Author(s): Lisko, Inna; Tiainen, Kristina; Raitanen, Jani; Jylhävä, Juulia; Hurme, Mikko; Hervonen, Antti; Jylhä, Marja; Stenholm, Sari

Title: Body Mass Index and Waist Circumference as Predictors of Disability in Nonagenarians : The Vitality 90+ Study

Year: 2017

Version:

Please cite the original version:

Lisko, I., Tiainen, K., Raitanen, J., Jylhävä, J., Hurme, M., Hervonen, A., Jylhä, M., & Stenholm, S. (2017). Body Mass Index and Waist Circumference as Predictors of Disability in Nonagenarians : The Vitality 90+ Study. Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 72(11), 1569-1574. https://doi.org/10.1093/gerona/glx032

This article has been published in the *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 2017, 72 (11), 1569–1574. Doi: 10.1093/gerona/glx032

Body Mass Index and Waist Circumference as Predictors of Disability in Nonagenarians: The Vitality 90+ Study

Inna Lisko[1,2,3], Kristina Tiainen[1,2], Jani Raitanen[1,2,4], Juulia Jylhävä[2,5,6], Mikko Hurme[2,5,6], Antti Hervonen[1,2], Marja Jylhä[1,2], and Sari Stenholm[1,2,7]

[1]Faculty of Social Sciences, University of Tampere, Finland
[2]Gerontology Research Center, University of Tampere and University of Jyväskylä, Finland
[3]Faculty of Sport and Health Sciences, University of Jyväskylä, Finland
[4]The UKK Institute for Health Promotion Research, Tampere, Finland
[5]Faculty of Medicine and Life Sciences, University of Tampere, Finland
[6]Center of Laboratory Medicine, Tampere University Hospital, Tampere, Finland
[7]Department of Public Health, University of Turku and Turku University Hospital, Finland

Address correspondence to:
Inna Lisko, MSc
E-mail: Lisko.Inna.K@student.uta.fi
Gerontology Research Center
Faculty of Sport and Health Sciences
P.O. Box 35
40014 University of Jyväskylä
FINLAND
Tel: +358 40 805 3570
Fax: +358 14 260 4600

Running head: OBESITY AND DISABILITY IN OLDEST OLD

ABSTRACT

Background. Only scarce data exists on the association between obesity and disability in the oldest old. The purpose of this prospective study is to examine if body mass index (BMI) and waist circumference (WC) are associated with incident mobility and activities of daily living (ADL) disability in nonagenarians.

Methods. We used longitudinal data from the Vitality 90+ Study, which is a population-based study conducted at the area of Tampere, Finland. Altogether 291 women and 134 men, aged 90–91 years, had measured data on BMI and/or WC, and did not have self-reported mobility or ADL disability at baseline. Incident mobility and ADL disability was followed-up on median 3.6 years (range 0.6–7.8 years). Mortality was also followed-up. Multinomial logistic regression models were used for the analyses, as death was treated as an alternative outcome. The follow-up time was taken into account in the analyses.

Results. Neither low or high BMI, nor low or high WC, were associated with incident mobility disability. In women, the lowest WC tertile (<82 cm) was associated with an increased probability of incident ADL disability when compared to the middle WC tertile (OR 3.98, 95% CI 1.35–11.77).

Conclusions. Obesity is not associated with incident mobility or ADL disability in nonagenarians. Instead, low WC is associated with an increased risk of developing ADL disability in nonagenarian women.

Key words: obesity, disability, mobility, physical function, oldest old, obesity paradox

INTRODUCTION

Obesity, indicated by high BMI or WC, is associated with many chronic diseases in older as in younger adults (1). Dixon and colleagues have proposed that the BMI range associated with optimal health changes over the life course (2). This refers to the so called obesity paradox, in which overweight or mild obesity in older adults have been associated with a lower mortality risk, with a more favorable disease prognosis in various chronic conditions, and a better recovery from surgical operations (3, 4). But when factors associated with weight loss have been taken into account, obesity has shown to be associated with shorter survival when compared to BMI 23–26.9 kg/m^2 at least to age 84 years (5).

It is widely acknowledged that the current guidelines for healthy BMI (6) are not appropriate for older adults (7, 8). Yet, the associations of BMI and WC with disability seem to be similar in middle-aged and older adults in that both low and high values are associated with mobility and/or ADL disability (1, 9-12). Indeed, obese BMI has shown to be more closely associated with incident disability than with mortality among older adults (13). But among persons aged 70–95 years the association between BMI and mortality becomes decreasingly U-shaped (14). As disability is closely associated with mortality (15), the association of obesity with disability requires separate examination in the oldest old persons.

Only a limited number of studies have examined the associations between obesity and mobility or ADL disability in the oldest old, i.e. in people aged ≥85 years. The oldest old are the fastest-growing segment of population in the developed countries (16) and obesity prevalence has reported being around 10–14% in Finland (17) and 13% in England (5). In our previous cross-sectional study, overweight and obese BMI, and high WC, were associated with ADL disability in the oldest old women, but not in men (17). Other cross-sectional findings also show associations between obesity and ADL disability (18, 19), and also between obesity and mobility disability (20), in both oldest old women and men. Also low WC or BMI have been cross-sectionally associated with ADL disability (18, 19) or with a lower ADL score (21, 22), both among population-based samples of the oldest old (18, 19) and among nursing home residents with an average age of ≥85 years (21, 22). Yet, cognitive status has shown to explain the association among nursing home residents (22). Additionally, few longitudinal studies have presented results on the relationship between obesity and disability in the oldest old (21, 23, 24). In them, associations between obesity and both mobility and ADL disability (23, 24), and between lower weight and decline in ADL score (21), have been found. Of these three longitudinal studies, one used self-reported measures of BMI and included participants who already had ADL disability at baseline (24), one studied only nursing-home residents (21), and one studied only women whose follow-up ended at the age of 85 years (23). Furthermore, the results of Reynolds and McIlvane on active life expectancy were weighted to reflect the population aged ≥70 years (24). Studies investigating the association between objectively measured BMI or WC and incident disability in the oldest old are lacking.

