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Current obesity, steady weight change and weight fluctuation as predictors of physical functioning in middle aged office workers: the Whitehall II study

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OBJECTIVES: (i) To investigate the effects of current obesity, steady weight change and weight fluctuation on physical functioning and (ii) to determine whether associations are independent of coronary heart disease.
DESIGN: Prospective cohort study with body mass index (BMI) measurements at four time points between the ages of 25 and 63 y.
SETTING: British civil servants based in London offices at baseline.
PARTICIPANTS: 6895 men and 3413 women aged 35–55 y at baseline.
MAIN OUTCOME MEASURE: Physical functioning was assessed using the 10-item scale from the Short Form 36 Health Survey, with a score in the lowest quartile indicating poor physical functioning.
RESULTS: After adjustment for age and confounders (employment grade, smoking, alcohol, exercise and menopausal status), current BMI was monotonically associated with poor physical functioning in women whereas a threshold effect at a BMI of 27 kg/m^2 was seen in men. The odds ratio of poor physical functioning was 1.55 (95% confidence interval (CI) 1.02–2.35) amongst women and 1.04 (95% CI 0.77–1.41) amongst men with BMI 23–24.9 kg/m^2 compared to those with BMI < 21 kg/m^2. Women in the upper, compared to the lower, tertile of steady weight change, had an odds ratio of poor physical functioning of 1.79 (1.24–2.60) after adjustment for age, confounders, current BMI and weight fluctuation. Women in the upper, compared to the lower, tertile of weight fluctuation had an odds ratio of poor physical functioning of 1.70 (1.23–2.34) adjusting for age, confounders, current BMI and steady weight change. Adjustment for the presence of coronary heart disease did not substantially alter any of these associations. Steady weight change and weight fluctuation had no independent effects in men.
CONCLUSION: Among women, current obesity, steady weight change and weight fluctuation are independently and monotonically associated with poor physical functioning. Development of overt coronary heart disease is unlikely to be the mechanism for these associations.

Keywords: obesity; weight change; physical functioning; SF-36

Introduction

The prevalence of obesity and weight gain is increasing in many developed countries[1–3] and dieting behaviours, which can lead to weight fluctuation as successive dieting attempts fail, are widespread.[4–6] Changes in weight may occur steadily or may fluctuate with repeated losses and gains. Steady changes in weight predict cardiovascular risk factors such as hypertension, high cholesterol and glucose intolerance[7–10] and coronary heart disease,[11,12] and these effects are independent of attained weight. Furthermore, independent of steady weight change, fluctuations in weight may predict mortality and morbidity from coronary heart disease,[13–16] although the mechanisms are not clear.[17]

Independent of their effects on cardiovascular risk factors, manifest disease and mortality, do obesity and weight change influence health? Perceived health is lower amongst the obese,[18,19] those who continuously gained weight[10] and those who lost and regained weight.[10,20] As part of the 'outcomes' movement, measurement of physical health functioning, a component of perceived health, has become widespread in clinical studies.[21] However, few population studies have examined the relationship between physical functioning and obesity or weight change. Overweight and obese subjects from the general population in Sweden reported greater physical impairment and reduced mobility.[19] There is a reported inverse relationship between obesity and work capacity in employed men and women[22,23] and between obesity

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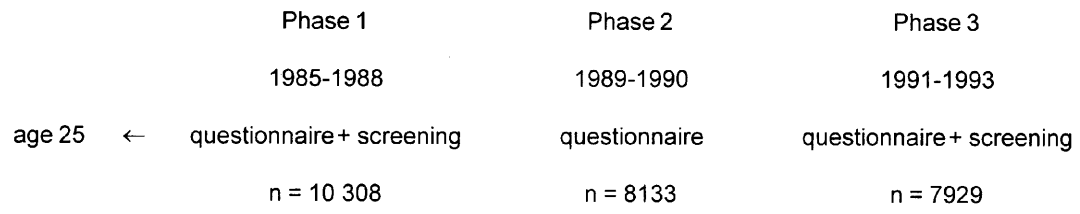

Figure 1 Whitehall II study design.

and physical well-being and loss of mobility in older subjects.[24,25] Weight loss between two time points has been associated with increased risk of disability among women but not men.[24,26]

The objectives of this study therefore were (i) to investigate the effects of current obesity, steady weight change and weight fluctuation on poor physical functioning and (ii) to determine whether these associations were independent of coronary heart disease. All the participants in the Whitehall II study were employed in the British Civil Service at recruitment and therefore represent a comparatively young, high functioning population. We used the physical functioning scale of the Short Form 36 Health Survey[27] (SF-36), a measure which is widely used in clinical outcome studies.

Methods

Study population

All non-industrial civil servants aged 35–55 y, working in the London offices of 20 departments, were invited to participate in this study. The design of the study is illustrated in Figure 1. Between 1985 and 1988 (Phase 1), a total of 10 308 subjects (6895 men and 3413 women) were enrolled into the study, completing a self-administered health questionnaire and attending for screening. Between 1989 and 1990, the first follow-up (Phase 2), was undertaken, in the form of a postal questionnaire only. At the second follow-up (Phase 3), between 1991 and 1993, subjects completed a third questionnaire and attended for a second screening. Full details of the screening examinations are reported elsewhere.[28,29] Before Phase 3 was completed, 197 participants died. A total of 4918 men (89.4% male respondents at Phase 3), and 2194 women (90.3% female respondents at Phase 3) had complete data on physical functioning, height and weight at Phase 3, at least two measures of body mass index (BMI), and were included in these analyses.

