REVIEW

Body weight and body composition in old age and their relationship with frailty

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Purpose of review
Aging is associated with various changes in body composition, including changes in weight, loss of muscle mass, and increase in fat mass. This article describes the role of body weight and body composition, and their changes, in the risk of frailty in old age.

Recent findings
Based on current literature, observational studies on obesity and high waist circumference show most convincing results for an association with frailty. The independent role of muscle mass and muscle fat infiltration remains unclear, mainly due to a lack of studies and a lack of accurate measurement of body composition by computed tomography or MRI. Weight loss and exercise training intervention studies can be of benefit to frail older adults.

Summary
Obesity and high waist circumference may be important determinants of frailty in old age, whereas the role of muscle mass and muscle fat infiltration is still unclear. More prospective studies that will specifically focus on frailty as an outcome measure are needed to identify specific body composition components as potential targets for the prevention of frailty in old age.

Keywords
body composition, body mass index, frailty

INTRODUCTION

The frailty phenotype, proposed by Fried in 2001, includes unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity [1]. Frailty is associated with increased risk of morbidity and mortality. It is, however, still unclear which factors, in particular body composition measures, contribute to the risk of becoming frail.

Aging is often associated with changes in body weight. Body weight generally tends to increase during life up till the age of 70–80 years, after which a decline in body weight is observed. Furthermore, both underweight/malnutrition as well as obesity are frequently observed phenomena in old age. Aging is also associated with changes in body composition, wherein loss of muscle mass and increase in total fat mass occurs. In addition, subcutaneous fat mass decreases, whereas visceral fat, liver fat, and muscle fat infiltration generally increase with age. The increase in total fat mass and the loss of muscle mass are independent of changes in weight.

Monitoring weight among older adults is important as changes in weight may reflect declining health. Previous studies have shown that weight loss, weight gain, and weight cycling are associated with higher mortality risk, whereas weight loss showed the strongest associations [2]. In addition, unintentional weight loss is associated with increased risk of incident mobility disability old age [3]. Previous studies [4,5] have shown that better muscle composition, characterized by more muscle mass and less muscle fat infiltration, is associated with improved physical function and gait speed in general older populations. It has also been shown that more muscle fat infiltration is associated with higher mortality risk [6–8].

This review describes the role of body weight and body composition, and their changes, in the risk

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KEY POINTS

- There is a current lack of studies (both observational and intervention) that focus on frailty as an outcome measure.
- More prospective studies focusing on change in body composition and risk of frailty are warranted.
- Studies on BMI (obesity as well as undernutrition) and waist circumference show strongest evidence for an association with frailty.
- More studies with accurate measurement of body composition are needed to investigate the role of overall body fat, muscle mass, and muscle fat infiltration as an independent determinant of frailty.

of frailty in old age (Fig. 1). Evidence from high quality cross-sectional and prospective observational studies as well as intervention studies conducted in older adults are reported.

ROLE OF BODY WEIGHT: MALNUTRITION AND OBESITY

Several cross-sectional studies show that older adults (clinical outpatients as well as community-dwelling older adults) who are malnourished or at risk of malnutrition, according to the Mini Nutritional Assessment (MNA) tool, have a greater likelihood of being frail according to the Fried Frailty Index [9–11] and the Study of Osteoporotic Fractures frailty index [12]. However, these associations should be carefully interpreted as some items used in the MNA tool show overlap with items used in frailty index scores [13]. For example, recent weight loss is included in both the MNA tool and the Fried Frailty Index. This overlap may potentially cause an overestimation of the observed associations between malnutrition and frailty.

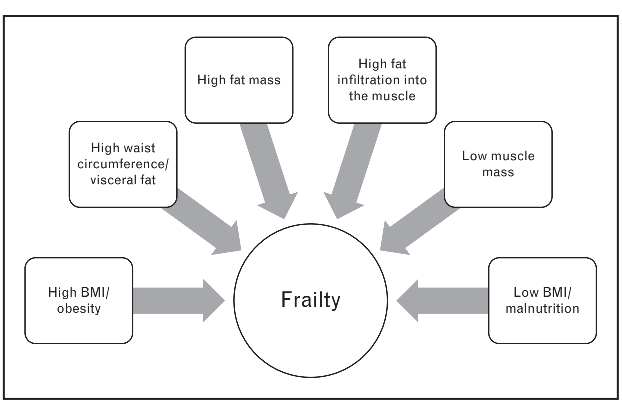

FIGURE 1. Potential body composition-related determinants of frailty in old age.