By using the representative Vitality 90+ data we examined whether BMI and WC are associated with incident mobility disability or ADL disability in 90-year-old persons.

METHODS

Design and Sample

We used longitudinal data from the Vitality 90+ Study, which is a prospective multidisciplinary population-based study of people aged 90 or older living in the area of Tampere, Finland. The flow chart of this study is presented in Figure 1. Data for the present study was gathered from participants born in 1909–1910, 1911, 1912–1913, and 1920. Baseline measurements for all cohorts were conducted during years of 2000, 2001, 2003 and 2010 and each year the study was aimed at all inhabitants aged 90–91 years, who were living in the city of Tampere according to the population register. All cohorts combined the basic population consisted of 1,828 persons, including both community-dwelling and institutionalized persons. Yet, in 2003 anthropometric measures were available only for community-dwelling people. Participants were followed-up with mailed questionnaires in 2001, 2003, 2007, 2010 and 2014 (Figure 1). The median follow-up for disability was 3.6 years (range 0.6–7.8 years). All-cause mortality was determined from the Statistics Finland until year 2014 and the dates of death linked to the data set with a Personal Identity Code.

For the current study, we included participants who were disability-free and had data on BMI and/or WC at baseline, and who answered to at least one mailed questionnaire, or died during the follow-up. The final analytical sample of participants included 291 women and 134 men. The baseline disability status was based on Barthel Index (25) and all participants had to be independent in walking 50 meters on a level ground, climbing stairs, dressing up, and getting in and out of bed.

The study protocol was approved by the Ethics Committee of the Tampere Health Center or the Ethics Committee of the Pirkanmaa Hospital District depending on the year of data collection. All participants or their legal representatives gave their written informed consent.

Anthropometric Measurements

Anthropometric measurements were conducted at baseline by trained study personnel. Height was measured standing against a wall from the top of the head to the floor and rounded to the nearest 1 cm. If someone had severe kyphosis or was a bed patient, height was not measured and the person was excluded from the analyses. Weight was measured by a digital scale (Soehnle, Germany) for all cohorts brought along by the study personnel and rounded to the nearest 1 kg. Though, in 7 cases the height or weight was self-reported. BMI was computed as weight in kilograms divided by height in meters squared (kg/m^2) and categorized as (i) underweight (<20.0 kg/m^2), (ii) normal weight (20.0–24.9 kg/m^2), (iii) overweight (25.0–29.9 kg/m^2) and (iv) obese (≥30.0 kg/m^2) (26). For the underweight we used a slightly higher cut-point than the standard 18.5 kg/m^2 recommended by WHO (27) because only 5 women and 1 man had a BMI below 18.5 kg/m^2. In 2000, 2001 and 2003 WC was measured midway between the level of the iliac crest and the lowest rib (27), and in 2010 at the level of the iliac crest. The decision for changing the measurement site was based on the recommendation of U.S. National Institute of Health (28). However, earlier research shows that the measurement site for WC has no substantial influence on the association between WC and morbidity or mortality (29). As both low and high WC has shown to be associated with disability in the oldest old (17, 19), we categorized WC according to sex-specific tertiles, and decided to use common cut-points for all cohorts. For women the WC tertiles were <82 cm, 82–89 cm, and ≥90 cm, and for men <91 cm, 91–99 cm, and ≥100 cm, respectively.

Disability Outcomes

Identical questions on disability were repeated in the mailed questionnaires each follow-up year. These questions were: 1) “Are you able to walk at least 400 meters?”, 2) “Are you able to climb stairs?”, 3) “Are you able to get in and out of bed?”, and 4) “Are you able to dress and undress yourself?”. In all these questions answers “Yes, without difficulty” and “Yes, but it’s difficult” were coded as independent, and answers “Only if somebody helps” and “No” were coded as dependent. Based on these questions, two outcomes for incident disability were formed (30).

Mobility disability was defined as being dependent in either walking 400 meters or climbing stairs. Those who were independent in climbing stairs and walking 400 meters were categorized as having no mobility disability. *ADL disability* was defined as being dependent in either dressing and undressing, or in getting in and out of bed, and having mobility disability. Those who were independent in dressing and undressing, and in getting in and out of bed, and who had no mobility disability were categorized as having no ADL disability. There was only one person in our analyses, who at the follow-up had no mobility disability, but who was dependent in either dressing and undressing, or in getting in and out of bed. When modelling the incidence of ADL disability, this person was included in the analyses as having no incident ADL disability.