Measurements of weight (with indoor clothing), and height (without shoes), were taken at Phase 1 and Phase 3 screening. Weights at the age of 25 y and Phase 2 were obtained from self-reports at Phase 1 and Phase 2, respectively, and BMI at these time points was calculated using measured height at Phase 1. Height was assumed on the basis of a previous study[30] not to have changed between the age of 25 y and Phase 2. Categories of BMI at Phase 3 (current BMI), were calculated using the following cut-off points: $< 21\,kg/m^2$, $21–22.9\,kg/m^2$, $23–24.9\,kg/m^2$, $25–26.9\,kg/m^2$, $27–28.9\,kg/m^2$ and $\geq 29\,kg/m^2$. These were chosen in order to investigate the effects of BMI within the so-called 'normal' range and have been used previously.[11]

Physical functioning was assessed using the 10-item scale of the Short Form 36 Health Survey (SF-36) at Phase 3 and was scored with the MOS scoring system.[27] The reliability and validity of the SF-36 has been extensively reported.[31–33] The physical functioning scale had high internal consistency (Cronbach's [34] $\alpha = 0.86$). Subjects were asked 'The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? a) vigorous activities, such as running, lifting heavy objects, participating in strenuous sports; b) moderate activities, such as moving a table, pushing a vacuum cleaner, bowling or playing golf; c) lifting or carrying groceries; d) climbing several flights of stairs; e) climbing one flight of stairs; f) bending, kneeling or stooping; g) walking more than 1 mile; h) walking half a mile; i) walking one hundred yards; j) bathing and dressing yourself.' The physical functioning scores ranged from a possible 0 (indicating severe limitation in performing all physical activities) to 100 (indicating no limitation in performing all types of physical activities including the most vigorous).

Responses to questions concerning employment grade, smoking status, amount smoked, alcohol intake, physical activity and menopausal status were obtained from the questionnaires in all three phases. Employment grade within the civil service was used as a measure of socio-economic status. Details are given elsewhere.[28] These factors have been associated with physical functioning[35] and obesity or weight change, and were considered as confounders. Adjustment was made for employment grade, physical activity, smoking status and menopausal status, all reported at the same time as physical functioning. Total amount smoked and average alcohol intake throughout follow-up were also adjusted for.

Coronary heart disease was identified at Phase 3 (numbers in brackets indicate number of subjects with disease) by: Rose angina questionnaire[36] ($n = 301$), self report of doctor diagnosed ischaemia ($n = 150$) and probable or possible ischaemia on resting electro-

cardiogram (Minnesota codes 1-1 to 1-3, 4-1 to 4-4, 5-1 to 5-3 and 7-1-1 ($n = 380$)). A total of 478 men and 247 women satisfied one or more of the above definitions. Other obesity related disorders were identified: hypertension (systolic blood pressure ≥ 160 mmHg and/or diastolic blood pressure ≥ 90 mmHg or the subject using anti-hypertensive medication ($n = 1497$)), diabetes (self report or on oral glucose tolerance test[37] ($n = 206$)) and musculoskeletal disorders (self report ($n = 838$)). A total of 1832 (37.3%) men and 785 (35.8%) women had coronary heart disease and/or other obesity related diseases. In order to determine whether the effects of obesity and weight change on physical functioning were independent of disease, adjustment was made for the above disorders, and for cholesterol and triglyceride levels.

Statistical Methods

Estimates of steady weight change between the age of 25 y and Phase 3 were obtained by regressing up to four measures of BMI on age, for each individual using a linear model with intercept. Weight fluctuation was estimated using the coefficient of variation of BMI: = the standard deviation of each individual's BMI value from the age of 25 y to Phase 3 (up to four BMI values) divided by the mean BMI for that subject.[14] The coefficient of variation reflects the extent to which each individual's BMI fluctuated around their own mean value. A high coefficient of variation indicates many changes in weight or large changes, whereas a low value indicates stability. This measure incorporates a component of steady weight change as well as a component of fluctuation; therefore demonstration of the independent effect of fluctuation requires a separate adjustment for steady weight change. This was achieved by including steady weight change and weight fluctuation in a multiple regression model.

The distribution of physical functioning scores was skewed to the left and a large proportion of subjects attained the maximum possible score. To overcome the distributional problems due to this ceiling effect, subjects were categorised according to whether or not they had poor physical functioning, defined as a score in the lowest gender-specific quartile. Using logistic regression, the odds ratio of poor physical functioning by current BMI was estimated in five models:

Model 1: Adjusted for age.
Model 2: As Model 1 + employment grade, smoking status, amount smoked, alcohol intake, physical activity and menopausal status.
Model 3: As Model 2 + steady weight change and weight fluctuation.
Model 4: As Model 3 + coronary heart disease.
Model 5: As Model 4 + other obesity related disorders.

The relationships between physical functioning, steady weight change and weight fluctuation were examined in the same way. Tests for linear trend were performed on continuous variables, but results are presented using categorical variables for ease of presentation. The reference groups were defined as subjects with BMI $< 21\,kg/m^2$, and subjects in the lowest tertiles of steady weight change and weight fluctuation. The lowest tertile of steady weight change included both subjects that had an overall loss in weight over the course of the study and subjects that had an overall gain, but no difference in physical functioning was found between them. All analyses were performed using the statistical package SAS, with separate analyses for men and women. Two-tailed tests were used throughout and a probability of less than 0.05 was taken to be statistically significant.

Results

The median age (range) of participants at Phase 3 was 49 y (39–63) for men and 50 y (39–63) for women. Over 20% of men and 30% of women had a BMI $\geq 27\,kg/m^2$. A greater proportion of women had a BMI $\geq 29\,kg/m^2$. The majority of subjects gained at least 5 kg in weight between age 25 y and Phase 3, as shown in Table 1. A greater proportion of women gained 20 kg or more during that time. Women had a higher mean and greater variation in steady weight change (mean slope $\pm$ s.d. $= 0.105 \pm 0.122\,kg/m^2$ per year for men and $0.137 \pm 0.175\,kg/m^2$ per year for women). Similarly, women had a higher mean and greater variation in weight fluctuation (mean coefficient of variation $\pm$ s.d. $= 0.064 \pm 0.040$ for men and 0.090 ± 0.058 for women). Subjects tended to underestimate their weight, with mean (s.d.) underestimation at Phase 1 of 0.51 kg (2.91) for men and 0.89 kg (3.03) for women. The degree of underestimation increased with increasing weight, but as a proportion of actual body weight the differences between self-reported and measured weights were small.

