Proceedings of the Nutrition Society (2011), **70**, 114–118
doi:10.1017/S0029665110003939

First published online 22 November 2010

The Summer Meeting of the Nutrition Society hosted by the Scottish Section was held at Heriot-Watt University, Edinburgh on 28 June–1 July 2010

Conference on 'Nutrition and health: cell to community'

Symposium 2: Exercise and protein nutrition
Obesity, sarcopenia and their functional consequences in old age

Marjolein Visser
Department of Health Sciences and the EMGO Institute for Health and Care Research, Faculty of Earth and Life Sciences, VU University Amsterdam, Amsterdam, The Netherlands; and Department of Epidemiology and Biostatistics and the EMGO Institute for Health and Care Research, VU University Amsterdam, Amsterdam, The Netherlands

The prevalence of obesity is high in older persons and recent trends show a rapid increase in this prevalence. Results from observational and intervention studies (i.e. weight loss studies) show the strong negative impact of obesity on functional status in old age. There are different potential pathways through which obesity may lead to functional decline in older persons. Furthermore, the presence of overweight and obesity during the life course and trends in medical care are likely to influence the impact of obesity on disability. The concepts sarcopenia (age-related loss of muscle mass) and dynapenia (age-related loss of muscle strength) receive a lot of research attention as potential determinants of functional decline in old age. There is no consensus on the definitions of these concepts. Recent studies conducted in large cohort studies of mainly community-dwelling older persons show that poor muscle strength is strongly associated with functional decline compared to low muscle mass. In several studies, no association between muscle mass and functional status was observed. Current research on the combination of obesity with poor muscle strength (dynapenic-obesity) suggests a potential additive effect of both components on poor functional status in old age which seems independent of the level of physical activity.

Sarcopenia: Obesity: Aged: Mobility limitation: Disability

Obesity in old age: a growing problem

In Western societies, the age group of the population with the highest prevalence of overweight (BMI 25·0–29·9 kg/m^2) and obesity (BMI $\geq$30 kg/m^2) generally ranges between 55 and 75 years[1]. Due to the aging of the population, the absolute number of older obese persons will continue to increase. However, other factors may also contribute to this ongoing trend. Research has shown that current generations of older persons are more likely to be obese compared to generations of similar age 10–20 years ago[2–4]. The current older generation seems to be prone to the obesity epidemic just as younger generations. Furthermore, the high overweight and obesity prevalence rates currently observed in young children and adolescents are expected to have a strong impact on the obesity prevalence of these same individuals in old age. Therefore, both in absolute and in relative numbers, obesity is considered a growing problem among older persons[5].

Relationship between obesity and functional status

Both cross-sectional and longitudinal studies have shown that obesity in older men and women is strongly associated with the presence of poor functional performance or disability and with future decline in functional performance or the new development of disability[6]. For example, data from a large French study show that obese older men and women with a BMI between 30 and 35 kg/m^2 were 50 % more likely to have mobility limitations compared to those with a BMI between 23 and 27 kg/m^2 [7]. A more than three-fold higher risk was observed in those with BMI of 35 kg/m^2 and higher. A higher waist circumference substantially increased the risk for developing disability after 2 years of follow-up in 3235 older, non-institutionalized persons in Spain[8]. An increased risk for mobility limitations was consistently observed in overweight and obese older persons regardless of the level of physical activity[9], indicating that obesity is an independent determinant of

Corresponding author: Professor M. Visser, fax +31 20 598 6940, email marjolein.visser@falw.vu.nl

functional status and not simply an indicator of physical inactivity. Other prospective studies, using more accurate assessments of body fatness as measured by dual-energy X-ray absorptiometry and adjusting for the level of physical activity, showed that higher amounts of total body fat in older men and women are associated with a greater risk for incident mobility limitations[10,11]. A study conducted in the Health, Aging and Body Composition Study showed that obesity in old age, defined as having a BMI of 30 kg/m^2 or more, had such a strong negative impact on incident mobility limitations that it overruled the negative impact of other unhealthy lifestyle factors on functional status, including current smoking, excessive alcohol use, physical inactivity and poor diet[12]. Prospective studies have also shown that weight gain at an older age is associated with a decline in functional status[13,14]. The observational studies consistently show the strong negative influence of obesity and excess body fat on functional status in old age. No clear cut-off point for BMI, waist circumference or body fat has been published at which functional status is negatively affected in old age. However, recent research suggests that the commonly used cut-off values for waist circumference should be higher when applied to older persons[15]. This research supports the findings of previous studies using other outcomes suggesting that the commonly used cut-off values for BMI to indicate overweight may be too low for older persons[16].

