# Association of midlife body composition with old-age health-related quality of life, mortality, and reaching 90 years of age: A 32-year follow-up of a male cohort

## The Helsinki Businessmen study

Satu K. Jyväkorpi[1], Annele Urtamo[1], Mika Kivimäki[1], Veikko Salomaa[2], Timo E. Strandberg[1,3]

[1]University of Helsinki, Clinicum and Helsinki University Central Hospital, Unit of Primary Health Care, Finland

[2]THL-National Insitute for Health and Welfare, Helsinki, Finland

[3]University of Helsinki, Clinicum, and Helsinki University Hospital, Helsinki, Finland; University of Oulu, Center for Life Course Health Research, Oulu, Finland

Corresponding author:

Satu Jyväkorpi

Tukholmankatu 8 B, 00014 University of Helsinki

Tel: +358 50 4920970

satu.jyvakorpi@gery.fi

Orchid ID: 0000-0001-5901-3584

**Data share statement**

The data described used in the manuscript will be made available to editors upon request either before or after publication for checking. Data described in the manuscript will be made available upon request pending application.

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## Abbreviations:

ANCOVA = Analysis of covariance

BF = Body fat

BMI = Body mass index

CI = Confidence interval

HBS = Helsinki Businessmen Study

HC = Hip circumference

HDL = High density lipoprotein

HRQoL = Health Related Quality of Life

LDL = Low density lipoprotein

OR = Odds ratio

SF = Short Form

SM = Skeletal muscle

WC = Waist circumference

# Abstract

**Background**: Overweight and obesity increase risk of morbidity and mortality. The relationships between body composition at midlife, health-related quality of life (HRQoL) in old age and longevity are, however, less studied.

**Objective**: We examined the association of midlife body composition with successful aging, defined as high HRQoL and reaching 90 years of age during 32-year follow-up.

**Design**: Participants were 1354 males from the Helsinki Businessmen Study, born 1919 to 1934. In 1985/86 (mean age 60 years) various health measurements were performed. Body fat (BF)% and skeletal muscle mass (SM)% were calculated using validated formulas (including waist and hip circumferences, weight and age) and divided into quartiles. In 2000 and 2007 (mean ages 74 and 80 years), HRQoL was assessed using RAND-36/SF-36 scales. Mortality was retrieved from registers through 2018, and longevity determined by calculating the proportion of participants reaching 90 years. Logistic regression was used to assess odds ratios (OR) with 95% confidence intervals (CI).

**Results**: Higher SM% at midlife in 1985/86 was associated ($P<0.05$) with higher scores in RAND-36 scales Physical functioning, Role limitations caused by physical health problems, Vitality, Social functioning, and General health in old age in 2000. In 2007 only the association with Physical functioning remained statistically significant ($P<0.01$). BF% quartiles in 1985/86 were inversely associated with several RAND-36 scales in 2000 and 2007. During the 32-year follow-up, 982 participants died and 281 reached age 90 years of age. Being in the highest SM% quartile at midlife increased (adjusted OR 2.32, 95% CI 1.53, 3.53; lowest SM% quartile as reference) and being in the highest BF% quartile decreased (OR 0.43, 95% CI 0.28, 0.66; lowest BF% quartile as reference) odds of reaching 90 years.

**Conclusions**: Desirable body composition in terms of both fat and skeletal muscle mass at midlife was associated with successful aging in males.

**Keywords**: Body composition, skeletal muscle, body fat, quality of life, successful aging, longevity

# Introduction

Body composition is key to health and disease, and its derangements are a growing public health problem (1). Body composition is the result of a wide range of factors including physical activity, nutrition, disease, and age-related hormonal changes (2). Excessive body fat (BF) is associated with various chronic diseases from midlife to old age. Skeletal muscle mass (SM), on the other hand, is an important predictor of health in adult life, while severe loss of SM is linked to physical frailty in old age (3). Moreover, SM is an important endocrine organ, affecting eg. glucose metabolism, and low SM may impair glucose tolerance and increase insulin resistance and risk of metabolic complications (4,5).

Excessive BF has been shown to be associated with lower muscle quality, and it predicts accelerated loss of lean mass (6). Sarcopenic obesity (i.e. low muscle mass combined with obesity) increases risk of poor functional outcomes compared to either of these conditions alone (7,8). Aging further increases undesirable changes in body composition, such as reduction in lean body mass and total body water and increase in total fat mass, even if the body weight is steady or reduced (9). These changes in body composition occur often simultaneously with decline in physical performance and may increase physical limitations. According to US statistics, 17% of people at age of 50 years have one or more physical limitations, the corresponding figure being 43% at 80 years (10). Moreover, physical limitations either self-reported or measured predict onset of disability (11). However, to best of our knowledge there are no studies on how midlife body composition contributes to the health-related quality of life (HRQoL) in old age.