Mean physical functioning score in the lowest quartile was 74.2 (range 0–89) for men and 57.1 (0–75) for women compared with a mean of 96.4 (90–100) for men and 93.2 (80–100) for women not in the

Table 1 Weight change between age 25 y and Phase 3 (1991–1993) in British civil servants, with median follow-up time (range) 49 y (39–64 y)

	Men		*Women*	
Weight change	*n*	*(%)*	*n*	*(%)*
Lost > 5 kg	173	(3.3)	82	(3.5)
No overall change (−5 kg–4.9 kg difference)	1745	(33.3)	714	(30.9)
Gained				
5–9.9 kg	1525	(29.1)	590	(25.5)
10–19.9 kg	1505	(28.8)	638	(27.6)
≥ 20 kg	285	(5.4)	286	(12.4)

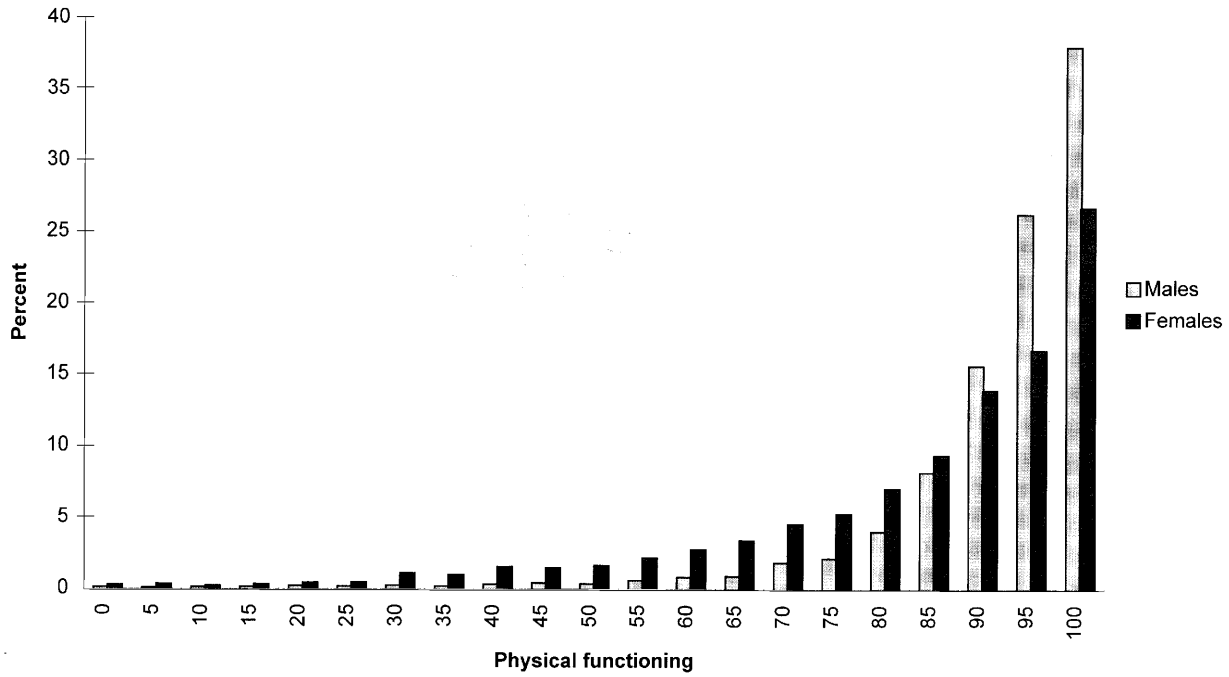

Figure 2 Distribution of physical functioning scores by gender.

lowest quartile (Figure 2). Subjects who were in the lowest quartile of physical functioning, tended to report that their ability to perform vigorous activities and to climb several flights of stairs was limited a lot. Their ability to perform moderate activities such as lift and carry, bend and kneel, and walk more than 1 mile, tended to be a little limited.

Table 2 shows the effects of current BMI on the odds of having poor physical functioning (both measures taken at Phase 3). The odds ratios of being in the lowest quartile of physical functioning increased with increasing BMI in all models (test for linear trend $P < 0.01$). This relationship was monotonic for women in models 1 and 2; with each increment of BMI above $21\,kg/m^2$ the odds of poor physical functioning increased. Adjusting for age and confounders, the odds ratio of poor physical functioning was 1.55 (95% confidence interval (CI) 1.02–2.35) amongst those with BMI 23–$24.9\,kg/m^2$ compared to those with BMI $< 21\,kg/m^2$. In men there was evidence of a threshold effect at a BMI of $27\,kg/m^2$. Men with a BMI $\geq 29\,kg/m^2$ *vs* $< 21\,kg/m^2$ had an

Table 2 Odds ratio (95% confidence interval of poor physical functioning at Phase 3 (1991–1993) by current body mass index (BMI), taking subjects with BMI $< 21\,kg/m^2$ as the reference group. Model 1: adjusted for age; Model 2: as Model 1 + confounders[a]; Model 3: as Model 2 + steady weight change and weight fluctuation; Model 4: as Model 3 + coronary heart disease[b] and Model 5: as Model 4 + other obesity related disorders[c]

	n	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Men						
$< 21\,kg/m^2$	424	1.00	1.00	1.00	1.00	1.00
21–22.9 kg/m^2	905	0.96 (0.69,1.32)	1.02 (0.73,1.41)	0.97 (0.70.1.34)	0.96 (0.69,1.34)	0.90 (0.64,1.26)
23–24.9 kg/m^2	1559	1.00 (0.74,1.34)	1.04 (0.77,1.41)	0.94 (0.69,1.29)	0.93 (0.68,1.26)	0.83 (0.61,1.14)
25–26.9 kg/m^2	1266	1.08 (0.80,1.46)	1.11 (0.81,1.51)	0.95 (0.69,1.31)	0.94 (0.68,1.29)	0.81 (0.59,1.12)
27–28.9 kg/m^2	715	1.45 (1.06,2.00)	1.41 (1.02,1.96)	1.15 (0.81,1.62)	1.12 (0.80,1.59)	0.93 (0.65,1.32)
$\geq 29\,kg/m^2$	580	2.41 (1.75,3.31) **	2.35 (1.67,3.26) **	1.78 (1.25,2.55) **	1.69 (1.18,2.42) **	1.41 (0.98,2.03) **
Women						
$< 21\,kg/m^2$	293	1.00	1.00	1.00	1.00	1.00
21–22.9 kg/m^2	448	1.02 (0.67,1.47)	1.07 (0.68,1.67)	0.97 (0.62,1.53)	0.95 (0.61,1.50)	0.93 (0.59,1.47)
23–24.9 kg/m^2	506	1.53 (1.03,2.28)	1.55 (1.02,2.35)	1.29 (0.84,1.98)	1.29 (0.84,1.98)	1.17 (0.76,1.80)
25–26.9 kg/m^2	415	1.71 (1.14,2.56)	1.65 (1.08,2.53)	1.23 (0.79,1.92)	1.24 (0.79,1.93)	1.08 (0.69,1.70)
27–28.9 kg/m^2	266	2.73 (1.79,4.17)	2.66 (1.70,4.15)	1.76 (1.10,2.84)	1.72 (1.07,2.77)	1.50 (0.93,2.42)
$\geq 29\,kg/m^2$	484	3.84 (2.62,5.63) **	3.73 (2.49,5.58) **	2.09 (1.31,3.32) **	2.04 (1.28,3.25) **	1.70 (1.06,2.72) *