Comorbidity

In 2001, 2003 and 2010 comorbidity was based on self-reported diagnoses gathered by a mailed questionnaire. It was asked in the questionnaire if a doctor had diagnosed the participant with heart disease, cancer, dementia, stroke, diabetes, osteoarthritis, Parkinson’s disease, hip fracture or depression. In the year 2000 comorbidity was based on medical diagnoses collected from health center records maintained by public health care physicians, including also diagnoses made in hospitals. For this study we chose the same diseases as gathered in the years 2001, 2003 and 2010. Comorbidity was classified according to the number of diseases as (i) low (0 diseases), (ii) middle (1 disease), (iii) high ($\geq$ 2 diseases), and (iv) data missing.

Statistical analyses

To assess differences between women and men at baseline, we used t-test, Chi-square test, and Mann-Whitney U test. Separate multinomial regression analyses were used in examining if BMI and WC were associated with incident mobility disability, or incident ADL disability. In both analyses the deceased were treated as an alternative outcome. Categorical BMI and WC were used as predictors in our analyses. The reference group for BMI was the overweight category, and for WC the middle tertile, and the baseline category for disability was those with no incident disability. The reason for using the overweight category as a reference group instead of the normal weight category was that in our earlier longitudinal analyses on the Vitality 90+ Study overweight persons had the lowest risk for mortality (31). Separate follow-up times were calculated for mobility disability and ADL disability, i.e. if the participant had incident mobility disability, the follow-up still continued for ADL disability. Follow-up started on the day of baseline measurement, and ended on the date of the latest questionnaire obtained. All analyses were adjusted for comorbidity and sample year at baseline. Differences in the follow-up time were taken into account as an offset option by using the natural logarithm of the follow-up time.

Due to the central role of mortality in this population, we also assessed death as an alternative outcome for mobility and ADL disability. Follow-up time for all-cause mortality started at the day of baseline measurements, and ended at the date of death. Those participants, who died during the follow-up without developing mobility or ADL disability, were categorized as deceased. Mortality was followed-up for the same time as disability (maximum follow-up time 7.8 years) but for the cohort born in 1920, the maximum follow-up time for mortality was 3.3 years and for disability 3.7 years.

All statistical analyses were performed with SPSS for Windows (SPSS Inc., Chicago, IL) version 22.

RESULTS

At baseline, 7% of women were categorized as underweight, 45% as normal weight, 36% as overweight and 12% as obese (Table 1). In men, 6% were underweight, 52% normal weight, 33% overweight and 10% obese. During the follow-up, 47% of women developed mobility disability as compared to 28% in men ($p<0.001$). Also, 15% of women developed ADL disability as compared to 8% in men ($p<0.001$). Supplementary Figure S1 shows proportions of participants with incident mobility and ADL disability as well as deaths according to each BMI category and WC tertile.

BMI or WC was not associated with incident mobility disability in either women or men (Table 2). The only statistically significant result for the disability outcomes was found between the lowest WC and ADL disability in women (lowest vs. middle WC tertile: odds ratio [OR] 3.98, 95% confidence interval [CI] 1.35–11.77).

BMI or WC was not associated with mortality when death was assessed as an alternative outcome for incident mobility disability (Table 2). But when death was assessed as an alternative outcome for incident ADL disability in women, normal weight (vs. overweight) increased the probability of death (OR 2.15, 95% CI 1.13–4.11) and the highest WC (vs. middle tertile) was borderline protective from death (OR 0.52 ,95% CI 0.27–1.02).

DISCUSSION

The study is among the first to investigate longitudinal associations of BMI and WC with disability in the oldest old. In nonagenarian women, but not in men, low WC was associated with incident ADL disability. Compared to overweight BMI, having a low or high BMI was not associated with incident mobility or ADL disability in men or women.

Our findings of the association between low WC and incident ADL disability in the oldest old women are supported by a recent cross-sectional study on the oldest old (19). Yet, in our previous cross-sectional study high WC was associated with ADL disability (17) which suggests that there may be divergent cross-sectional and longitudinal associations on obesity and ADL disability in very old persons. There is also some evidence that obesity may predict ADL disability in the oldest old (24) but more prospective studies are needed to elucidate the role of obesity in the development of disability in the oldest old population.

The association we found for low WC and ADL disability reflects the dangers associated with low weight. People with low weight may suffer from malnutrition, which makes them more susceptible to disease and disability (32). Weight loss and underweight are also associated with severe diseases, such as cancer, and low weight is also a typical feature in frailty, which is closely associated with disability (33, 34). The reason why the results for the underweight BMI did not provide statistically more significant results may partly be explained by the low number of underweight participants and the relatively low participation rates. One explanation for finding no longitudinal associations between obesity and incident mobility or ADL disability may relate to the characteristics of nonagenarians. They are a highly selected population group and they are prone to experience rapid changes in health and functional status for various health related reasons. Thus, obesity does not arise as a significant factor associated with disability when examined prospectively. It may even be viewed that obesity in the oldest old could be a sign of good health, especially if the person is free of disabilities. Though, in case of sarcopenic or dynapenic obesity, which is characterized with low muscle mass or strength in combination with obesity (35), disability incidence may be high (36) also among the oldest old. Due to small number of obese persons in our study, we were not able to separately examine disability incidence among persons with sarcopenic obesity.

Mortality may play a role in the gender differences showing that women, but not men, with low WC were prone to develop ADL disability. For the follow-up data, the intervals between the data collections varied between 1 and 4 years for the different cohorts and some of the incident mobility and ADL disabilities were undoubtedly lost to mortality. It is well known that in older adults women are more disabled than men but men have a higher mortality risk (37). Tiainen and colleagues have demonstrated in the oldest old that mobility and ADL disability increase mortality risk more in men than in women (38). It may be that a relatively large part of men with incident disability died before they got the chance to answer to the mailed questionnaire.