There are indications that the relationship between obesity and functional impairment in older persons is changing over time. Obese persons aged 60 years and older who participated in the National Health and Nutrition Examination Survey study between 1999 and 2004 had a higher probability of functional impairments compared to obese persons of similar age examined between 1988 and 1994[17]. The probability of functional impairments in persons without obesity, however, remained similar over time. What is causing this increase in risk among obese older persons? One potential explanation might be the reduced obesity-related mortality rate over time. The increased survival time may have negative consequences for functional status by increasing the prevalence of weight-related diseases and their complications. Another potential explanation might be the longer duration of overweight and obesity in more recent generations of obese older persons. The earlier and long-term burden of obesity on the body may cause an earlier onset of functional impairments and/or a higher severity of these impairments. Indeed, several recent studies support this explanation by showing that the lifetime history of overweight and obesity is associated with functional status in old age. Cross-sectional data from Finland showed that persons aged 55 years and older who had been obese since the age of 30 were about eight times more likely to have walking limitations compared to those who were never obese. A clear dose–response relationship was observed between obesity duration during life and the presence of walking limitations[18]. More recently, men and women between the age of 70 and 79 years who had been overweight or obese since the age of 25 were 2·85 times more likely to develop mobility limitations compared to those who had a normal weight throughout life[19]. The risk for new mobility limitations was lower (1·72) for those who developed overweight or obesity in old age. These studies suggest that a lifetime history of overweight and obesity may increase the risk of functional decline in obese older persons.

Based on the findings of the studies discussed, the prevention of overweight and obesity across all ages seems relevant for the prevention of functional decline in old age. An important question for older persons who are already obese is whether voluntary weight loss at old age would improve physical functioning. A landmark study addressing this specific question is the study by Villareal *et al.*[20] conducted in twenty-seven frail older obese persons. A weight loss of 8·4 % in 6 months in conjunction with exercise training three times weekly led to a significant improvement in physical performance compared to the control group. No decline in fat-free body mass was observed, suggesting that the weight loss consisted mainly of fat mass. To what extent the fat loss and/or the exercise training caused the improvement in physical performance is not known. However, weight loss alone has been shown to improve functional status in older obese patients with knee osteoarthritis[21] and to increase endurance capacity in older obese persons[22]. The functional benefits of intentional weight loss in obese older persons have also been acknowledged by the American Society for Nutrition in 2005[23]. However, more research is needed to optimize weight loss strategies for older persons, to investigate who will benefit most from what kind of weight loss treatment and to examine the long-term benefits of intentional weight loss in older persons.

Sarcopenia

The term sarcopenia, indicating the age-related loss of muscle mass, was first introduced by Dr I. H. Rosenberg[24]. The loss of muscle mass with aging is hypothesized to have negative consequences for health and physical functioning in old age[25,26]. Prospective data using accurate body composition methodology showed that men and women aged 70–79 years lose about 1 % of their muscles per year[27]. To investigate the prevalence of sarcopenia and its impact on health and functioning in old age, and to diagnose sarcopenia in clinical practice, a definition should be available. Several definitions have been developed and described in the literature and are generally based on a cut-off point indicating low muscle mass instead of loss of muscle mass[28–30]. Currently, there is no consensus on the definition of sarcopenia[31].

Relationship between sarcopenia and functional status

The usefulness of previously developed definitions of sarcopenia was tested by investigating the association between sarcopenia and (change in) physical functioning[28–30,32]. Other studies have related continuous or categorical measures of skeletal muscle mass to functional status in order to determine the role of low muscle mass in functional decline. While some studies have indeed shown that low muscle mass is associated with poor functional status or decline in functional status[28,29] this result has not been consistently reported by all studies. In fact, most studies show that low muscle mass is not or only weakly associated with functional status. These studies did, however, show that high body fat mass was a consistent and independent determinant of functional status in older men and women[10,11,33–37], even after adjustment for the level of physical activity [10,11].

The term sarcopenia has also been used to refer to the age-related loss of muscle strength or the presence of low muscle strength in old age. Recently, the term dynapenia rather than sarcopenia was proposed to specifically indicate the loss of muscle strength with aging[38]. Poor muscle strength is a well-recognized determinant of poor functional status based on observational studies[11,39–41]. Moreover, strength training leads to significant improvements in functional status without significant or only small increases in skeletal muscle mass[42–44]. Observational studies investigating both low muscle mass and poor muscle strength in relation to functional status in older persons consistently showed a strong association between muscle strength and function, with no or much weaker associations between muscle mass and function[39,40]. Thus, at least in the wide range of study samples of community-dwelling older persons used in these studies, the function of the muscle seems more relevant in relation to functional status in old age as compared to muscle size.

