Changing distributions of body size and adiposity with age

Antonis Vlassopoulos, Emilie Combet and Michael EJ Lean*

Human Nutrition, School of Medicine, College of Medical, Veterinary & Life Sciences,

University of Glasgow, Glasgow, G3 8SJ, UK

***Corresponding Author**:

Professor Mike Lean,

University of Glasgow Department of Human Nutrition,

Walton Building level 4,

Glasgow Royal Infirmary,

Glasgow G4 0SF

Tel +44 141 211 4686, Fax: +44(0)141 211 4844, E-mail: Mike.Lean@glasgow.ac.uk

Running title: Distributions of BMI and waist with age

Abstract (300 words)

Background: Adiposity and health risks are better indicated by waist-circumference than BMI. Patterns of change with age are incompletely documented.

Methods: Adults aged 18-92y in the Scottish and English Health Surveys of 1994-96 and 2008-10 were divided into fifteen 5-year age-bands. Sex-specific prevalences of overweight/obesity and of increased/high waist-circumference against age were compared using ANCOVA .

Results: Data, available for 7932 Scottish and 55,925 English subjects in 1994-96, and for 27,391 Scottish and 30,929 English in 2008-10, showed generally similar patterns of change in the two countries. Prevalences of both elevated BMI and waist-circumference rose with age for longer in 2008-10 than 1994-96, reaching higher peaks at greater ages, particularly among men.

Between 1994-96 and 2008-10, maximum prevalences of BMI>30 increased from 25% to 38% (larger increases in men than women), reaching peak at age 60-70y in both sexes. This peak-prevalence was 5-10y later than in 1994-96 for men, unchanged for women.

Between 1994-96 and 2008-10, maximum prevalences of high waist-circumference (men>102cm, women>88cm) increased from 30% to 70% in both sexes, peaking in 2008-10 at ages 80-85y(men), 65-70y(women).

In 2008-10, proportions of adults with 'normal' BMI (18.5-25) fell with age to 15%-20% at age 60-70y(men) and 75y(women). Among all those with BMI 18.5-25, aged>65y, the proportions with unhealthily elevated waist-circumference were 30%(men>94cm) and 55%(women>80cm).

Conclusions: Almost 40% of men and women are now becoming obese. People are growing fatter later in life, with waist-circumference rising more persistently than BMI, which may indicate increased loss of muscle mass and sarcopenia in old age. Among older people, few now have 'normal' BMI, and of these up to half have elevated waist-circumference, raising questions for the suitability of BMI as a measure of adiposity in this age-group.

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Keywords: Obesity, overweight, elderly, waist, survey

Introduction

Mean Body Mass Index (BMI, kg/m^2), and prevalence of obesity (qua BMI>30kg/m^2), rise with age and are increasing in most populations.[1] Risks of type 2 diabetes and coronary heart disease (CHD) rise with very modest increases in weight in younger adults, and greater accumulation of body fat promotes a wide range of extra physical disabilities, inflammatory, neoplastic and metabolic diseases among older people.[2] Much research has focused on increasing adiposity in childhood[3, 4] but most 'obese children', as currently defined, still need to gain a substantial amount of weight to reach BMI>30 as adults. Emerging patterns of change of adiposity at later ages, and the potential impact on health of older people, are not well documented.[5]

Some have suggested that a modest degree of overweight is beneficial at older ages in terms of mortality.[6-8] A recent meta-analysis suggested an apparent protective effect from BMI 25-30, only BMI>35 being associated with increased mortality.[9] However, mortality may not be the best outcome to consider, nor BMI an optimal measure for this purpose, as BMI does not distinguish between body fat and muscle mass, which have opposite health impacts. Moreover, as overweight (BMI 25-30) and obesity (BMI>30) have become so much more frequent, the numbers with 'healthy' BMI 18·5-25 has dwindled.[10] The fewer older people with BMI <25 and 25-30 are likely to include more individuals who have lost weight (and specifically muscle) from a previously higher category of BMI, through illness and inactivity.[11] Sarcopenia is more frequent among older individuals, and sarcopenic obesity (low muscle with high body fat) may exist among those with BMI>30 and even 25-30, impairing health and increasing mortality.[12] Waist circumference (WC) is a slightly better measure of adiposity than BMI[13], and of health risks in older people, particularly when the BMI is below 30 where variations in muscle mass are not dominated by fat accumulation.[14] Better documentation of relationships between anthropometric measurements and health outcomes is required, particularly among older people. Applying standard BMI criteria, which originated from actuarial survival data in mid-20th century insured Americans, may be misleading. The first step is to document associations and patterns of change. Elucidating the causes of changes, and distinguishing between effects of age and cohort in these relationships over time demands analyses of longitudinal datasets.