The study has some limitations that are important to consider when interpreting the results. First, the small sample size especially in men restricts drawing any strict conclusions on the results. Also the relatively low participation rates have most likely led to a selection bias. It is likely that especially persons, who have low weight and who are close to death, have not taken part to the baseline measurements nor answered to the mailed questionnaire. Second, at baseline mobility disability concerned walking 50 meters independently, whereas at follow-up it concerned walking 400 meters independently. However, both at baseline and at follow-up, the question referred to walking outside, and the effect of possible bias was equal for each BMI and WC group. Third, height is not always easy to measure optimally among the oldest old due to kyphosis, a slouching posture , and/or osteoporotic compression (40). This may have caused some overestimation of the BMI values. For WC the measurement site was different for the 2010 cohort as compared to the other cohorts. Yet, we believe we could separate adequately those with low, middle and high WC. In general it is difficult to reach a representative sample of the oldest old and due to different illnesses and functional limitation the measurement of their WC is often a challenging procedure in practice. Fourth, the relationship between obesity and disability may have changed between the study years 2000 and 2010 (41). A previous study from the US suggests that obesity is associated with more functional impairment in later cohorts as compared to earlier cohorts (41), however, corresponding data is not available in Finland. Therefore, we decided to include all available study cohorts to maximize our study sample and differences between cohorts were controlled for adjusting for the cohort in the analyses. Finally, in 2001, 2003 and 2010 comorbidity was defined based on self-reported diseases and in 2000 based on health center data. Due to these different sources of information some diseases may have been overreported or underreported in 2001, 2003 and 2010 as compared to 2000 (42). However, adjusting for the cohort in the analysis should at least partly take into account the possible discrepancy in the comorbidity variable.

The strengths of the study include a unique data set of a representative population-based sample of nonagenarians. Similar studies with the oldest old population are scarce. Objectively measured height, weight and WC are included to the strengths of the study as well. Taking into account the very high age of our participants, we had a high participation rate during the follow-up, and 94% of the participants meeting the baseline criteria provided outcome data.

To conclude, obesity is not associated with incident mobility or ADL disability in nonagenarians. Instead, low WC is associated with an increased risk of developing ADL disability in nonagenarian disability-free women. The results emphasize the importance of weight surveillance among the oldest old.

FUNDING

This work was supported by the The Juho Vainio Foundation (IL), the Academy of Finland (projects 273850 to M.H.; 250602 to M.J.; 286294 and 294154 to S.S.), and Competitive Research Funding of the Pirkanmaa Hospital District (project number 9N019 to M.H.; project number 9P002 to M.J.).

ACKNOWLEDGEMENTS

We thank our collaborators working in health and social care in the city of Tampere for their help and support during the data collection.

REFERENCES

1. Samper-Ternent R, Al Snih S. Obesity in Older Adults: Epidemiology and Implications for Disability and Disease. Rev Clin Gerontol. 2012;22:10-34.

2. Dixon JB, Egger GJ, Finkelstein EA, Kral JG, Lambert GW. 'Obesity paradox' misunderstands the biology of optimal weight throughout the life cycle. Int J Obes (Lond). 2015;39:82-84.

3. Lainscak M, von Haehling S, Doehner W, Anker SD. The obesity paradox in chronic disease: facts and numbers. J Cachexia Sarcopenia Muscle. 2012;3:1-4.

4. Valentijn TM, Galal W, Tjeertes EK, Hoeks SE, Verhagen HJ, Stolker RJ. The obesity paradox in the surgical population. Surgeon. 2013;11:169-176.

5. Bowman K, Delgado J, Henley WE, et al. Obesity in Older People With and Without Conditions Associated With Weight Loss: Follow-up of 955,000 Primary Care Patients. J Gerontol A Biol Sci Med Sci. 2016.

6. WHO. Obesity: Preventing and managing the global epidemic. report of a WHO consultation. *World Health Organ Tech Rep Ser.* Switzerland:2000;894:i-xii, 1-253.

7. Heiat A, Vaccarino V, Krumholz HM. An evidence-based assessment of federal guidelines for overweight and obesity as they apply to elderly persons. Arch Intern Med. 2001;161:1194-1203.

8. Flicker L, McCaul KA, Hankey GJ, et al. Body mass index and survival in men and women aged 70 to 75. J Am Geriatr Soc. 2010;58:234-241.

9. Ferraro KF, Su YP, Gretebeck RJ, Black DR, Badylak SF. Body mass index and disability in adulthood: a 20-year panel study. Am J Public Health. 2002;92:834-840.

10. Mendes de Leon CF, Hansberry MR, Bienias JL, Morris MC, Evans DA. Relative weight and mobility: a longitudinal study in a biracial population of older adults. Ann Epidemiol. 2006;16:770-776.

11. Backholer K, Wong E, Freak-Poli R, Walls HL, Peeters A. Increasing body weight and risk of limitations in activities of daily living: a systematic review and meta-analysis. Obes Rev. 2012;13:456-468.

12. Nam S, Kuo YF, Markides KS, Al Snih S. Waist circumference (WC), body mass index (BMI), and disability among older adults in Latin American and the Caribbean (LAC). Arch Gerontol Geriatr. 2012;55:e40-7.

13. Al Snih S, Ottenbacher KJ, Markides KS, Kuo YF, Eschbach K, Goodwin JS. The effect of obesity on disability vs mortality in older Americans. Arch Intern Med. 2007;167:774-780.