Test for linear trend: *$P < 0.01$, **$P < 0.001$.
[a]Confounders adjusted for are employment grade (6 levels from administrative to clerical), smoking status (never, ex and current), amount smoked (packyears), alcohol intake (units per week), physical activity (vigorous, moderate, mild/none) and menopausal status (pre-menopausal, natural menopause, hysterectomy – women only).
[b]Angina, doctor diagnosed ischaemia and possible or probable ischaemia on resting electrocardiogram.
[c]Hypertension, diabetes, musculoskeletal disorders, cholesterol and triglycerides.

Table 3 Odds ratio (95% confidence interval of poor physical functioning at Phase 3 (1991–1993) by steady weight change, taking subjects in the lower tertile as the reference group. Model 1: adjusted for age; Model 2: as Model 1 + confounders[a]; Model 3: as Model 2 + current BMI and weight fluctuation; Model 4: as Model 3 + coronary heart disease[b] and Model 5: as Model 4 + other obesity related disorders[c]

Tertile	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Men					
Lower (-1.05–$0.05\,kg/m^2/y$)	1.00	1.00	1.00	1.00	1.00
Middle (0.06–$0.13\,kg/m^2/y$)	1.23 (0.95,1.32)	1.09 (0.92,1.29)	0.90 (0.75,1.08)	0.91 (0.75,1.09)	0.90 (0.75,1.08)
Upper (0.14–$1.40\,kg/m^2/y$)	1.75 (1.49,2.07) **	1.53 (1.29,1.81) **	0.91 (0.71,1.17)	0.93 (0.72,1.19)	0.89 (0.69,1.14)
Women					
Lower (-2.58–$0.06\,kg/m^2/y$)	1.00	1.00	1.00	1.00	1.00
Middle (0.07–$0.18\,kg/m^2/y$)	1.42 (1.11,1.79)	1.41 (1.10,1.81)	1.23 (0.94,1.63)	1.24 (0.94,1.64)	1.19 (0.89,1.57)
Upper (0.18–$1.28\,kg/m^2/y$)	3.12 (2.48,3.94) **	2.98 (2.34,3.80) **	1.79 (1.24,2.60) *	1.78 (1.23,2.59) *	1.68 (1.15,2.44) (*)

Test for linear trend: (*)$P < 0.1$, *$P < 0.05$, **$P < 0.001$
[a]Confounders adjusted for are employment grade (six levels from administrative to clerical), smoking status (never, ex and current), amount smoked (pack/y), alcohol intake (units per week), physical activity (vigorous, moderate, mild/none) and menopausal status (pre-menopausal, natural menopause, hysterectomy–women only).
[b]Angina, doctor diagnosed ischaemia and possible or probable ischaemia on resting electrocardiogram.
[c]Hypertension, diabetes, musculoskeletal disorders, cholesterol and triglycerides.

odds ratio of 2.35 (95% (CI) 1.67–3.26) for poor physical functioning. The corresponding odds ratio for women was 3.73 (95% CI 2.49–5.58). On further adjustment for steady weight change and weight fluctuation, these odds ratios were attenuated to 1.78 (95% CI 1.25–2.55) in men and 2.09 (95% CI 1.31–3.32) in women.

Participants with steady weight change in the upper tertile were more likely to have poor physical functioning compared with those in the lower tertile in age and confounder adjusted models (Table 3). These associations were smaller among men and were abolished on adjustment for current BMI and weight fluctuation. In contrast, women in the upper, compared to the lower, tertile of steady weight change had an odds ratio of poor physical functioning of 1.79 (95% CI 1.24–2.60) after adjustment for age, confounders, current BMI and weight fluctuation. Adjustment for the presence of coronary heart disease or other obesity related diseases had little effect on this estimate. Figure 3 shows the effect of steady weight change on physical functioning, separately for subjects with BMI $< 27\,kg/m^2$ and $\geq 27\,kg/m^2$. In women, the effect of steady weight change appeared to be greater for those whose attained BMI was $< 27\,kg/m^2$, although the test for interaction did not achieve significance ($P = 0.1$).

Increasing weight fluctuation was associated with odds of poor physical functioning in all models (test for linear trend $P < 0.05$, Table 4). The odds ratio of