Here, we hypothesized that midlife body composition has long-standing consequences for health, physical function and longevity. Therefore, we explored the relationships between body composition (BF% and SM%) at midlife and successful aging, defined as a combination of high HRQoL and reaching 90 years of age among males from the Helsinki Businessmen Study (HBS) cohort during a 32-year follow-up.

# Subjects and Methods

These are secondary analyses of HBS, a Finnish cohort originally consisting of 3490 Caucasian males, born between 1919 and 1934, who have been followed-up since the 1964 (12, 13). All participants in the cohort belong to the highest socio-economic class and they had been mostly business leaders or executives during their working lives. In the present analysis we focused on a representative sample of males in this cohort who had been clinically healthy (no chronic diseases or medications) during the clinic visit in 1974 (n=1815) and who responded to a health survey and underwent laboratory measurements in 1985/86 (n=1399; 81.9% of 1709 eligible) when participants' mean age was 60 years (14).

*Measurements*

Because participants were living in various parts of Finland during the clinic visit in 1985/1986, measurements were performed locally by trained, registered nurses, who were given written instructions how to measure body mass index (kg/m$^2$) waist circumference (WC, cm) and hip circumference (HC, cm) according to Larsson et al (15). In addition, questionnaires were used to define their health, medications, and lifestyle, including current smoking (no/yes), weekly alcohol consumption (beer, wine, spirits separately, consumption calculated as grams/week), and regular physical activity (hours /week) (14). Laboratory measurements (blood pressure, fasting serum lipids and blood glucose) were performed with standard methods in certified laboratories.
In 1985/86 only 13 males (1%) had body mass index below 20 kg/m$^2$. Because their exclusion did not affect main results, all males were analyzed together.

In 2000, surviving males were assessed using mailed questionnaires including questions about health, medications, current weight, smoking, alcohol consumption, and physical activity (12,16). In addition, the questionnaire included the RAND-36 HRQoL instrument which is practically identical to Short Form [SF]-36) (17). The instrument has been validated in the Finnish general population (18) and consists of 8 scales: Physical functioning, Role limitations caused by physical health problems, Role limitations caused by emotional health problems, Vitality, Mental health, Social functioning, Bodily pain, and General health (17). The questionnaire survey with RAND-36 was repeated in 2007. We calculated the 8 scales using standard procedures (17) and present the scales separately in the analyses. Using personal identification number, vital status was verified from the Population Information System of Finland through March 2018 and the proportion of males reaching 90 years of age was calculated.

*Calculation of percentages of SM and BF*

The BF% and SM% were calculated according to validated anthropometric formulas (19,20) for the participants who attended clinic visits in 1985/86 as follows: BF% = 0.567 × Waist Circumference (WC) in cm + 0.101× age (years) −31.8, and for SM (kg) = 39.5 + 0.665 × body weight (kg)−0.185 WC in cm−0.418 × Hip Circumference (HC) in cm−0.08 × age in years. SM% is SM (kg)/body weight (kg) x 100%.

*Statistical analysis*

The SM% and BF% were divided into quartiles. We used descriptive statistics, Armitage test for trend in proportions, and analysis of covariance (ANCOVA, Bonferroni test for multiple comparisons) to compare SM% and BF% quartiles. Because dichotomous outcome (yes/no) was known for all participants, logistic regression was used to compare SM% and BF% quartile groups in reaching 90 years of age. Other basic assumptions of logistic regression were also met. Participants were living in various parts of Finland and did not include siblings or family members, there was linearity in continuous variables used, absence of multicollinearity, and no strongly influential outliers. Odds ratios (OR) with 95% confidence intervals (CI) were calculated and adjusted for age and various lifestyle-related variables (current smoking yes/no; alcohol consumption, grams/week; weekly physical activity, cut-point median time of 3 hours) at baseline.

Because the outcome, reaching 90 years of age, was relatively common (>20%) and odds ratios may overestimate associations between risk factors and common outcomes, we repeated data analysis using log-binomial regression instead of logistic regression. This led to very similar estimates, and therefore only logistic regression data are shown.

Statistical significance was taken as two-sided P-value <0.05, but because multiple tests were performed in logistic regression, we also report as a sensitivity analysis ORs with P-value <0.001 (and 99.9% CIs) to control for type 1 error. Statistical analyses were performed using NCSS statistical software (Kaysville, UT, www.ncss.com, version 8) and SPSS program, version 24 (SPSS IBM, Armonk, NY, USA).

*Ethics*

All participants signed informed consent and the follow-up study was approved by the ethical committee of the Department of Medicine, Helsinki University Central Hospital and the study is registered with ClinicalTrials.gov identifier: NCT02526082.