Similar to the importance of life history of overweight and obesity on functional status in old age, as discussed earlier, the life history of muscle strength may also impact functional status in old age. A remarkable study is that of Rantanen *et al.*[45] showing that grip strength assessed in a large sample of healthy Japanese-American men aged 45–68 years was highly predictive of functional limitations and disability 25 years later when all participants were at least 70 years of age. These results suggest that optimal body fat mass and high muscle strength throughout life may contribute to the prevention of disability later in life.

Sarcopenic-obesity and the relationship with functional status

To examine whether different body composition components have independent influences on functional status in old age and may potentially interact, the concept sarcopenic-obesity was launched in 2004[46,47]. Older persons who were sarcopenic based on a cut-off point of the skeletal muscle index and who had a high percentage of body fat had a twofold higher risk to develop instrumental activity of daily living disability compared to those with no sarcopenia and normal fat levels. However, more recent studies failed to clearly demonstrate that a combination of low muscle mass and high body fat mass was more detrimental to functional status in old age compared to having a high body fat mass only[48,49]. In fact, in most studies sarcopenia alone did not increase the risk of poor functional status[37,48–50]. A recent study conducted on 1308 French women showed that those who were sarcopenic-obese (defined as having a body fat percentage $>40\%$ and a skeletal muscle index $<5{\cdot}45\,kg/m^2$) tended to have a higher risk for having difficulty climbing down stairs compared to those who were obese only[37]. However, the other six physical function items included in the study did not confirm these findings.

Acknowledging the recent research findings showing that poor muscle strength might be a more important determinant of functional status than low muscle mass, Stenholm *et al.*[51] took a slightly different approach in defining sarcopenic-obesity. Older persons who were obese based on their BMI ($\geq 30\,kg/m^2$) and were in the lowest sex-specific tertile of grip strength were considered sarcopenic-obese. The advantage of this definition, which should be indicated as dynapenic-obesity, is its reliance on relatively simple measures which may enhance the application in clinical practice. The prevalence of dynapenic-obesity according to this definition varied from 4·4% to 9·1% based on data from four large cohort studies conducted in Europe and the USA. Using prospective data from 930 Italian men and women aged 65 years and older, it was shown that men and women with dynapenic-obesity (based on BMI $\geq 30\,kg/m^2$ and knee extensors strength in lowest sex-specific tertile) had the steepest decline in walking speed over time and greatest development of disability independent of their level of physical activity[52]. The effects of obesity and dynapenia were additive and not multiplicative. After the age of 80, clear differences between the groups were no longer observed. These results were recently confirmed in a cross-sectional study[53].

Conclusion

Based on epidemiological studies conducted in large samples of older men and women, dynapenia, but not sarcopenia, seems to play an important role in the functional decline of older persons. Another important body composition component influencing functional status in old age is body fatness. Dynapenic-obesity may be an important concept to consider in future studies trying to identify potential modifiable determinants for functional decline in older persons.

Acknowledgements

The author has no conflict of interest.

References

1. Gulland A (2010) Obesity among 65 s in UK reflects lifetime of gaining weight. *BMJ* **341**, c3585.
2. Stenholm S, Simonsick EM & Ferrucci L (2010) Secular trends in body weight in older men born between 1877 and 1941: the Baltimore longitudinal study of aging. *J Gerontol A Biol Sci Med Sci* **65**, 105–110.
3. Visser M, Pluijm SM, van der Horst MH *et al.* (2005) Lifestyle of Dutch people aged 55–64 years less healthy in 2002/'03 than in 1992/'93. *Ned Tijdschr Geneeskd* **149**, 2973–2978 (in Dutch).
4. Eiben G, Dey DK, Rothenberg E *et al.* (2005) Obesity in 70-year-old Swedes: secular changes over 30 years. *Int J Obes* **29**, 810–817.
5. Houston DK, Nicklas BJ & Zizza CA (2009) Weighty concerns: the growing prevalence of obesity among older adults. *J Am Diet Assoc* **109**, 1886–1895.