Cross-sectional studies also indicate that a lower BMI is associated with higher risk of frailty in older adults [11]. In a landmark study [14] that first described the cross-sectional link between obesity and frailty in old age, obesity (BMI $\geq$ 30 kg/m^2) was associated with a higher risk of prefrailty [odds ratio (OR) 2.23 (95% CI 1.29–3.84)] and frailty [OR 3.52 (95% CI 1.34–9.13)]. This study was conducted among 599 community-dwelling older adults aged 70–79 years. The association remained statistically significant after adjustment for multiple conditions and inflammation status [14]. Recent results among men aged 71–92 years from the British Regional Heart Study revealed that compared with nonfrail, those with frailty had a higher odds of being obese [OR 2.03 (95% CI 1.38–2.99)] [15]. In contrast, another study [16] showed no higher risk of frailty among obese [OR 0.81 (95% CI 0.38–1.73)] versus underweight/normal older adults after adjustment for age and sex among 255 older adults from elderly centers, although inclusion of underweight persons (who have a higher frailty risk) in the reference group may have contributed to this finding. A limited number of prospective studies investigated the association between BMI and incident frailty in old age. In a key study among 28 181 participants aged 65–79 years of the Women's Health Initiative Observational Study the associations between BMI and the risk of frailty were investigated during 3 years of follow-up. It was shown that obesity in old age was associated with an almost four-fold increased risk of developing frailty [OR 3.95 (95% CI 3.50–4.47)]. Furthermore, low BMI (<18.5 kg/m^2) also increased the risk of frailty [OR 1.65 (95% CI 1.11–2.45)] as compared to those with a normal BMI (18.5–24.9 kg/m^2) [17]. Other studies [18,19▪▪] showed that even overweight and obesity at young age and in midlife already predispose to frailty in old age, showing the importance of healthy body weight in young adults for the prevention of frailty at later life.

Few prospective observational studies examined the association of change in body weight in old age with frailty risk. A study among 622 Helsinki businessmen (mean age 73 years) showed that measured weight loss (i.e., those who moved from the BMI $\geq$25 to the BMI <25 kg/m^2 group) in the previous 26 years of life, increased the risk of frailty in the subsequent 12-year follow-up period more than three-fold [OR 3.7 (95% CI 1.3–10.5)] as compared to weight stability [20]. Unfortunately, weight change intention was not recorded. In contrast, those who increased in weight in the previous 26 years of life (i.e., those who moved from the

BMI <25 to the BMI ≥25 kg/m^2 group) did not increase their frailty risk [OR 0.6 (95% CI 0.2–2.5)] [20]. In a recent study from the Health and Retirement Study (10 827 older men and women, mean age 65.1 years, SD 9.7) it was investigated whether trajectories of BMI were associated with frailty over a 10-year period. Compared to persons who were consistently overweight, persons who gained weight between 2004 and 2012 had the highest likelihood to become frail [OR 3.61 (95% CI 2.39–5.46)]. Persons in the consistent obesity and weight loss trajectories also had an increased risk of frailty [OR 2.72 (95% CI 2.06–3.58) and OR 2.81 (95% CI 1.84–4.30)], respectively. Weight and height were self-reported and weight change intentions were not recorded in this study [21▪].

ROLE OF VISCERAL FAT

We are not aware of any studies that have specifically focused on visceral fat as measured by computed tomography (CT) imaging or MRI and the association with frailty. Therefore, results of waist circumference as a proxy for visceral fat will be described.

Pooled data from two population-based cohorts, the Seniors-ENRICA (older men and women aged 60 years and older) and the Toledo Study for Healthy Aging (older men and women aged 65 years and older) showed that persons with a large waist circumference (>102 cm for men, >88 cm for women) had an increased risk of being frail after 3.5 years of follow-up [OR 1.67 (95% CI 1.09–2.25)], after adjustments were made for demographics, lifestyle behavior, and chronic diseases [22]. However, adjustment for BMI attenuated this association and it became nonsignificant. Furthermore, it was also shown that individuals with a combination of obesity (BMI ≥ 30) and a large waist circumference had the highest risk of becoming frail [OR 2.55 (95% CI 1.23–3.86)]. Results from the British Regional Heart Study among men aged 71–92 years revealed that compared with nonfrail, those with frailty had a higher odds of having a high waist circumference [>102 cm, OR 2.30 (95% CI 1.67–3.17)] [15]. Additional studies, including a more specific determination of visceral fat using CT or MRI, are warranted to understand the relationship between visceral fat and frailty.

ROLE OF MUSCLE MASS AND MUSCLE FAT INFILTRATION

Muscle tissue contains muscle mass and fat infiltrated into the muscle. Muscle mass represents the actual muscle fibers with the primary function to establish locomotion and remain posture. Muscle fat infiltration can be distinguished in intermuscular adipose tissue and intramuscular adipose tissue. Intermuscular adipose tissue is the visible fat within the fascia surrounding muscles, whereas intramuscular adipose tissue is the lipid within muscle fibers.

Cross-sectional data from the Berlin Aging Study II showed that older adults with low appendicular lean mass (ALM) [measured by dual-energy X-ray absorptiometry (DXA)] divided by BMI (ALM_{BMI}) were at increased risk of difficulties in self-reported activities of daily living (ADL) limitations [23▪]. Furthermore, low ALM_{BMI} was associated with a 2.4 (95% CI 1.7–3.5) times increased risk of being prefrail or frail, based on the Fried Frailty Index, and was associated with an increased risk of the frailty components weakness, slow walking speed, and low physical activity. On the contrary, no associations with frailty or its components were found when low ALM divided by height^2 (ALM/height^2) was examined. These findings raise the question whether a high BMI (or more fat mass) rather than a low muscle mass is responsible for the strong increased risk of frailty.