# Results

The flow chart of the study is shown in **Figure 1**. Of the 1399 participants attending the clinic visit in 1985/86, SM% and BF% could be calculated for 1342 and 1351 males, respectively. The quartile cut-offs of SM% were: $Q_1 \leq 34.03339$; $Q_2 > 34.03339$ and $\leq 35.93856$; $Q_3 > 35.93856$ and $\leq 37.7719$; $Q_4 > 37.77179$. The corresponding cut-offs of BF% quartiles were: $Q_1 \leq 25.795$; $Q_2 > 25.795$ and $\leq 28.7114$; $Q_3 > 28.7114$ and $\leq 32.10375$; $Q_4 > 32.10375$.

At baseline, higher SM% quartiles were linearly and statistically significantly ($P < 0.05$) associated with various cardiovascular health indicators (**Table 1**), including lower BMI, lower waist and hip circumference, lower systolic and diastolic blood pressure, lower fasting blood glucose levels, higher serum high density lipoprotein (HDL) cholesterol, and lower triglyceride levels. Smoking, coffee or tea drinking were not associated with SM% quartiles and consumption of alcohol was inversely associated with the SM% quartiles (P = 0.01). Regular physical activity was more frequent in higher SM% quartiles (P < 0.01).

BF% quartiles (Table 1) were linearly and statistically significantly (P < 0.05) associated with BMI, waist and hip circumference, systolic and diastolic blood pressure, fasting blood glucose levels, serum low density lipoprotein (LDL) cholesterol and triglyceride levels, and inversely associated with HDL cholesterol level. Tea and coffee drinking were not associated with BF% quartiles, whereas smoking and regular physical activity were inversely and consumption of alcohol positively associated with increasing BF% quartiles (Table 1.).

The number of participants taking part of the follow-up survey in 2000 was 995 (90.5% of the 1100 eligible males). Their BMIs were somewhat lower than at baseline. However, those in SM% quartile $Q_1$ at baseline had the highest BMI at follow-up, and those in the SM% $Q_{4,}$ the lowest BMI (**Table 2**). Neither alcohol consumption nor smoking differed between SM% quartiles in 2000. Regular physical activity at baseline was linearly associated with SM% quartiles at follow-up (P < 0.01).

In 2000, BMI was the highest in BF% $Q_4$ and declined linearly towards BF% $Q_1$ (P < 0.01). Alcohol consumption was the lowest in the lowest BF% quartile and increased linearly toward the highest BF% $Q_4$ (P < 0.01). Smoking did not differ between the BF% quartiles, whereas physical activity was inversely associated with the BF% quartiles.

*Health Related Quality of life*

Higher SM% at baseline was linearly associated with higher scores in many of the RAND-36 scales at follow-up in 2000 (**Table 3**). Significant associations were observed in Physical functioning, Role limitations caused by physical health problems, Vitality, Social functioning, and General health. In 2007, the associations with two physical subscales of RAND-36 remained statistically significant: Physical functioning and Role limitations caused by physical health problems (Table 3).

BF% quartiles at baseline showed an inverse relationship with several RAND-36 subscales at follow-up in 2000, including Physical functioning, Role limitations caused by physical health problems, Role limitations caused by emotional health problems, Vitality, Social functioning, and General health (Table 3). Several of these inverse relations between BF% quartiles and RAND-36 subscales remained at the second follow-up in 2007: Physical functioning, Role limitations caused by physical health problems, Role limitations caused by emotional health problems, Bodily pain, and General health (Table 3).

*Mortality and odds for reaching 90 years of age*

During 32 years of follow-up through March 2018, 982 (72.7%) participants died (Figure 1). Total mortality was 83.3% (n=280), 74.4% (n=249), 70.2% (n=235), and 62.5% (n=209) with increasing SM% quartiles ($P < 0.001$), respectively, and 64.9% (n=216), 69.8% (n=240), 74.3% (n= 252), and 81.1% (n=274) with increasing BF% quartiles ($P < 0.001$), respectively.

Through March 2018, 281 (20.8%) participants had reached 90 years of age. Both SM% and BF% were associated with odds of reaching this age (**Table 4**). In the fully adjusted model (age plus lifestyle variables in 1985/86), OR for the highest SM% quartile, as compared to the lowest quartile, was 2.32 (95% CI, 1.53, 3.53). The corresponding OR for the highest BF% quartile, as compared to the lowest quartile, was 0.43 (95% CI, 0.28, 0.66).

We also performed a sensitive analysis by setting the threshold for statistical significance at P-value $<0.001$, and the main results in the fully adjusted model remained significant. Accordingly, OR for the highest SM% quartile, as compared to the lowest quartile, was 2.32 (99.9% CI 1.14, 4.08). The respective OR for the highest BF% quartile, as compared to the lowest quartile, was 0.43 (99.9% CI 0.23, 0.93).