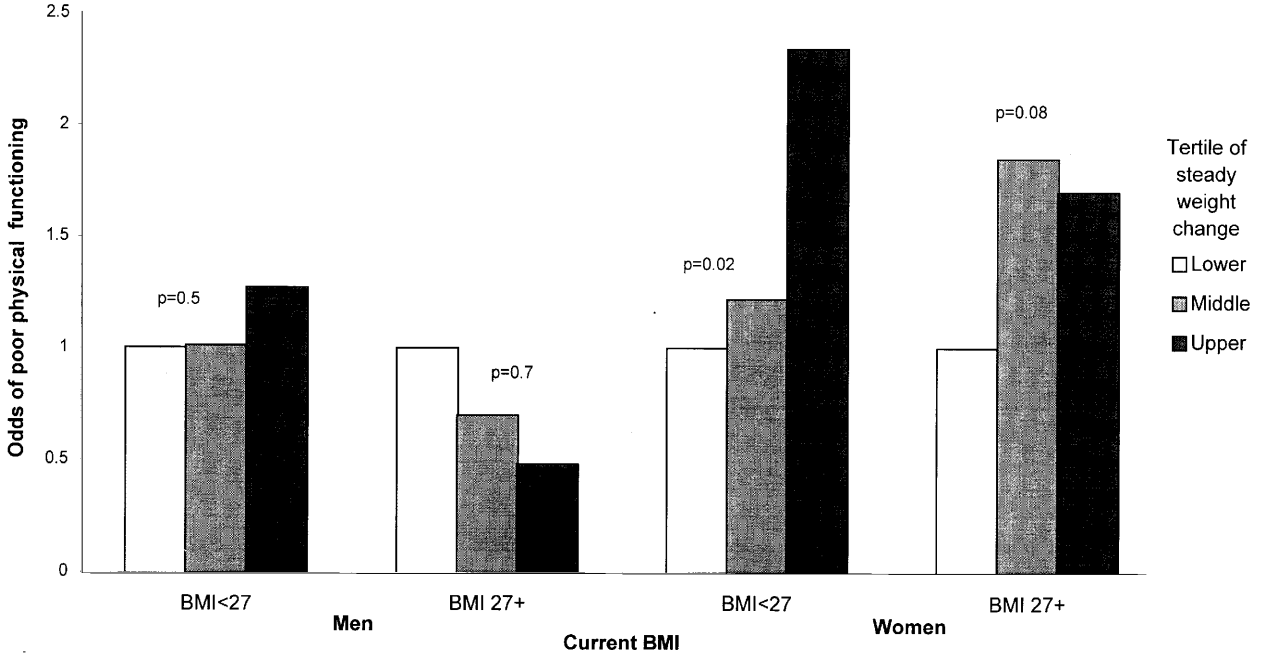

Figure 3 Effect of steady weight change on physical functioning by current body mass index (BMI). *P*-values indicate test for trend in steady weight change for BMI $< 27\,kg/m^2$ and BMI $\geq 27\,kg/m^2$ adjusted for age, employment grade, smoking, physical activity, alcohol intake, weight fluctuation, coronary heart disease and other obesity related disorders.

Table 4 Odds ratio (95% confidence interval of poor physical functioning at Phase 3 (1991–1993) by weight fluctuation, taking subjects in the lower tertile as the reference group. Model 1: adjusted for age; Model 2: as Model 1 + confounders[a]; Model 3: as Model 2 + current BMI and steady weight change; Model 4: as Model 3 + coronary heart disease[b] and Model 5: as Model 4 + other obesity related disorders[c]

Tertile	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Men					
Lower (0.00–0.03)	1.00	1.00	1.00	1.00	1.00
Middle (0.04–0.07)	1.21 (1.02,1.43)	1.15 (0.96,1.37)	1.00 (0.83,1.20)	1.01 (0.84,1.22)	0.99 (0.82,1.19)
Upper (0.07–0.59)	1.86 (1.48,2.18) **	1.61 (1.36,1.90) **	1.16 (0.94,1.43) *	1.18 (0.95,1.46) *	1.11 (0.90,1.38) *
Women					
Lower (0.00–0.05)	1.00	1.00	1.00	1.00	1.00
Middle (0.06–0.09)	1.75 (1.37,2.24)	1.70 (1.32,2.20)	1.43 (1.08.1.88)	1.42 (1.08,1.88)	1.38 (1.04,1.83)
Upper (0.10–0.46)	3.02 (2.39,3.82) **	2.92 (2.28,3.74) **	1.70 (1.23,2.34) *	1.65 (1.20,2.28) *	1.59 (1.15,2.20) *

Test for linear trend: $*P < 0.05$, $**P < 0.001$.
[a]Confounders adjusted for are employment grade (six levels from administrative to clerical), smoking status (never, ex and current), amount smoked (pack/y), alcohol intake (units per week), physical activity (vigorous, moderate, mild/none) and menopausal status (pre-menopausal, natural menopause, hysterectomy–women only).
[b]Angina, doctor diagnosed ischaemia and possible or probable ischaemia on resting electrocardiogram.

poor physical functioning in the upper tertile of weight fluctuation was 1.16 (95% CI 0.94–1.43) for men and 1.70 (95% CI 1.23–2.34) for women compared to subjects in the lower tertile, adjusting for age, confounders, current BMI and steady weight change. Adjustment for the presence of disease did not substantially alter these associations. Figure 4 shows the effects of weight fluctuation on physical functioning separately for subjects with BMI $< 27\,kg/m^2$ and $\geq 27\,kg/m^2$. In women, the effect of weight fluctuation appeared to be greater for those whose attained BMI was $< 27\,kg/m^2$.

Discussion

Current BMI was monotonically associated with poor physical functioning in women. Additionally, there were independent effects of steady weight change and weight fluctuation. Amongst men, there was evidence of a threshold effect of current BMI at $27\,kg/m^2$ but no independent effects of steady change or weight fluctuation on poor physical functioning. Coronary heart disease and other obesity related disorders did not explain these associations. The effect of weight