6. Jensen GL & Hsiao YP (2010) Obesity in older adults: relationship to functional limitation. *Curr Opin Clin Nutr Metab Care* **13**, 46–51.
7. Larrieu S, Pérès K, Letenneur L *et al*. (2004) Relationship between body mass index and different domains of disability in older persons: the 3C study. *Int J Obes Relat Metab Disord* **28**, 1555–1560.
8. Guallar-Castillón P, Sagardui-Villamor J, Banegas JR *et al*. (2007) Waist circumference as a predictor of disability among older adults. *Obesity* **15**, 233–244.
9. Koster A, Patel KV, Visser M *et al*. (2008) Joint effects of adiposity and physical activity on incident mobility limitation in older adults. *J Am Geriatr Soc* **56**, 636–643.
10. Visser M, Langlois J, Guralnik JM *et al*. (1998) High body fatness, but not low fat-free mass, predicts disability in older men and women: the cardiovascular health study. *Am J Clin Nutr* **68**, 584–590.
11. Visser M, Goodpaster BH, Kritchevsky SB *et al*. (2005) Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J Gerontol A Biol Sci Med Sci* **60**, 324–333.
12. Koster A, Penninx BW, Newman AB *et al*. (2007) Lifestyle factors and incident mobility limitation in obese and non-obese older adults. *Obesity* **15**, 3122–3132.
13. Fine JT, Colditz GA, Coakley EH *et al*. (1999) A prospective study of weight change and health-related quality of life in women. *JAMA* **282**, 2136–2142.
14. Busetto L, Romanato G, Zambon S *et al*. (2009) The effects of weight changes after middle age on the rate of disability in an elderly population sample. *J Am Geriatr Soc* **57**, 1015–1021.
15. Heim N, Snijder MB, Heymans MW *et al*. (2010) Exploring cut-off values for large waist circumference in older adults: a new methodological approach. *J Nutr Health Aging* **14**, 272–277.
16. Janssen I & Mark AE (2007) Elevated body mass index and mortality risk in the elderly. *Obes Rev* **8**, 41–59.
17. Alley DE & Chang VW (2007) The changing relationship of obesity and disability, 1988–2004. *JAMA* **298**, 2020–2027.
18. Stenholm S, Rantanen T, Alanen E *et al*. (2007) Obesity history as a predictor of walking limitation at old age. *Obesity* **15**, 929–938.
19. Houston DK, Ding J, Nicklas BJ *et al*. (2009) Overweight and obesity over the adult life course and incident mobility limitation in older adults: the health, aging and body composition study. *Am J Epidemiol* **169**, 927–936.
20. Villareal DT, Banks M, Sinacore DR *et al*. (2006) Effect of weight loss and exercise on frailty in obese older adults. *Arch Intern Med* **166**, 860–866.
21. Christensen R, Bartels EM, Astrup A *et al*. (2007) Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis. *Ann Rheum Dis* **66**, 433–439.
22. Shah K, Wingkum NJ, Lambert CP *et al*. (2008) Weight-loss therapy improves endurance capacity in obese older adults. *J Am Geriatr Soc* **56**, 1157–1159.
23. Villareal DT, Apovian CM, Kushner RF *et al*. (2005) Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. *Am J Clin Nutr* **82**, 923–934.
24. Rosenberg IH (1997) Sarcopenia: origins and clinical relevance. *J Nutr* **127**(Suppl), 990S–991S.
25. Roubenoff R & Hughes VA (2000) Sarcopenia: current concepts. *J Gerontol A Biol Sci Med Sci* **55**, M716–M724.
26. Cruz-Jentoft AJ, Landi F, Topinková E *et al*. (2010) Understanding sarcopenia as a geriatric syndrome. *Curr Opin Clin Nutr Metab Care* **13**, 1–7.
27. Goodpaster BH, Park SW, Harris TB *et al*. (2006) The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. *J Gerontol A Biol Sci Med Sci* **61**, 1059–1064.
28. Visser M (2009) Towards a definition of sarcopenia – results from epidemiologic studies. *J Nutr Health Aging* **13**, 713–716.
29. Baumgartner RN, Koehler KM, Gallagher D *et al*. (1998) Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* **147**, 755–763.
30. Janssen I, Baumgartner RN, Ross R *et al*. (2004) Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. *Am J Epidemiol* **159**, 413–421.
31. Newman AB, Kupelian V, Visser M *et al*. (2003) Sarcopenia: alternative definitions and associations with lower extremity function. *J Am Geriatr Soc* **51**, 1602–1609.
32. Delmonico MJ, Harris TB, Lee JS *et al*. (2007) Alternative definitions of sarcopenia, lower extremity performance, and functional impairment with aging in older men and women. *J Am Geriatr Soc* **55**, 769–774.
33. Visser M, Harris TB, Langlois J *et al*. (1998) Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. *J Gerontol A Biol Sci Med Sci* **53**, M214–M221.
34. Lebrun CE, van der Schouw YT, de Jong FH *et al*. (2006) Fat mass rather than muscle strength is the major determinant of physical function and disability in postmenopausal women younger than 75 years of age. *Menopause* **13**, 474–481.
35. Zoico E, Di Francesco V, Mazzali G *et al*. (2007) High baseline values of fat mass, independently of appendicular skeletal mass, predict 2-year onset of disability in elderly subjects at the high end of the functional spectrum. *Aging Clin Exp Res* **19**, 154–159.
36. Jankowski CM, Gozansky WS, Van Pelt RE *et al*. (2008) Relative contributions of adiposity and muscularity to physical function in community-dwelling older adults. *Obesity* **16**, 1039–1044.
37. Rolland Y, Lauwers-Cances V, Cristini C *et al*. (2009) Difficulties with physical function associated with obesity, sarcopenia, and sarcopenic-obesity in community-dwelling elderly women: the EPIDOS (EPIDemiologie de l'OSteoporose) Study. *Am J Clin Nutr* **89**, 1895–1900.
38. Clark BC & Manini TM (2008) Sarcopenia = / = dynapenia. *J Gerontol A Biol Sci Med Sci* **63**, 829–834.
39. Lauretani F, Russo CR, Bandinelli S *et al*. (2003) Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol* **95**, 1851–1860.
40. Visser M, Deeg DJ, Lips P *et al*. (2000) Skeletal muscle mass and muscle strength in relation to lower-extremity performance in older men and women. *J Am Geriatr Soc* **48**, 381–386.
41. Ferrucci L, Penninx BW, Volpato S *et al*. (2002) Change in muscle strength explains accelerated decline of physical function in older women with high interleukin-6 serum levels. *J Am Geriatr Soc* **50**, 1947–1954.
42. Fiatarone MA, O'Neill EF, Ryan ND *et al*. (1994) Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med* **330**, 1769–1775.
43. Chandler JM, Duncan PW, Kochersberger G *et al*. (1998) Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? *Arch Phys Med Rehabil* **79**, 24–30.
44. Vincent KR, Braith RW, Feldman RA *et al*. (2002) Resistance exercise and physical performance in adults aged 60 to 83. *J Am Geriatr Soc* **50**, 1100–1117.