14. Thinggaard M, Jacobsen R, Jeune B, Martinussen T, Christensen K. Is the relationship between BMI and mortality increasingly U-shaped with advancing age? A 10-year follow-up of persons aged 70-95 years. J Gerontol A Biol Sci Med Sci. 2010;65:526-531.

15. Keeler E, Guralnik JM, Tian H, Wallace RB, Reuben DB. The impact of functional status on life expectancy in older persons. J Gerontol A Biol Sci Med Sci. 2010;65:727-733.

16. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. Lancet. 2009;374:1196-1208.

17. Lisko I, Stenholm S, Raitanen J, et al. Association of Body Mass Index and Waist Circumference With Physical Functioning: The Vitality 90+ Study. J Gerontol A Biol Sci Med Sci. 2015;70:885-891.

18. Yang M, Hao Q, Luo L, et al. Body mass index and disability in Chinese nonagenarians and centenarians. J Am Med Dir Assoc. 2014;15:303.e1-303.e6.

19. Yin Z, Shi X, Kraus VB, et al. Gender-dependent association of body mass index and waist circumference with disability in the Chinese oldest old. Obesity (Silver Spring). 2014;22:1918-1925.

20. Hajek A, Lehnert T, Ernst A, et al. Prevalence and determinants of overweight and obesity in old age in Germany. BMC Geriatr. 2015;15:83-015-0081-5.

21. Kaiser R, Winning K, Uter W, et al. Functionality and mortality in obese nursing home residents: an example of 'risk factor paradox'? J Am Med Dir Assoc. 2010;11:428-435.

22. Kiesswetter E, Schrader E, Diekmann R, Sieber CC, Volkert D. Varying Associations Between Body Mass Index and Physical and Cognitive Function in Three Samples of Older Adults Living in Different Settings. J Gerontol A Biol Sci Med Sci. 2015;70:1255-1261.

23. Rillamas-Sun E, LaCroix AZ, Waring ME, et al. Obesity and late-age survival without major disease or disability in older women. JAMA Intern Med. 2014;174:98-106.

24. Reynolds SL, McIlvane JM. The impact of obesity and arthritis on active life expectancy in older Americans. Obesity (Silver Spring). 2009;17:363-369.

25. Mahoney FI, Barthel DW. Functional Evaluation: the Barthel Index. Md State Med J. 1965;14:61-65.

26. Sergi G, Perissinotto E, Pisent C, et al. An adequate threshold for body mass index to detect underweight condition in elderly persons: the Italian Longitudinal Study on Aging (ILSA). J Gerontol A Biol Sci Med Sci. 2005;60:866-871.

27. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser. 1995;854:1-452.

28. The practical guide to the identification, evaluation, and treatment of overweight and obesity in adults. bethesda, MD: National institutes of healt, 2000. (NIH publication no.00-4084).

29. Ross R, Berentzen T, Bradshaw AJ, et al. Does the relationship between waist circumference, morbidity and mortality depend on measurement protocol for waist circumference? Obes Rev. 2008;9:312-325.

30. Stenholm S, Guralnik JM, Bandinelli S, Ferrucci L. The prognostic value of repeated measures of lower extremity performance: should we measure more than once? J Gerontol A Biol Sci Med Sci. 2014;69:894-899.

31. Lisko I, Tiainen K, Stenholm S, Luukkaala T, Hervonen A, Jylha M. Body mass index, waist circumference, and waist-to-hip ratio as predictors of mortality in nonagenarians: the Vitality 90+ Study. J Gerontol A Biol Sci Med Sci. 2011;66:1244-1250.

32. Ahmed T, Haboubi N. Assessment and management of nutrition in older people and its importance to health. Clin Interv Aging. 2010;5:207-216.

33. Willett WC, Dietz WH, Colditz GA. Guidelines for healthy weight. N Engl J Med. 1999;341:427-434.

34. Topinkova E. Aging, disability and frailty. Ann Nutr Metab. 2008;52 Suppl 1:6-11.

35. Stenholm S, Harris TB, Rantanen T, Visser M, Kritchevsky SB, Ferrucci L. Sarcopenic obesity: definition, cause and consequences. Curr Opin Clin Nutr Metab Care. 2008;11:693-700.

36. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. Obes Res. 2004;12:1995-2004.

37. Oksuzyan A, Juel K, Vaupel JW, Christensen K. Men: good health and high mortality. Sex differences in health and aging. Aging Clin Exp Res. 2008;20:91-102.

38. Tiainen K, Luukkaala T, Hervonen A, Jylha M. Predictors of mortality in men and women aged 90 and older: a nine-year follow-up study in the Vitality 90+ study. Age Ageing. 2013;42:468-475.

39. Nishiwaki Y, Michikawa T, Eto N, Takebayashi T. Body mass index misclassification due to kyphotic posture in Japanese community-dwelling adults aged 65 years and older. J Gerontol A Biol Sci Med Sci. 2011;66:326-331.

40. Alexandru D, So W. Evaluation and management of vertebral compression fractures. Perm J. 2012;16:46-51.

41. Alley DE, Chang VW. The changing relationship of obesity and disability, 1988-2004. JAMA. 2007;298:2020-2027.

42. Goebeler S, Jylha M, Hervonen A. Self-reported medical history and self-rated health at age 90. Agreement with medical records. Aging Clin Exp Res. 2007;19:213-219.