This report documents patterns of change in BMI and WC in large national health surveys across a 14-year period, focussing particularly on age-specific peak-prevalences of adults with elevated figures, and the trough proportions with 'normal' BMI. Distinguishing changes in BMI and WC may clarify the influences of altered body composition on health outcomes at older ages.

Subjects and Methods

This study is a secondary analysis of data from the Scottish Health Survey (SHS) and the Health Survey for England (HSE), available through the Economic and Social Data Service (ESDS). These UK Health Surveys (UKHSs) sample the population sequentially using multistage, stratified, random sampling of private households from a Postcode Address File, to provide nationally representative data on health-related variables. During the first stage, personal interviews were conducted by a trained interviewer, to collect information on socio-demographic factors, self-assessed health, disability, eating habits, health conditions, lifestyle factors such as smoking and drinking behaviours, and health services use. Anthropometric measurements were taken, by a trained nurse, including weight, height, waist and hip circumference.[15, 16]

Data from four SHSs (1995, 2008, 2009 and 2010) and six HSE (1994, 1995, 1996, 2008, 2009 and 2010) were combined into a single database, as two year-groups, 1994-1996 and 2008-2010. Participants' ages at last birthday were grouped into fifteen 5-year age-bands, identified by the middle year from 20 (that is, ages 18–22) to 90 (ages 88-92) years. These groupings aimed to provide sufficient participants for discrimination among narrow age-bands. There were insufficient participants older than 92y for inclusion. Pregnant women were excluded. From 133,649 participants in the two UKHSs studied here, 88% had data available on BMI and 30% on WC.

Variables and measurements

All anthropometric measurements followed a specified protocol using calibrated scales and inextensible plastic tapes. Height was measured to nearest even millimetre, without shoes, head in the Frankfort Plane position. Weight was measured with light clothing without shoes, to nearest 0.1kg. WC was measured with an inelastic tape, to nearest 0.1cm, mid-way between the lowest rib and the iliac crest. Means of two measurements were used: if they differed by 3 cm or more, a third measurement was recorded. Established BMI and WC cut-offs were employed to calculated prevalences in the study population.[17, 18] Three BMI categories 18.5- 24.9 kg/m^2 (normal weight), >25 kg/m^2 (overweight/obese), and>30 kg/m^2 (obese) were used. WC values were classified as normal (WC <94cm for men and <80cm for women), increased/high (≥94 cm for men and ≥80 cm for women) and high (≥102 cm for men and ≥88 cm for women).

Statistical methods

Analyses were conducted separately for men and women using SPSS statistical software package version 19.0.0 (IBM, SPSS Software). Simple exploratory techniques were used to describe 14-year changes in BMI and WC for each age group, and for the overall population. Age- and sex-adjusted

changes in mean BMI and WC were assessed using univariate general linear models (ANCOVA). Statistical significance was set to 5%.

Results

Overall numbers of records available are shown in Table1.

Scottish Health Survey Data

BMI: Between 1994-96 and 2008-10, mean BMI increased significantly in all age-bands for both men and women, as did the prevalences of BMI>25 and BMI>30 ($p<0.001$; ANCOVA)

Among young adults entering adult life (18-22y), prevalence of BMI>30 tripled over the 14-years, reaching 12·1% in men and 20·1% in women in 2008-10 (Figures1&2).

In men, the maximum prevalence of BMI>25 within any 5-year age-band increased and occurred five years older: 74·5% at age 55y in 1994-96, and 84·3% at age 60y in 2008-10. Maximum prevalence of BMI>30 within a 5-year age-band increased similarly, and age at that peak-prevalence was delayed by five years, from 24·6% at age 55y in 1994-96 to 38·5% at age 60y in 2008-10. The proportion with BMI 18·5-25 (normal-weight) at age 60y fell to 15% in 2008-10, rising at greater ages (Figures 1&2).