# Discussion

In our study among males, desirable body composition -- characterized by higher skeletal muscle mass and lower body fat at midlife -- was associated with lower mortality and increased odds of reaching 90 years of age. In addition, higher skeletal muscle mass in midlife was associated with higher scores in the physical aspects of HRQoL at mean ages of 73 and 80 years. In contrast, higher body fat percentage at midlife was inversely associated with the scores of several aspects of HRQoL at both follow-ups. These results suggest that body composition at midlife has long-standing consequences for longevity and quality of life in old age.

As societies are aging, healthy and active aging and good quality of life in old age are increasingly important goals, but there are only few studies on long-term predictors of healthy aging. In a previous report of the Helsinki Businessmen Study, we found that even metabolically healthy overweight and obesity at midlife are related to reduced odds of successful aging (21). To the best of our knowledge, the present study is the first to explore the associations between midlife body composition and components of HRQoL in old age in a longitudinal study design with a very long follow-up time (32 years). The lack of studies may be due to the fact that body composition measuring devices were rarely available for scientific use decades ago. Thus, our study has a novel design for using validated anthropometric formulas based on waist and hip circumference to estimate skeletal muscle mass and body fat at midlife (19,20).

There are a number studies with cross-sectional or longitudinal designs with short follow-ups (1 to 3 years) on associations between body composition and HRQoL in older people (22-24). In those, especially low muscle mass and higher amount of body fat have been associated with lower HRQoL and mobility limitations (23). Our results suggest that midlife body composition is an important predictor of mobility limitations in old age. There are several plausible explanations for this finding. First, skeletal muscle mass naturally decreases with increasing muscle loss between 40-59 years due to hormonal and other lifestyle factors (25). Muscle loss is further accelerated at end of lifespan. Although muscle loss with aging is a normal phenomenon, sarcopenia (also including loss of strength) is a clinical condition that increases risk of falls, functional decline, frailty, and mortality (3, 26,27). Thus, those who already have low percentage of skeletal muscle mass at midlife may be at increased risk of sarcopenia in old age. This would explain the consistent association with the physical component of HRQoL at mean ages of 73 and 80 in our study. Second, the accumulation of body fat and especially the accumulation of visceral fat is associated with harmful consequences of obesity, not only due to the accumulating cardiovascular-metabolic burden, but also due to the increased risk of mobility limitations in old age (1, 24,28). It is therefore plausible that obesity reduces HRQoL. Furthermore, sarcopenic obesity -- where both high body fat and low skeletal muscle mass are present – is a strong predictor of ill health and poor physical function (29). Although most participants in our cohort were not obese, those in the highest quartile of body fat percentage had consistently lower physical components of HRQoL in old age, and the association remained significant at the last measuring point, where the participants had a mean age of 80 years.

In our study midlife smoking was associated with lower body fat percentage at baseline. This is consistent with the finding that tobacco smoking accelerates metabolism and may reduce appetite (30). However, from baseline (1985/86) to the first follow-up (in 2000), the number of current smokers reduced dramatically as some of them died and others ceased smoking. Only 6% reported smoking at the first follow-up in 2000, and there were no differences in the prevalence of smoking between SM% or BF% quartiles. Thus, those who survived and had higher HRQoL were not likely to be smokers. Use of alcohol at baseline, on the other hand, was inversely associated with skeletal muscle mass and linearly associated with body fat, and this association remained significant in body fat quartiles at the latter follow-up in 2007. Alcohol is very energy dense and regular drinking may increase food intake, and thus weight gain. The mean alcohol consumption in the highest BF%

quartile was 161 g/week, which equals to moderate drinking in males. However, within the group, there were also those who drank considerably more, which may impair odds for successful aging. Regular physical activity was inversely associated with BF, and linearly associated with SM mass. These findings suggest that unhealthy lifestyle habits may cluster in persons with low SM mass and high BF, contributing to adverse body composition and ultimately reduced HRQoL in old age.

**Strengths and limitations**

The main strength of our study is the very long follow-up time combined with high participation in two follow-ups 7 years apart and reliable retrieval of information for males who reached 90 years of age from national registers. Using anthropometric formulas instead of a body composition device can be both advantageous and disadvantageous. The formulas we used to estimate percentage of skeletal muscle mass and body fat percentage are well-validated (19,20). On the other hand, use of a golden standard DXA-device to measure body composition would have given additional information on an individual's body composition. This was not possible at the time the baseline measurements were done.

Due to the nature of the observational study, no causal relationships can be determined on the basis of this study. In addition, we did not have more detailed information about nutritional factors and dietary intakes at midlife. A further limitation is that the cohort of male survivors in a long-term observational study is obviously selected. The participants were surviving Caucasian males from high socio-economic groups, and their health and characteristics probably differ from those of the general population. Therefore, the results cannot be directly generalized to other populations. However, homogeneousness of the cohort is also a strength through reducing confounding by socioeconomic factors, which may be important in a study related to lifestyle.