Table 1. Characteristics of the Study Population Aged 90–91 years: The Vitality 90+ Study

	Women n = 291*	Men n = 134*	P Value
Baseline			
Height, m	1.57 (8.4)	1.71 (0.06)	<0.001
Weight, kg	62.7 (10.2)	73.2 (11.4)	<0.001
BMI, kg/m^2, Mean (SD)	25.3 (4.1)	25.0 (3.5)	0.468
BMI categories, kg/m^2, n (%)			0.653
Underweight (<20.00)	19 (6.8)	7 (5.8)	
Normal weight (20.00–24.99)	125 (45.0)	62 (51.7)	
Overweight (25.00–29.99)	101 (36.3)	39 (32.5)	
Obese (≥30.00)	33 (11.9)	12 (10.0)	
WC, cm, Mean (SD)	86.8 (11.2)	96.2 (10.6)	<0.001
WC tertiles, cm, n (%)			0.943
I (<82 cm for women, < 91 cm for men)	89 (31.9)	38 (30.2)	
II (82–89 cm for women, 91–99 cm for men)	93 (33.3)	44 (34.9)	
III (≥90 cm for women, ≥100 cm for men)	97 (34.8)	44 (34.9)	
Comorbidity, n (%)			0.309
Low (0 diseases)	47 (16.5)	26 (19.4)	
Middle (1 disease)	91 (31.3)	51 (38.1)	
High (≥2 diseases)	135 (46.4)	51 (38.1)	
Data missing	17 (5.8)	6 (4.5)	
Follow-up			
Mobility disability			<0.001
No Incident Disability, n (%)	60 (20.6)	25 (18.7)	
Incident Disability, n (%)	136 (46.7)	37 (27.6)	
Deceased, n (%)	95 (32.6)	72 (53.7)	
ADL disability[§]			0.003
No Incident Disability, n (%)	108 (37.1)	38 (28.4)	
Incident Disability, n (%)	44 (15.1)	10 (7.5)	
Deceased, n (%)	138 (47.4)	86 (64.2)	
Follow-up time for mobility disability, years, Median (IQR)	3.3 (1.6–4.5)	3.0 (1.5–4.3)	0.397
Follow-up time for ADL disability, years, Median (IQR)	3.6 (2.5–6.4)	3.5 (1.9–4.8)	0.021

Notes: BMI = body mass index; WC = waist circumference; ADL = activities of daily living
SD = standard deviation; IQR = interquartile range

*Total number of participants. For BMI and WC the number of participants is 278 and 279 in women, and 120 and 126 in men, respectively.

[§]For ADL disability n=290 in women

Table 2. The Association of BMI and WC with incident mobility and ADL disability in a maximum follow-up of 7.8 years in women and men aged 90–91 years

	Mobility Disability*			ADL Disability*		
	No Incident Disability	Incident Disability	Deceased	No Incident Disability	Incident Disability	Deceased
	OR (95% Cl)			OR (95% Cl)		
Women (n = 291)						
BMI[§]						
underweight vs. overweight	1.0	0.50 (0.13–1.92)	0.57 (0.11–3.06)	1.0	2.51 (0.45–13.84)	2.18 (0.65–7.37)
normal weight vs. overweight	1.0	1.24 (0.57–2.72)	1.11 (0.38–3.25)	1.0	1.72 (0.70–4.23)	**2.15 (1.13–4.11)**
obese vs overweight	1.0	1.64 (0.57–4.76)	0.47 (0.12–1.83)	1.0	0.79 (0.18–3.47)	0.73 (0.29–1.87)
WC tertiles[‖]						
I vs II	1.0	1.66 (0.66–4.15)	2.79 (0.88–8.82)	1.0	**3.98 (1.35–11.77)**	1.58 (0.75–3.30)
III vs II	1.0	1.19 (0.54–2.62)	0.96 (0.34–2.73)	1.0	1.68 (0.60–4.76)	0.52 (0.27–1.02)
Men (n = 134)						
BMI[§]						
underweight vs. overweight	1.0	NA	NA	1.0	NA	NA
normal weight vs. overweight	1.0	0.81 (0.16–4.17)	1.31 (0.25–6.93)	1.0	0.10 (0.004–2.47)	0.95 (0.28–3.25)
obese vs overweight	1.0	1.45 (0.14–14.57)	0.92 (0.05–16.30)	1.0	NA	0.31 (0.05–1.85)
WC tertiles[‖]						
I vs II	1.0	0.56 (0.08–4.03)	0.50 (0.08–3.17)	1.0	0.54 (0.04–7.59)	0.73 (0.21–2.54)
III vs II	1.0	1.21 (0.21–6.94)	0.42 (0.07–2.53)	1.0	0.61 (0.05–6.87)	0.49 (0.14–1.65)

Notes: BMI = body mass index; WC = waist circumference; ADL = activities of daily living; OR = odds ratio; CI = confidence interval; NA = not applicable; not enough participants for the analyses

*Multinomial logistic regression analyses. Adjusted for comorbidity and sample year at baseline.

Differences in follow-up times were taken into account by using a natural logarithm of follow-up time.

[§]BMI classifications: Underweight, <20.0 kg/m^2; normal weight, 20.0–24.9 kg/m^2 ; overweight, 25.0–29.9 kg/m^2; obese: ≥30.0 kg/m^2

[‖]WC tertiles for women <82 cm, 82–89 cm, and ≥90 cm, and for men <91 cm, 91–99 cm, and ≥100 cm.