45. Rantanen T, Guralnik JM, Foley D *et al*. (1999) Midlife hand grip strength as a predictor of old age disability. *JAMA* **281**, 558–560.
46. Zamboni M, Mazzali G, Fantin F *et al*. (2008) Sarcopenic obesity: a new category of obesity in the elderly. *Nutr Metab Cardiovasc Dis* **18**, 388–395.
47. Baumgartner RN, Wayne SJ, Waters DL *et al*. (2004) Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes Res* **12**, 1995–2004.
48. Davison KK, Ford E, Cogswell M *et al*. (2002) Percentage of body fat and body mass index are associated with mobility limitations in people aged 70 and older from NHANES III. *J Am Geriatr Soc* **50**, 1802–1809.
49. Zoico E, Di Francesco V, Guralnik JM *et al*. (2004) Physical disability and muscular strength in relation to obesity and different body composition indexes in a sample of healthy elderly women. *Int J Obes Relat Metab Disord* **28**, 234–241.
50. Bouchard DR, Dionne IJ & Brochu M (2009) Sarcopenic/obesity and physical capacity in older men and women: data from the nutrition as a determinant of successful aging (NuAge)-the Quebec longitudinal Study. *Obesity* **17**, 2082–2088.
51. Stenholm S, Harris TB, Rantanen T *et al*. (2008) Sarcopenic obesity: definition, cause and consequences. *Curr Opin Clin Nutr Metab Care* **11**, 693–700.
52. Stenholm S, Alley D, Bandinelli S *et al*. (2009) The effect of obesity combined with low muscle strength on decline in mobility in older persons: results from the InCHIANTI study. *Int J Obes* **33**, 635–644.
53. Bouchard DR & Janssen I (2010) Dynapenic-obesity and physical function in older adults. *J Gerontol A Biol Sci Med Sci* **65**, 71–77.

NS Proceedings of the Nutrition Society