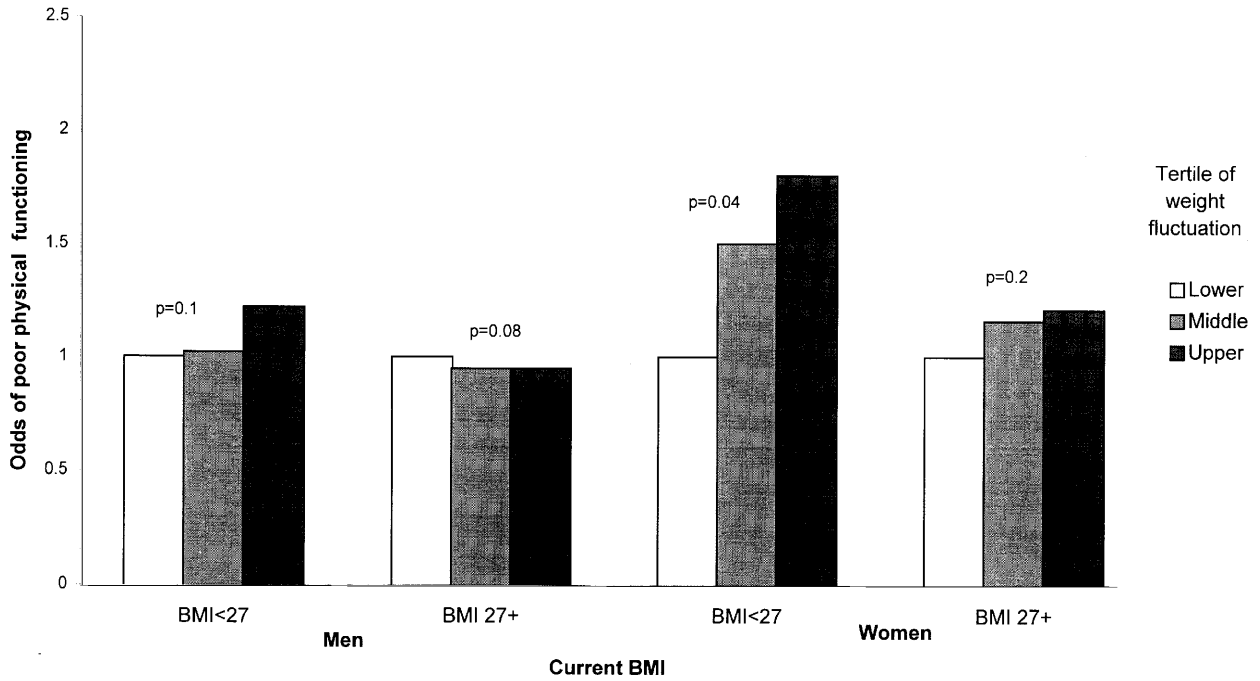

Figure 4 Effect of weight fluctuation on physical functioning by current body mass index (BMI). *P*-values indicate test for trend in weight fluctuation for BMI $< 27\,kg/m^2$ and BMI $\geq 27\,kg/m^2$ adjusted for age, employment grade, smoking, physical activity, alcohol intake, steady weight change, coronary heart disease and other obesity related disorders.

fluctuation appeared to be greater amongst women with BMI $< 27\,kg/m^2$. This is consistent with other studies,[20,38,39] where greater adverse effects of weight change on health were seen amongst those that were not overweight (where weight loss is more likely to be unintentional),[40] than amongst those who were overweight.

The gender differences in associations between weight change and physical functioning were striking. Even when poor physical functioning was defined as a score of less than 50, associations between physical functioning, steady weight change and weight fluctuation were not seen in men (data not shown). Women demonstrated greater impairment on the physical functioning scale as well as a greater tendency to steady weight change and weight fluctuation. To our knowledge, there are no data on gender differences in unintentional weight loss, but both the point prevalence and the cumulative number of episodes of dieting with the intention of weight loss are more common in women.[4] This may explain the lack of independent effects of steady weight change and weight fluctuation in men. Patterns of weight change are an alternative explanation. Using the coefficient of variation to estimate fluctuation does not allow us to distinguish between patterns of weight change (for example, repeated gains and losses, gain then maintenance). Men may demonstrate different patterns of change, which may not be associated with poor physical functioning. For example, women who experienced continuous weight gain or weight loss followed by regain were more likely to rate their health as poor than women who maintained a stable weight or lost or gained weight and then reached a stable weight.[10] The gender differences were not due to the menopause (which is not associated with weight change independently of age in these data or in other studies),[41] or parity. Gender differences could, however, be explained by differential associations between mental health, obesity and weight change. Much of the evidence that mental health is associated with obesity and weight change relates to women.[18,42–45] Mental health is also associated with physical functioning.[46] Thus greater effects of obesity and weight change on mental health in women may result in greater effects on physical functioning.

The importance of assessing functional health outcomes, as well as disease status, has recently been strongly emphasised, particularly as the population prevalence of physical disability is increasing.[47] In this comparatively young, occupational cohort, poor physical functioning was defined by relatively mild impairments. Few participants would be categorised as dependent on others for the activities of daily living scales widely used in studies of older populations. We would expect to see effects of morbid obesity and extreme weight gain on functioning. The fact that we see smaller impairments in the presence of a lesser degree of obesity and weight change indicates that the SF-36 is a sensitive instrument, although the large proportion of subjects attaining the maximum score decreases the power to detect differences. Other studies have used a physical component summary measure,[48] derived analytically and incorporating scores on other scales. Whilst this summary may be useful for avoiding multiple comparison problems, we were specifically interested in physical functioning, a scale which has been validated.[49] The causes and consequences of impaired physical functioning within a middle aged, high functioning population have rarely been studied, yet the public health importance (in terms of health service utilisation and sickness absence alone) of identifying factors which offer the potential for preventing decline in physical functioning before old age is likely to be great.

It is not yet clear how weight fluctuation increases the risk of morbidity and mortality, or indeed whether this relationship is causal, although plausible mechanisms have been proposed.[17] We found that adjustment for the presence of coronary heart disease and other obesity related disorders did not account for the association between weight fluctuation and physical functioning. Since physical functioning provides an assessment of the integrated impact of both the number and severity of the comorbidities of study participants, results from this study suggest a mechanism which involves early or pre-clinical vascular disease[50] or direct physiologic effects (such as increased wear and tear on joints, loss of flexibility and limited cardio-pulmonary function[51]) in the absence of disease.

Potential limitations of this study should be considered. We cannot distinguish between intentional and unintentional changes in weight. We have adjusted for disease status, which may explain a degree of unintentional weight change. However, we did not adjust for other causes of unintentional weight loss such as stress and depression. As physical functioning was not measured at baseline, we cannot directly address the question of whether poor physical functioning may have preceded, rather than been a result of, obesity and weight change. However, subjects were in employment and aged 35–55 y at baseline so the prevalence of physical disability should have been low. Further phases of data collection will enable us to examine the effects of obesity and weight change on changes in physical functioning. The possibility of reporting bias must also be considered when interpreting these results. Subjects with high BMI and/or weight change may report more limitations irrespective of actual functional ability. Since two measures of weight were self-reported, weight fluctuation and steady weight change may have been under- or overestimated. However, we found no differences in the relationship between BMI at baseline, and physical functioning between subjects who underestimated their weight and those who did not. Subjects excluded because of missing values tended to be older, with higher mean BMI, weight fluctuation and steady weight change and lower mean physical

functioning. This is likely to have biased the odds ratios towards unity.