Prospective studies investigating the association between muscle composition and (risk of) frailty are lacking. Instead, studies have investigated differences in muscle composition among frail versus nonfrail older adults. One small cross-sectional study among 42 older adults from Spain showed that, compared to nonfrail older adults, frail older men and women had lower-dense muscle tissue (indicating more muscle fat infiltration) [24]. Comparable results were observed among 26 older adults (eight frail and 18 nonfrail), in which the frail older adults had a lower muscle mass compared with their nonfrail counterparts (81.9 vs. 88.3%), and more muscle fat infiltration (18.0 vs. 11.7%) as assessed by MRI [25].

Small studies suggest that frail older adults have less muscle mass and more fat infiltration into the muscle compared with nonfrail older adults. However, as no studies investigated prospectively whether persons with low muscle mass or higher fat infiltration are at higher risk to develop frailty over time, the direction of the association remains unclear.

In this paragraph, intervention studies will be described that aimed to improve body weight in obese older adults and enhance physical function through improved body composition (decreased fat mass, increased muscle mass, and decreased muscle fat infiltration) in frail or prefrail persons. Outcomes of these studies were usually physical performance outcomes, with only a very few studies examining frailty as an outcome measure. Often changes in body composition are not, or only briefly, described. Therefore, a causal relationship between changes in body composition and the risk of frailty cannot be established in these studies.

Recent studies investigating the impact of nutritional intervention in older undernourished adults did not include a Fried Frailty Index as an outcome measure. Moreover, recent studies investigating the impact of nutritional intervention in frail older adults did not include undernourished older adults or older adults with a low BMI specifically. Therefore, it remains unclear whether providing supplemental energy and protein in undernourished older adults or older adults with a low BMI may prevent or delay the onset of frailty. In the study of Abizanda *et al.* [26], the effect of oral nutritional supplementation (including energy, protein, fiber, vitamin D and calcium) along with physical exercise was tested in 91 institutionalized older adults meeting at least three of the Fried Frailty Index. The effect of the intervention on improvement of objective physical functioning [assessed by the change in Short Physical Performance Battery (SPPB) score] and subjective physical functioning was larger in those who had a lower BMI at baseline compared with those who had a higher BMI at baseline. However, after adjustment for age, sex, and baseline serum vitamin D level, this association was no longer present.

To our knowledge, the impact of voluntary weight loss in frail overweight or obese older adults on change in frailty scores has hardly been studied. Only one recent pilot study among 67 obese [BMI $\geq 30\,kg/m^2$, mean body weight 103.2 (SD 19.6) kg], frail older persons (aged 60 and over) investigated the effect of weight loss only (control group) or weight loss with higher protein intake (protein group) on change in physical performance score and lean mass during 6 months [27▪]. Both groups lost weight [−7.5 (SD 6.2) for the control group and −8.7 (SD 7.4) for the protein group] and had increased physical performance scores, especially in the protein group. Both groups experienced a reduction of lean mass (3.8% in the control group and 2.1% in the protein group). Larger trials with focus on frailty outcomes and conservation of lean mass are warranted.

In 2011, a 1-year randomized controlled trial among 107 obese older adults showed that weight management combined with exercise was most beneficial in terms of objectively measured physical performance score (21% increase) and subjective functional status (10% increase) compared to weight management or exercise alone [28]. There was a decrease of 8.6 ± 3.8 kg (9%) in body weight (compared to <1% in the control group), with a small decrease in lean body mass of 1.8 ± 1.7 kg (3%) and a decrease in fat mass of 6.3 ± 2.8 kg (16%). Persons who received exercise intervention alone showed a slight increase in muscle mass, but had less increase in physical performance score and functional status (15 and 6%, respectively). These results suggest a potential beneficial impact of voluntary weight loss combined with exercise on frailty indices.

In 2015, a systematic review was performed on the effects of exercise interventions in frail older adults [29▪]. In this review, only two small studies [30,31] included measurements of body composition as secondary outcomes. It was found that a 3-month exercise programme induced a greater increase in fat-free mass (by DXA) compared to low intensity exercise training among frail older Japanese women (aged 75 years and older) [30]. This study also found positive effects on frailty status. In another study, a multicomponent exercise programme of 12 weeks in 24 frail older persons (mean age 91.9 years, SD 4.1) showed an increase in muscle mass and a decrease in muscle fat infiltration in the muscle compared to the control group [31]. Both studies show positive effects on body composition, which should be confirmed in larger trials.

CONCLUSION

Observational studies on obesity and high waist circumference show most convincing results for an association with frailty. The independent role of body composition (overall fat mass, muscle mass, and muscle fat infiltration) remains unclear, mainly due to a lack of studies and a lack of accurate measurement of body composition by CT or MRI. Furthermore, almost all studies have a cross-sectional design, which makes it impossible to infer causality. Weight loss and exercise interventions that positively affect body composition may be of benefit to frail older adults.

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Conflicts of interest

There are no conflicts of interest.

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Papers of particular interest, published within the annual period of review, have been highlighted as:
▪ of special interest
▪▪ of outstanding interest

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