A limitation of the HRQoL results is that the questionnaire in 1985/86 did not include items about quality of life, and it is unknown whether differences between SM% and BF% already existed at baseline. However, a proxy of HRQoL (and one of RAND-36 items) could be self-rated health, which was asked from the participants using a 5-step scale, the same measure as used in the Whitehall study (31) in 1974, i.e. 12 years earlier than the baseline of the current study (12). In 1974, no significant difference in self-rated health was observed between SM% quartiles (P= 0.58) nor between BF% quartiles (P=0.24)(unpublished observations).

Furthermore, the associations of SM% and BF% with HRQoL could be affected by mortality and nonresponse, if these occurred differently in quartiles of SM% and BF%. However, longevity was less probable with lower SM% and higher BF%, and nonresponders in 2007 – more frequent with lower SM% and higher BF% (Figure 1) -- had worse HRQoL in 2000 (unpublished observations). This suggests that differences in HRQoL between SM% and BF% quartiles, if anything, would have been even larger, if all participants had responded.

Finally, our study sample was not very large, but the long follow-up time combined with the robust results between the body composition and successful aging enhance the significance of this study.

# Conclusions

Components of body composition, both low muscle mass and high fat mass at midlife, appear to adversely affect health-related quality of life in old age and were associated with reduced odds of successful aging.

# Acknowledgements

### *Conflict of Interest*

SKJ, AU, MK, report no disclosures, VS has participated in a conference trip sponsored by Novo Nordisk and received a modest honorarium from the same source for participating in an advisory group meeting, TES reports various cooperation (educational, research, consultation) with several companies marketing cholesterol-lowering drugs including Amgen, AstraZeneca, Merck, OrionPharma, Pfizer,  Servier. Minor stock in OrionPharma.

### *Author's contribution*

SKJ and TES designed the analysis, TES and SKJ carried out the statistical analysis and all the authors wrote the manuscript and approved the final version of it.

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TABLE 1. Age-adjusted characteristics of participants of the Helsinki Businessmen Study (HBS) according to skeletal muscle % and body fat % quartiles at baseline in 1985/86

| SM% quartiles (Q)[1] / Characteristics | $Q_1$ n = 336 | $Q_2$ n = 336 | $Q_3$ n = 335 | $Q_4$ n = 335 | P-value |
|---|---|---|---|---|---|
| Age, mean, years (SE) | 61.0 (0.2) | 60.5 (0.2) | 59.3 (0.2) | 58.4 (0.2) | < 0.01 |
| BMI. $kg/m^2$ (SE) | 27.2 (0.2) | 26.3 (0.2) | 26.0 (0.2) | 24.8 (0.2) | < 0.01 |
| Waist circumference, cm (SE) | 102 (0.4) | 98 (0.4) | 96 (0.4) | 90 (0.4) | < 0.01 |
| Hip circumference, cm (SE) | 106 (0.3) | 101 (0.3) | 99 (0.3) | 93 (0.3) | < 0.01 |
| Use of alcohol, g/week (SE) | 138 (7.7) | 121 (7.7) | 109 (7.7) | 104 (7.7) | 0.01 |
| Current smoking, % | 16 | 18 | 15 | 19 | 0.29 |
| Regular physical activity, % | 74 | 75 | 78 | 83 | < 0.01 |
| Regular physical activity, h/week (SE) | 3.4 (0.2) | 3.6 (0.2) | 3.8 (0.2) | 4.3 (0.2) | 0.036 |
| Coffee, cups/d (SE) | 3.5 (0.1) | 3.7 (0.1) | 3.9 (0.1) | 3.5 (0.1) | 0.10 |
| Tea, cups/d (SE) | 1.1 (0.1) | 1.2 (0.1) | 1.1 (0.1) | 1.2 (0.1) | 0.45 |
| Systolic BP, mm Hg (SE) | 142 (0.9) | 140 (0.9) | 139 (0.9) | 138 (0.9) | < 0.01 |
| Diastolic BP, mm Hg (SE) | 88 (0.5) | 89 (0.5) | 88 (0.5) | 86 (0.5) | 0.013 |
| Fasting blood glucose, mmol/L (SE) | 5.1 (0.1) | 4.9 (0.1) | 4.8 (0.1) | 4.9 (0.1) | < 0.01 |
| Cholesterol, mmol/L (SE) | 6.5 (0.1) | 6.5 (0.1) | 6.4 (0.1) | 6.5 (0.1) | 0.84 |
| HDL cholesterol, mmol/L (SE) | 1.3 (0.0) | 1.4 (0.0) | 1.4 (0.0) | 1.5 (0.0) | < 0.01 |
| LDL cholesterol, mmol/L (SE) | 4.4 (0.1) | 4.4 (0.1) | 4.4 (0.1) | 4.5 (0.1) | 0.70 |
| Triglycerides, mmol/L (SE) | 1.7 (0.1) | 1.5 (0.0) | 1.4 (0.0) | 1.3 (0.0) | < 0.01 |