The data presented here for physical functioning, extend those in relation to fatal and non-fatal coronary heart disease,[11] indicating that there is a graded, rather than threshold, effect of current BMI amongst women. It appears that the desirable range of BMI may be different for men and women. Previous recommendations[52] concerning the health consequences of obesity proposed that a BMI between 21 kg/m^2 and 27 kg/m^2 is desirable and made no comment on absolute changes in body weight. Recent guidelines[53] specify a healthy weight target of BMI < 25 kg/m^2 and a 10% reduction in weight amongst the overweight. The abolition of a lower limit of BMI recognises that, among the disease-free, there is a monotonic effect of BMI on health, although this and other studies[11,54] suggest that an upper limit of 25 kg/m^2 may still be too high. Our results add to the evidence from observational studies that weight fluctuation may have an adverse effect on health, particularly amongst those that are not currently overweight, and re-iterate the need for further investigation into the effects of intentional and unintentional weight loss. The levels of weight and weight change at which odds of poor physical functioning are increased are by no means confined to the extremes of the population. For example, taking the average height to be 1.75 m for men and 1.60 m for women, a BMI of 29 kg/m^2 corresponds to a weight of 89 kg for men and 74 kg for women. Steady changes in BMI of 0.14 kg/m^2/y for men and 0.18 kg/m^2/y for women correspond to weight gains of 0.4 kg/y for men and 0.5 kg/y for women. Weight fluctuation in the upper tertile was at least 0.07 for men and 0.10 for women, corresponding to variations in weight of 7% and 10% of mean body weight.

These findings suggest that for women, maintaining a steady, moderate weight may reduce not only the temporally distant risk of coronary heart disease, but also the more immediate risk of poor physical functioning. The mechanisms by which obesity, steady weight change and weight fluctuation may affect the risk of poor physical functioning, and the reasons for gender differences in these associations are not yet understood. Physical functioning may be a useful outcome for interventions designed to influence favourable patterns of weight change or stability.

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References

1 Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. Increasing prevalence of overweight among US adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. *JAMA* 1994; **272**: 205–211.
2 OPCS. *Health Survey for England, 1993*. HMSO: London, 1995.
3 Kuskowska-Wolk A, Bergstrom R. Trends in body mass index and prevalence of obesity in Swedish men 1980–89. *J Epidemiol Community Health* 1993; **47**: 103–108.
4 Jeffery RW, Adlis SA, Forster JL. Prevalence of dieting among working men and women: the healthy worker project. *Health Psychology* 1991; **10**: 274–281.
5 Jeffery RW, Folsom AR, Luepker RV, Jacobs DRJ, Gillum RF, Taylor HL, Blackburn H. Prevalence of overweight and weight loss behaviour in a metropolitan adult population: the Minnesota Heart Survey experience. *Am J Public Health* 1984; **74**: 349–352.
6 Horm J, Anderson K. Who in America is trying to lose weight? *Ann Intern Med* 1993; **119**: 672–676.
7 Sonne-Holm S, Sorensen TI, Jensen G, Schnohr P. Independent effects of weight change and attained body weight on prevalence of arterial hypertension in obese and non-obese men. *Br Med J* 1989; **299**: 767–770.
8 Khoury P, Morrison JA, Mellies MJ, Glueck CJ. Weight change since age 18 years in 30- to 55-year-old whites and blacks. Associations with lipid values, lipoprotein levels and blood pressure. *JAMA* 1983; **250**: 3179–187.
9 Feskens EJ, Bowles CH, Kromhout D. A longitudinal study on glucose tolerance and other cardiovascular risk factors: associations within an elderly population. *J Clin Epidemiol* 1992; **45**: 283–300.
10 French SA, Jeffery RW, Folsom AR, McGovern P, Williamson DF. Weight loss maintenance in young adulthood: prevalence and correlations with health behaviour and disease in a population-based sample of women aged 55–69. *Int J Obes* 1996; **20**: 303–310.
11 Willett WC, Manson JE, Stampfer MJ, Colditz GA, Rosner B, Speizer FE, Hennekens CH. Weight, weight change, and coronary heart disease. *JAMA* 1995; **273**: 461–465.
12 Wannamethee G, Shaper AG. Weight change in middle-aged British men: implications for health. *Eur J Clin Nutr* 1990; **44**: 133–142.
13 Hamm P, Shekelle R, Stampler J. Large fluctuations in body weight during young adulthood and twenty-five year risk of coronary death in men. *Am J Epidemiol* 1989; **129**: 312–318.
14 Lissner L, Odell P, Agostino R, Stokes J, Kreger B, Belanger A, Brownell K. Variability of body weight and health outcomes in the Framingham population. *N Engl J Med* 1991; **324**: 1839–1844.
15 Iribarren C, Sharp DS, Burchfiel CM, Petrovitch H. Association of weight loss and weight fluctuation with mortality among Japanese American men. *N Engl J Med* 1995; **333**: 686–692.
16 Blair SN, Shaten J, Brownell KD, Collins G, Lissner L. Body weight fluctuation, all-cause mortality and cause-specific mor-