Table titles:

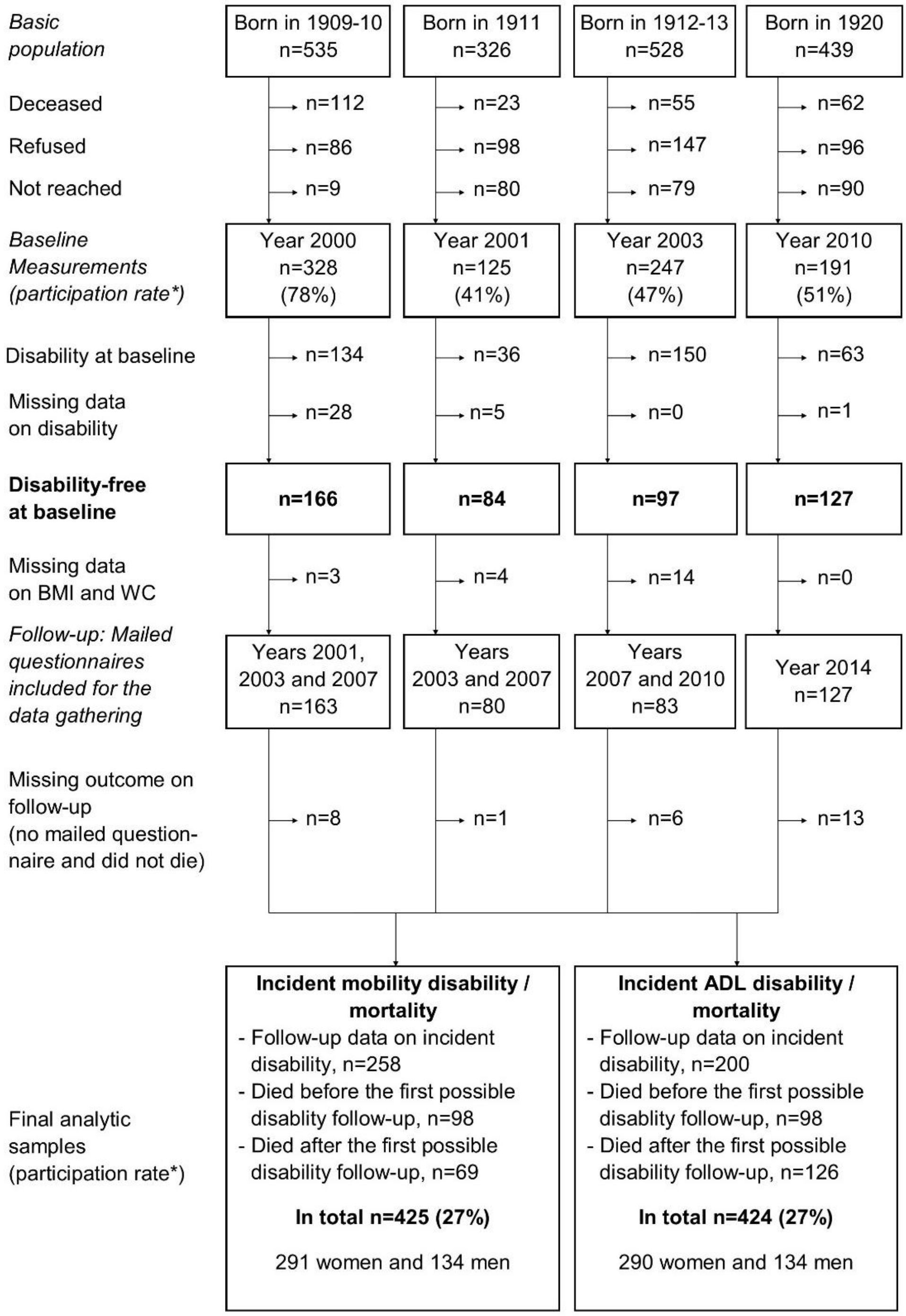
Table 1. Characteristics of the Study Population Aged 90–91 years: The Vitality 90+ Study