| BF% quartiles (Q)[2] / Characteristics | $Q_1$ n = 333 | $Q_2$ n = 343 | $Q_3$ n = 339 | $Q_4$ n = 336 | P-value |
|---|---|---|---|---|---|
| Age, mean, years (SE) | 59.2 (0.2) | 59.8 (0.2) | 60.1 (0.2) | 60.0 (0.2) | 0.015 |
| BMI $kg/m^2$ (SE) | 23.2 (0.1) | 25.1 (0.1) | 26.5 (0.1) | 29.3 (0.1) | < 0.01 |
| Waist circumference, cm (SE) | 86 (0.2) | 94 (0.2) | 99 (0.2) | 108 (0.2) | < 0.01 |
| Hip circumference, cm (SE) | 92 (0.3) | 98 (0.3) | 101 (0.3) | 107 (0.3) | < 0.01 |
| Use of alcohol, g/week (SE) | 93 (7.6) | 110 (7.5) | 106 (7.5) | 161 (7.6) | < 0.01 |
| Current smoking, % | 21 | 16 | 17 | 14 | < 0.01 |
| Regular physical activity, % | 86 | 80 | 78 | 66 | < 0.01 |
| Regular physical activity, h/week (SE) | 4.4 (0.2) | 3.8 (0.2) | 3.9 (0.2) | 3.0 (0.2) | <0.001 |
| Coffee, cups/d (SE) | 3.4 (0.1) | 3.6 (0.1) | 3.7 (0.1) | 3.8 (0.1) | 0.26 |
| Tea, cups/d (SE) | 1.2 (0.1) | 1.1 (0.1) | 1.1 (0.1) | 1.0 (0.1) | 0.11 |
| Systolic BP, mm Hg (SE) | 134 (0.9) | 140 (0.9) | 142 (0.9) | 144 (0.9) | < 0.01 |
| Diastolic BP, mm Hg (SE) | 84 (0.5) | 87 (0.5) | 89 (0.5) | 90 (0.5) | < 0.01 |
| Fasting blood glucose, mmol/L (SE) | 4.7 (0.1) | 4.8 (0.1) | 5 (0,1) | 5.2 (0.1) | < 0.01 |
| Cholesterol, mmol/L (SE) | 6.4 (0.1) | 6.6 (0.1) | 6.5 (0.1) | 6.5 (0.1) | 0.16 |
| HDL cholesterol, mmol/L (SE) | 1.5 (0.0) | 1.4 (0.0) | 1.3 (0.0) | 1.3 (0.0) | < 0.01 |
| LDL cholesterol, mmol/L (SE) | 4.3 (0.1) | 4.6 (0.1) | 4.4 (0.1) | 4.3 (0.1) | 0.03 |
| Triglycerides, mmol/L (SE) | 1.2 (0.0) | 1.4 (0.0) | 1.6 (0.0) | 1.9 (0.0) | < 0.01 |

BMI = body mass index; BF = body fat; ; Q = quartile; SE = standard error; SM = skeletal muscle. Armitage test for trend in proportions and analysis of covariance (ANCOVA) were used to compare the quartiles. [1] The cut-offs for SM% are: $Q_1$ ≤34.03339; $Q_2$ >34.03339 and ≤ 35.93856; $Q_3$ >35.93856 and ≤37.7719; $Q_4$ >37.77179. [2] The cut-offs for BF% are: $Q_1$ ≤ 25.795; $Q_2$ > 25.795 and ≤ 28.7114; $Q_3$ > 28.7114 and ≤ 32.10375; $Q_4$ > 32.10375.

Table 2. Age-adjusted characteristics of participants of the Helsinki Businessmen Study (HBS) during follow-up in 2000 according to skeletal muscle % and body fat % quartiles at baseline

| Baseline SM% quartiles (Q)[1] / Characteristics in 2000 | $Q_1$ n = 229 | $Q_2$ n = 244 | $Q_3$ n = 253 | $Q_4$ n = 269 | P-value |
|---|---|---|---|---|---|
| Age, mean, years (SE) | 75 (0.2) | 75 (0.2) | 73 (0.2) | 72 (0.2) | <0.01 |
| BMI, kg/m$^2$ (SE) | 26.6 (0.2) | 25.7 (0.2) | 25.9 (0.2) | 24.6 (0.2) | < 0.01 |
| Use of alcohol, g/week (SE) | 123 (9.1) | 120 (8.8) | 122 (8.7) | 109 (8.4) | 0.67 |
| Current smoking, % | 5.7 | 5.3 | 6.7 | 6.3 | 0.62 |
| Regular physical activity, % | 76 | 82 | 86 | 85 | < 0.01 |
| Regular physical activity, h/week (SE) | 5.0 (0.4) | 5.6 (0.4) | 5.7 (0.3) | 5.3 (0.3) | 0.46 |
| **Baseline BF% quartiles (Q)[2] / Characteristics in 2000** | **$Q_1$ n = 264** | **$Q_2$ n = 263** | **$Q_3$ n = 240** | **$Q_4$ n = 235** | **P-value** |
| Age, mean, years (SE) | 73 (0.2) | 74 (0.2) | 74 (0.2) | 74 (0.2) | 0.01 |
| BMI kg/m$^2$ (SE) | 23.4 (0.2) | 24.9 (0.2) | 26.4 (0.2) | 28.4 (0.2) | < 0.01 |
| Use of alcohol, g/week (SE) | 103 (8.3) | 110 (8.4) | 116 (8.9) | 146 (9.0) | < 0.01 |
| Current smoking, % | 6.8 | 5.7 | 6.3 | 5.1 | 0.50 |
| Regular physical activity, % | 90 | 84 | 85 | 72 | < 0.01 |
| Regular physical activity, h/week (SE) | 5.9 (0.3) | 5.5 (0.3) | 5.3 (0.4) | 4.7 (0.4) | 0.13 |