In women, the maximum prevalence of BMI>25 within a 5-year age-band increased from 69·9% at in 1994-96 to 77·5% in 2008-10, both at age 65y. Peak-prevalence of BMI>30 also increased, from 29·5% in 1994-96 to 37·6% in 2008-10, both at age 65y (Figures 1&2). In 2008-10 BMI 18·5-25 (normal-weight) fell to a minimum of 22·9% at age 65y, increasing at greater ages.

While age-specific prevalences of elevated BMI increased in both sexes, a shift in age at peak-prevalences was seen in men only, by five years for both BMI>25 and BMI>30, from 55y in 1994-96 to 60y in 2008-10. Among women, maximum prevalences of both BMI>25 and BMI>30 remained at age 65y (Figures 1&2).

WC: Similar to BMI, overall mean WC (all age-bands) and overall prevalences of both WC>80/94cm and WC>88/102cm rose significantly in both men and women between 1994-96 and 2008-10 (all $p<0.001$;ANCOVA).

In young adults (18-22y), prevalence of high WC increased strikingly between 1994-96 and 2008-10. In young men, prevalence of WC>102cm increased 4-fold to reach 12·7% in 2008-10. In young women, WC>88cm prevalences climbed from 5·7% in 1994-96 to 28·2% in 2008-10.

Among men, the maximum prevalence of WC>94cm within a 5-year age-band increased and occurred 15 to 20 years later: 57·6% at age 65y in 1994-96, 80% at age 80-85y in 2008-10. Peak-prevalence of WC>102cm increased markedly, with a 20 year age-shift, from 28·8% at 65y in 1994-96 to 66·7% at 85y in 2008-10 (Figures 3&4). By 85y, the proportion with healthy waist (<94cms) had fallen to 20%.

Similar increases were seen in women. Maximum prevalence of WC>80 cm increased and occurred five years later: 65·3% at 60y in 1994-96 to 91% at 65y in 2008-10. Maximum prevalence of WC>88cm also increased, from 40·3% at age 65 in 1994-96 to 68·8% at age 65 in 2008-10 (Figures 3&4). Thus by 2008-10, under 10% of the female Scottish population had a WC<80 cm at age 65y.

In summary, for women the changes in dynamics of the patterns of high WC over the 14 years separating the two surveys were broadly similar to those of BMI. Indeed, the maximum prevalence of WC>88 occurred at the same age for both surveys (65y), with a modest five year shift for the maximum prevalence of WC>80 (Figures 3&4). In men, however, there was a much bigger between-survey shift in the age with maximum prevalences of WC>94 and WC>102 (20y later for both), compared to the shift in age with maximum prevalences of BMI>25 and BMI>30 (5y later for both).

High WC always reached its peak-prevalence later in life than BMI. In 1994-96 in men, there was a 10y difference in the age with maximum prevalence of BMI>25 (55y) and with maximum prevalence for WC>88 (65y). This difference widened markedly in the 2008-10 survey with a 20-25 years age-difference between maximum prevalences of BMI>25 (60y) and WC>88 (80-85y). This was not seen among women.

Amongst the small numbers of older 'normal-weight' older Scottish individuals (aged 65y), 13% of men had WC >94cm, increasing to 46% at age 80y, and 70% of women had WC >80cm, 15% above 88cm (data for individual countries not shown).

<u>English Health Survey Data</u>

BMI: Between 1994-96 and 2008-10, mean BMI increased significantly at all ages, for both men and women and so did the prevalences of BMI>25 and BMI>30 ($p<0.001$;ANCOVA)

Among young men (18-22y), the prevalence of BMI>30 doubled from 5·2% in 1994-96 to 10·7% in 2008-10. In young women (18-22y), the increase was larger, BMI>30 reaching 17·8% in 2008-10(Figures 1&2).

The maximum prevalence of BMI>25 within a 5-year age-band increased in men, from 73·4% at age 60y in 1994-96 to 83·0% at age 70y in 2008-10. Maximum prevalence of BMI>30 within a 5-year age-band also increased, and age at that peak prevalence was delayed by five years, from 22·3% at age 65y in 1994-96 to 35·2% at age 70y in 2008-10. In women, maximum prevalence of BMI>25 within a 5-year age-band increased from 68·7% in 1994-96 to 75·6% in 2008-10, both at age 70. Peak-prevalence of BMI>30 also increased and occurred 10-15y older (27·2% at age 60y in 1994-96 , 36·4% at age 70-75y in 2008-10) (Figures 1&2).