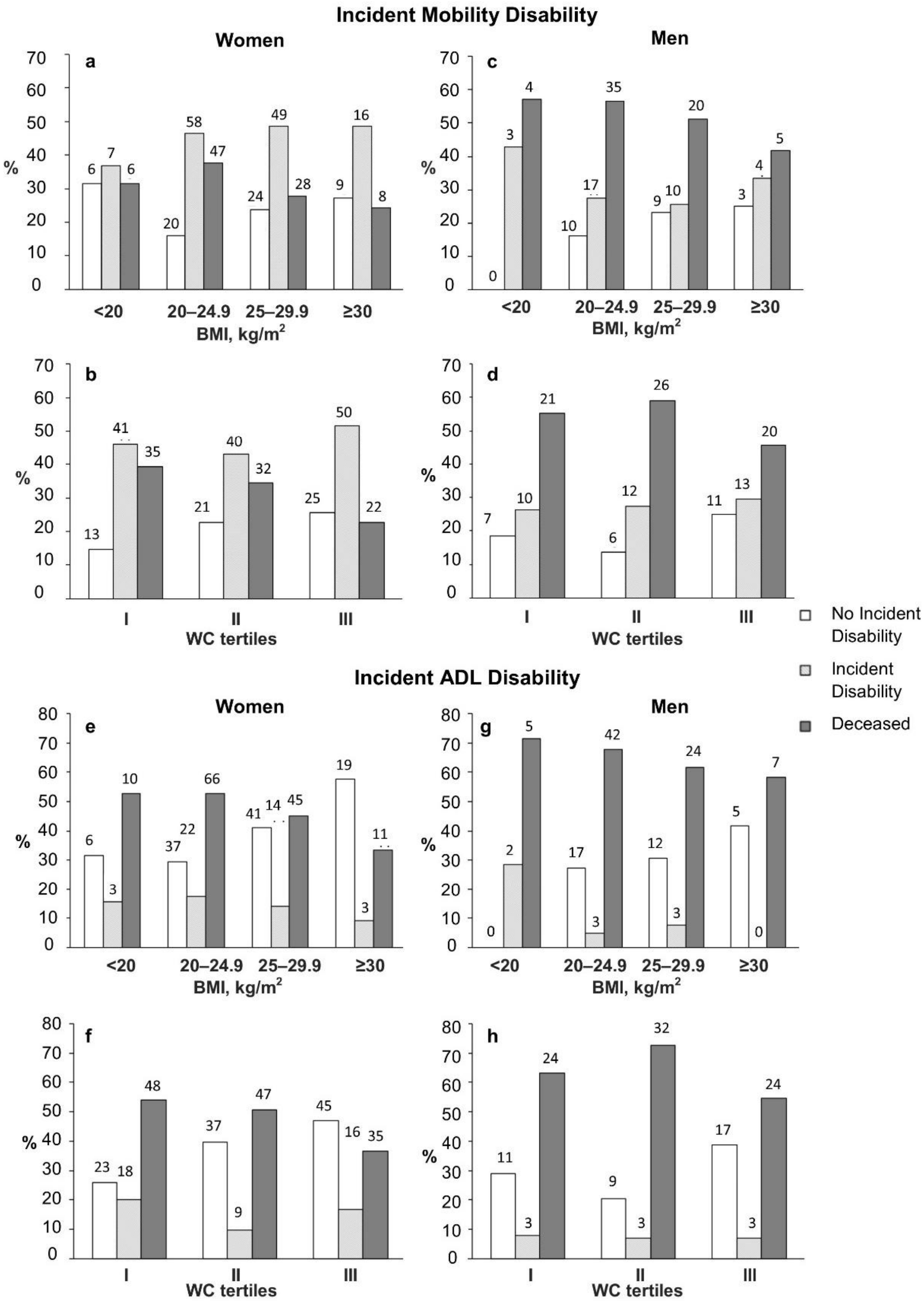
Table 2. The Association of BMI and WC with incident mobility and ADL disability in a maximum follow-up of 7.8 years in women and men aged 90–91 years

Figure captions:

Figure 1. Flow chart of the 90-year-old study population. Baseline measurements and face-to-face interviews at baseline and mailed questionnaires at follow-up within the Vitality 90+ Study. *For the calculations of the participation rates, the deceased are not included for the basic population

Figure S1. Incident mobility disability and activities of daily living (ADL) disability according to body mass index (BMI) categories and waist circumference (WC) tertiles in women (a–b and e–f) and in men (c–d and g–h) in the Vitality 90+ Study. Age of the participants at baseline was 90 years and the median follow-up for disability 3.6 years (range 0.6–7.8 years). Number of participants in each group is presented on the top of each bar.


Basic population
Born in 1909-10 n=535
Born in 1911 n=326
Born in 1912-13 n=528
Born in 1920 n=439
Deceased
n=112
n=23
n=55
n=62
Refused
n=86
n=98
n=147
n=96
Not reached
n=9
n=80
n=79
n=90
Baseline Measurements (participation rate*)
Year 2000 n=328 (78%)
Year 2001 n=125 (41%)
Year 2003 n=247 (47%)
Year 2010 n=191 (51%)
Disability at baseline
n=134
n=36
n=150
n=63
Missing data on disability
n=28
n=5
n=0
n=1
Disability-free at baseline
n=166
n=84
n=97
n=127
Missing data on BMI and WC
n=3
n=4
n=14
n=0
Follow-up: Mailed questionnaires included for the data gathering
Years 2001, 2003 and 2007 n=163
Years 2003 and 2007 n=80
Years 2007 and 2010 n=83
Year 2014 n=127
Missing outcome on follow-up (no mailed question-naire and did not die)
n=8
n=1
n=6
n=13
Final analytic samples (participation rate*)
Incident mobility disability / mortality
- Follow-up data on incident disability, n=258
- Died before the first possible disablity follow-up, n=98
- Died after the first possible disability follow-up, n=69
In total n=425 (27%)
291 women and 134 men
Incident ADL disability / mortality
- Follow-up data on incident disability, n=200
- Died before the first possible disablity follow-up, n=98
- Died after the first possible disability follow-up, n=126
In total n=424 (27%)
290 women and 134 men


Incident Mobility Disability
Women
Men
a
6 7 6
20 58 47
24 49 28
9 16 8
<20
20–24.9
25–29.9
≥30
BMI, kg/m2
c
0 3 4
10 17 35
9 10 20
3 4 5
b
13 41 35
21 40 32
25 50 22
d
7 10 21
6 12 26
11 13 20
I
II
III
WC tertiles
%
No Incident Disability
Incident Disability
Deceased
Incident ADL Disability
e
6 3 10
37 22 66
41 14 45
19 3 11
g
0 2 5
17 3 42
12 3 24
5 0 7
f
23 18 48
37 9 47
45 16 35
h
11 3 24
9 3 32
17 3 24