BMI = body mass index;  BF = body fat; ; Q = quartile; SE = standard error; SM = skeletal  muscle Armitage test for trend in proportions and analysis of covariance (ANCOVA) were used to compare the quartiles. [1] The cut-offs for SM% are: $Q_1$ ≤34.03339; $Q_2$ >34.03339 and ≤ 35.93856; $Q_3$ >35.93856 and ≤37.7719; $Q_4$ >37.77179. [2] The cut-offs for BF% are: $Q_1$ ≤ 25.795; $Q_2$ > 25.795 and ≤ 28.7114; $Q_3$ > 28.7114 and ≤ 32.10375; $Q_4$ > 32.10375.

Table 3. Age-adjusted subscales of health-related quality of life (HRQoL) during follow-up according to different skeletal muscle % and body fat % quartiles at baseline

| Baseline SM% quartiles (Q)[1] / RAND-36 scales in 2000 and 2007, points | $Q_1$ n = 203 (2000) n = 115 (2007) | $Q_2$ n = 228 (2000) n = 139 (2007) | $Q_3$ n = 235 (2000) n = 167 (2007) | $Q_4$ n = 257 (2000) n = 175 (2007) | P-value |
|---|---|---|---|---|---|
| Physical Functioning (SE) | | | | | |
| 2000 | 73 (1.5) | 77 (1.4) | 79 (1.4) | 82 (1.3) | < 0.01 |
| 2007 | 68 (2.0) | 73 (1.9) | 75 (1.7) | 77 (1.7) | < 0.01 |
| Role limitations caused by physical health problems (SE) | | | | | |
| 2000 | 60 (2.5) | 69 (2.4) | 70 (2.3) | 74 (2.3) | < 0.01 |
| 2007 | 57 (1.4) | 68 (3.1) | 73 (2.9) | 70 (2.8) | < 0.01 |
| Role limitations caused by emotional health problems (SE) | | | | | |
| 2000 | 73 (2.3) | 77 (2.2) | 79 (2.2) | 79 (2.1) | 0.23 |
| 2007 | 73 (3.1) | 81 (2.7) | 79 (2.5) | 79 (2.5) | 0.23 |
| Vitality (SE) | | | | | |
| 2000 | 66 (1.4) | 69 (1.3) | 70 (1.3) | 71 (1.2) | 0.039 |
| 2007 | 69 (1.7) | 70 (1.5) | 72 (1.4) | 69 (1.4) | 0.34 |
| Mental Health (SE) | | | | | |
| 2000 | 81 (1.6) | 81 (1.1) | 81 (1.1) | 82 (1.1) | 0.90 |
| 2007 | 80 (1.4) | 81 (1.2) | 83 (1.1) | 80 (1.1) | 0.40 |
| Social Functioning (SE) | | | | | |
| 2000 | 83 (1.4) | 85 (1.4) | 85 (1.3) | 89 (1.3) | 0.018 |
| 2007 | 82 (1.6) | 83 (1.4) | 85 (1.3) | 84 (1.3) | 0.25 |
| Bodily Pain (SE) | | | | | |
| 2000 | 76 (1.5) | 79 (1.4) | 78 (1.4) | 81 (1.4) | 0.059 |
| 2007 | 76 (1.9) | 82 (1.7) | 78 (1.6) | 81 (1.6) | 0.17 |
| General Health (SE) | | | | | |
| 2000 | 56 (1.2) | 61 (1.2) | 61 (1.2) | 61 (1.1) | 0.013 |
| 2007 | 55 (1.6) | 61 (1.4) | 60 (1.3) | 61 (1.3) | 0.75 |

