older	27	ND	LAGB	ND	35% EWL	19.6 mo	0	0	0.8 d	Late complications: 1 port fracture; 1 no weight loss
				L-GBP	ND	71% EWL	9.3 mo	7.7%		1.9 d	1 stricture
St Peter et al[124]	60 or older	20 (15.4%)	110	L-GBP	46.4	28.3% 12.6 BMI units	9.7 mo	10%	0	2.9 d	Complications: 1 wound infection, 1 leak
Varela et al[127]	60 or older	1339 (2.7%)	47,936	LAGB, L-VBG, L-GBP	ND	ND	ND	18.9%	0.7%	4.9 d	Complications: pulmonary 4.3%, bleeding 2.5%; wound infection 2.5% Deaths due to cardiac, liver and kidney diseases
Dorman et al[128]	65 or older	1994 (4.1%)	46,384	LAGB, L-GBP, DS	46.8	ND	ND	65-69 4.3% ≥ 70 2.8%	65-69 0.4% ≥ 70 0.6%	> 6 d open 65-69 29% ≥ 70 50% > 3 d laparosc 65-69 23% ≥ 70 20%	8 deaths

BMI indicates body mass index; DS, duodenal switch; EWL, excessive weight loss; HGB, horizontal gastroplasty; LAGB, laparoscopic adjustable gastric banding; laparosc, laparoscopic surgery; L-GBP, laparoscopic gastric bypass; L-VBG, laparoscopic vertical banded gastroplasty, ND, no data provided; open surgery; VBG, vertical banded gastroplasty.

survival during a mean of 6.7 years of follow-up was observed in obese older men with obesity-related comorbidities, which could partly be explained by the shortness of follow-up but which might also be related to the fact that bariatric surgery appeared to be more difficult in severely obese male patients.

CONCLUSIONS

Obesity is a major public health problem. The population is growing older and the prevalence of obesity in the elderly is rising. Ageing and obesity are 2 conditions that represent an important part of health care costs. An increasing obese elderly population will undoubtedly offer growing financial problems to the health care system. Although not much is to be gained in life expectancy in the old age, obesity-related comorbidities and, in particular, obesity-related disabilities are of major concern as they may interfere with independency and activities of daily living and with quality of life. Increased health care and societal costs of treatment are justified by a lesser need for medication, a lower need of nursing home admission, and a better quality of the remaining life.

Although cutoff values of BMI, waist circumference, and percentages of fat mass have not been defined for the elderly, it is clear from several meta-analyses that mortality and morbidity associated with overweight and obesity only increase at a BMI above 30 kg/m^2 in the elderly. Thus, treatment should only be offered to patients who are obese rather than overweight (by BMI definition) and who have functional impairments, metabolic complications, or obesity-related diseases, that can benefit from weight loss. The weight loss therapy should minimize muscle and bone loss and vigilance as to the development of sarcopenic obesity should always be present.

Lifestyle intervention should be the first step and its effects are well studied in the obese elderly. This should consist of a balanced diet with a 500 kcal (2.1 MJ) energy deficit and an adequate intake of protein of high biological quality, together with calcium and vitamin D, behavioral therapy, and multicomponent exercise. Multicomponent exercise includes flexibility training, balance training, aerobic exercise, and resistance training. The adherence rate in most studies is around 75%. Knowledge of constraints and modulators of physical inactivity should be of help to engage the elderly in physical activity. The role of pharmacotherapy and bariatric surgery in the elderly is largely unknown as in most studies people aged 65 years and older were excluded.

Research on the definition of obesity in the elderly, on clinical tools to evaluate sarcopenia, on the optimal diet and the pharmacology of drugs in the obese elderly, as well as cost-benefit studies on the management of obesity in the elderly should be encouraged.

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