tality in the Multiple Risk Factor Intervention Trial. *Ann Intern Med* 1993; **119**: 749–757.
17 Wing RR. Weight cycling in humans: a review of the literature. *Ann Behav Med* 1992; **14**: 113–119.
18 Sullivan M, Karlsson J, Sjostrom L, Backman L, Bengtsson C, Bouchard C, Dahlgren S, Jonsson E, Larsson B, Lindstedt S, Naslund I, Olbe L, Wedel H. Swedish obese subjects (SOS) – an intervention study of obesity. Baseline evaluation of health and psychosocial functioning in the first 1743 subjects examined. *Int J Obes* 1993; **17**: 503–512.
19 Rossner S. Obesity and self-perceived health in Sweden. *Int J Obes* 1996; **20**: 369–372.
20 French SA, Jeffrey RW, Folsom AR, Williamson DF, Byers T. Relation of Weight Variability and Intentionality of Weight Loss to Disease History and Health-related Variables in a Population-based Sample of a Women aged 55–69 Years. *Am J Epidemiol* 1995; **142**: 1306–1313.
21 Greenfield S, Rogers W, Mangotich M, Carney MF, Tarlov AR. Outcomes of patients with hypertension and non-insulin dependent diabetes mellitus treated by different systems and specialities. *JAMA* 1995; **274**: 1436–1444.
22 Rissanen A, Heliovaara M, Knekt P, Reunanen A, Aromaa A, Maatela J. Risk of disability and mortality due to overweight in a Finnish population. *Br Med J* 1990; **301**: 835–837.
23 Mansson NO, Eriksson KF, Israelsson B, Ranstam J, Melander A, Rastam L. Body Mass Index and Disability Pension in Middle-Aged Men - Non-Linear Relations. *Int J Epidemiol* 1996; **25**: 80–85.
24 Launer LJ, Harris T, Rumpel C, Madans J. Body mass index, weight change, and risk of mobility disability in middle-aged and older women. *JAMA* 1994; **271**: 1093–1098.
25 Lacroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in later life.II.Smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol* 1993; **137**: 858–869.
26 Tully CL, Snowdon DA. Weight change and physical function in older women: findings from the Nun Study. *J Am Geriatr Soc* 1995; **43**: 1394–1397.
27 Ware JE, Snow KK, Kosinski M, Gandek B. *SF-36 Health survey manual and interpretation guide.* New England Medical Center: Boston, 1993. pp 6.1–6.22.
28 Marmot MG, Davey Smith G, Stansfeld S, Patel C, North F, Head J, White I, Brunner EJ, Feeney A. Health inequalities among British Civil Servants: the Whitehall II study. *Lancet* 1991; **337**: 1387–1393.
29 Brunner EJ, Marmot MG, White IR, O'Brien JR, Etherington MD, Slavin BM, Kearney EM, Davey Smith G. Gender and employment grade differences in blood cholesterol, apolipoproteins and haemostatic factors in the Whitehall II study. *Atherosclerosis* 1993; **102**: 195–207.
30 Leon DA, Davey Smith G, Shipley M, Strachan D. Adult height and mortality in London: early life, socioeconomic confounding, or shrinkage? *J Epidemiol Comm Health* 1995; **49**: 5–9.
31 Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36):I. Conceptual framework and item selection. *Med Care* 1992; **30**: 473–483.
32 McHorney CA, Ware JE, Raczek AE. The MOS 36-item short-form health survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. *Med Care* 1993; **31**: 247–263.
33 McHorney CA, Ware JE, Lu JFR, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): III. Test of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care* 1994; **32**: 40–66.
34 Cronbach LJ. Coefficient alpha and the internal structure of a test. *Psychometrika* 1951; **16**: 297–334.
35 Stafford M, Hemingway H, Stansfeld S, Brunner E, Marmot M. Behavioural and biological correlates of physical functioning in middle aged civil servants: the Whitehall II study. Submitted. *J Epid Comm Hlth*. In Press.
36 Rose G, Blackburn H, Gillum RF, *et al*. *Cardiovascular survey methods.* 2nd edn WHO: Geneva, 1982.
37 WHO Study Group. *Diabetes mellitus: Report of a WHO Study Group.* WHO: Geneva, 1985.
38 Harris TB, Ballard-Barbasch R, Madans J, Makuc DM, Feldman JJ. Overweight, weight loss, and risk of coronary heart disease in older women. The NHANES I Epidemiologic Follow-up Study. *Am J Epidemiol* 1993; **137**: 1318–1327.
39 Kannel WB, D'Agostino RB, Cobb JL. Effect of weight on cardiovascular disease. *Am J Clin Nutr* 1996; **63(suppl)**: 419–412.
40 Meltzer AA, Everhart JE. Unintentional weight loss in the United States. *Am J Epidemiol* 1995; **142**: 1039–1046.
41 Wing RR, Matthews KA, Kuller LH, Meilahn EN, Plantinga PL. Weight gain at the time of menopause. *Arch Intern Med* 1991; **151**: 97–102.
42 Kral JG, Sjostrom LV, Sullivan MB. Assessment of quality of life before and after surgery for severe obesity. *Am J Clin Nutr* 1992; **55(suppl)**: 611–614.
43 Black DW, Goldstein RB, Mason EE. Prevalence of mental disorder in 88 morbidly obese bariatric clinic patients. *Am J Psychiatry* 1992; **149**: 227–234.
44 Rumpel C, Ingram DD, Harris TB, Madans J. The association between weight change and psychological well-being in women. *Int J Obes* 1994; **18**: 179–183.
45 DiPietro L, Anda RF, Williamson DF, Stunkard AJ. Depressive symptoms and weight change in a national cohort of adults. *Int J Obes* 1992; **16**: 745–753.
46 Spitzer RL, Kroneke K, Linzer M, Hahn SR, Williams JBW, deGruy FV, Brody D, Davies M. Health-related quality of life in primary care patients with mental disorders. Results from the PRIME-MD 1000 study. *JAMA* 1995; **274**: 1511–1517.
47 Kaplan G. Epidemiologic observations on the compression of morbidity: evidence from the Alameda county study. *J Aging Health* 1991; **3**: 155–171.
48 Ware JE, Kosinski M, Bayliss MS, McHorney CA, Rogers WH, Raczek A. Comparison of methods for the scoring and statistical analysis of SF-36 health profile and summary measures: summary of results from the Medical Outcomes Study. *Med Care* 1995; **33**: AS264–AS279.
49 Haley SM, McHorney CA, Ware JE. Evaluation of the MOS SF-36 physical functioning scale (PF-10): I Unidimensionality and reproducibility of the Rasch item scale. *J Clin Epidemiol* 1994; **47**: 671–684.
50 Bild DE, Fitzpatrick A, Fried LP, Wong ND, Haan MN, Lyles M, Bovill E, Polak JF, Schulz R. Age-related trends in cardiovascular morbidity and physical functioning in the elderly: the Cardiovascular Health Study. *J Am Geriatr Soc* 1993; **41**: 1047–1056.
51 Rubinstein I, Zamel N, DuBarry L, Hoffstein V. Airflow limitation in morbidly obese, nonsmoking men. *Ann Intern Med* 1990; **112**: 828–832.
52 US Dept of Agriculture UD. *Nutrition and your health: dietary guidelines for Americans.* 3rd edn US Government Printing Office: Washington DC; 1990.
53 Meisler JG, St.Jeor S. Summary and recommendations from the American Health Foundation's Expert Panel on Healthy Weight. *Am J Clin Nutr* 1996; **63(suppl)**: 474–477.
54 Manson JE, Willett WC, Stampfer MJ, Colditz GA, Hunter DJ, Hankinso SE, Hennekens CH, Speizer FE. Body weight and mortality among women. *N Engl J Med* 1995; **333(11)**: 677–685.