Continues…

TABLE 3 continued

| Baseline BF % quartiles(Q)[2] / RAND-36 scales in 2000 and 2007, points | $Q_1$ n = 244 (2000) n = 170 (2007) | $Q_2$ n = 243 (2000) n = 174 (2007) | $Q_3$ n = 224 (2000) n = 129 (2007) | $Q_4$ n = 219 (2000) n = 129 (2007) | P-value |
|---|---|---|---|---|---|
| Physical Functioning (SE) | | | | | |
| 2000 | 82 (1.3) | 80 (1.3) | 75 (1.4) | 74 (1.4) | < 0.01 |
| 2007 | 79 (1.7) | 74 (1.7) | 71 (1.9) | 69 (1.9) | < 0.01 |
| Role limitations caused by physical health problems (SE) | | | | | |
| 2000 | 77 (2.3) | 73 (2.3) | 62 (2.4) | 61 (2.4) | < 0.01 |
| 2007 | 76 (2.9) | 68 (2.8) | 67 (3.3) | 56 (3.3) | < 0.01 |
| Role limitations caused by emotional health problems (SE) | 83(2.1) | 77 (2.1)81 | 75 (2.2) | 72 (2.3) | < 0.01 |
| 2000 | 80 (2.5) | (2.4) | 76 (2.9) | 70 (2.9) | 0.03 |
| 2007 | | | | | |
| Vitality (SE) | | | | | |
| 2000 | 72 (1.3) | 69 (1.3) | 68 (1.3) | 66 (1.3) | < 0.01 |
| 2007 | 72 (1.4) | 70 (1.4) | 69 (1.6) | 67 (1.6) | 0.14 |
| Mental Health (SE) | | | | | |
| 2000 | 83 (1.1) | 81 (1.1) | 81 (1.1) | 80 (1.1) | 0.20 |
| 2007 | 83 (1.1) | 82 (1.1) | 80 (1.3) | 78 (1.3) | 0.08 |
| Social Functioning (SE) | | | | | |
| 2000 | 88 (1.3) | 87 (1.3) | 84 (1.4) | 83 (1.4) | 0.027 |
| 2007 | 85 (1.3) | 85 (1.3) | 84 (1.5) | 81 (1.5) | 0.25 |
| Bodily Pain (SE) | | | | | |
| 2000 | 81 (1.4) | 79 (1.4) | 77 (1.4) | 77 (1.4) | 0.13 |
| 2007 | 82 (1.6) | 77 (1.6) | 81 (1.8) | 76 (1.9) | 0.02 |
| General Health (SE) | | | | | |
| 2000 | 63 (1.1) | 61 (1.1) | 58 (1.2) | 58 (1.2) | < 0.01 |
| 2007 | 63 (1.3) | 60 (1.3) | 58 (1.5) | 56 (1.5) | < 0.01 |

[1] The cut-offs for SM% are: $Q_1 \leq 34.03339$; $Q_2 > 34.03339$ and $\leq 35.93856$; $Q_3 > 35.93856$ and $\leq 37.7719$; $Q_4 > 37.77179$. [2] The cut-offs for BF% are: $Q_1 \leq 25.795$; $Q_2 > 25.795$ and $\leq 28.7114$; $Q_3 > 28.7114$ and $\leq 32.10375$; $Q_4 > 32.10375$.

TABLE 4. Odds ratios of reaching 90 years of age during the 32-year follow- up of the Helsinki Businessmen Study according to skeletal muscle % and body fat % quartiles at baseline

| | OR of reaching 90 years of age[1] | | | |
|---|---|---|---|---|
| | SM% $Q_1$ | SM% $Q_2$ | SM% $Q_3$ | SM% $Q_4$ |
| Model 1 (95%, CI) | 1.0 (ref) | 1.18 (0.79, 1.76) | 1.90 (1.27, 2.83) | 2.36 (1.56, 3,56) |
| Model 2 (95%, CI) | 1.0 (ref) | 1.19 (0.79, 1.79) | 1.80 (1.19, 2.70) | 2.32 (1.53, 3.53) |
| | OR of reaching 90 years of age[1] | | | |
| | BF% $Q_1$ | BF% $Q_2$ | BF% $Q_3$ | BF% $Q_4$ |
| Model 1 (95%, CI) | 1.0 (ref) | 0.72 (0.49-1.05) | 0.78 (0.53-1.13) | 0.41 (0.27, 0.62) |
| Model 2 (95%, CI) | 1.0 (ref) | 0.74 (0.50, 1.09) | 0.77 (0.52, 1.13) | 0.43 (0.28, 0.66) |

BF = body fat; Cl = confidence interval; OR = odds ratio; Q = quartile; SM = skeletal muscle. [1]OR was calculated using logistic regression with lowest quartile as reference (OR=1.0). Model 1 adjusted for age at baseline in 1985/86; Model 2 adjusted for age, smoking (yes/no), alcohol consumption (grams/week), and regular exercise (cut-point 3 hours/week) at baseline in 1985/86.

## Legend for the figure:

Figure 1. Flowchart of the study. BF = body fat; SM = skeletal muscle.