In 2008-10 the proportion of all adults with BMI 18·5-25 (normal-weight) had fallen to 14·7% of men (at age 70y), and 19·3% of women at age 75y. Above these ages the proportion with BMI 18·5-25 increased.

WC: Similar to BMI, mean WC and overall prevalences of WC>80/94cm and WC>88/102cm also rose significantly between 1994-96 and 2008-10, in all age-bands among both men and women ($p<0.001$;ANCOVA).

In young adults (18-22y) prevalence of high WC and BMI increased comparably between 1994-96 and 2008-10. In young men, prevalences of WC>102cm increased from 4·6% in 1994-96 to 10·7% in 2008-10. In young women, prevalence of WC>88cm rose from 9·25 in 1994-96 to 24·4% in 2008-10.

Among men, the maximum prevalence of WC>94cm within a 5-year age-band increased and occurred 15-years later: 72% at age 65 in 1994-96, 81·4% at age 80 in 2008-10. Peak-prevalence of WC>102cm changed little (Figures 3&4).

In women, maximum prevalence of WC>80 cm increased from 80% at 70y in 1994-96 to 87·9% at 70y in 2008-10. Maximum prevalence of WC>88cm increased much more, from 52·7% at age 70y in 1994-96, to 70·5% at 70y in 2008-10 (Figures 3&4). No shift was seen in the age at maximum prevalence among women. In 2008-10, only 12% of women and 18·6% of men in England had a healthy WC at 70y and 80y, respectively.

Amongst the small numbers of older 'normal-weight' English individuals (65y BMI 18.5-25): 32% of men had WC >94cm, 2.4% >102cm; 49% of women had WC >80cm, 11% >88cm (data for individual countries not shown).

Discussion

Trends towards increasing obesity and overweight, using conventional BMI categories, in older people have been documented earlier [19, 20], but how these trends reflect adiposity and health risks is less clear[9]. A large longitudinal Norwegian study documented rising BMI among younger individuals throughout 11-years' follow-up, but reductions above 70 years of age, with a peak in BMI at about age 70y.[21] The Baltimore Longitudinal Study of Aging followed over 1000 men from birth to death and reported that body weight increased throughout life until five years before death.[22] The present larger study, in two neighbouring countries, allowed distributions of adult body compositions, by age, to be explored over 14 years (1994-96 vs. 2008-10) and also between measures of adiposity (BMI vs. WC).

Comparisons between 1994-96 and 2008-10

Many more young adults now emerge from childhood already obese, illustrating the dramatic effect of increased adiposity in childhood. In 2008-10, 12% of men and 20% of women already had BMI>30 at age 20, at least double the prevalence observed 14 years earlier. While 'childhood obesity' is of clinical concern in some cases, and it increasingly impacts obesity prevalence in early adulthood, the overall health burdens of obesity across whole populations are mainly driven by further weight gain in adult life, when prevalence of BMI>30 now rises to almost 40% of the entire population. As a corollary, the BMI category 18·5-25 has dwindled to very low proportions of older people. Although this category is usually considered 'normal', BMI18·5-25 may not now indicate normal body composition in older people, among whom WC is more often increased.

In 2008-10, people were most likely to be classified as overweight or obese (BMI>25 or >30) in their late 60s-early 70s. At that age, only 20% of all men and 15% of all women had BMI 18·5-25, and amongst these 'normal-weight individuals, about 30% of the men and 55% of the women had unhealthily increased waist-circumferences (>94cms in men, >80cms in women)[18, 23](**Figure 5**). It is tempting to speculate on the changes in the ages at which peak BMIs occur and reason for sex differences, but the cross-sectional nature of the present study prevents distinction between the influences of cohort effects (including environmental factors) and aging. The rising life expectancy probably plays a part[22], but there remain fundamental differences in body composition between the sexes, women gaining more fat as adolescents[20] and men more in later adult life. Longitudinal studies are needed to elucidate causal factors.

Interpretation of different measures of body composition

Our data document generally greater WC, primarily indicating greater total body fat, in older people.[13] While BMI decreases with age after reaching its peak-prevalence at about age 65-70 (in 2008-10), WC continues to increase, only peaking at 75-80 years of age. This suggests risks of sarcopenia, or sarcopenic obesity[12], with associated physical and metabolic health risks. Frailty and weight loss are traditional focuses of concern in the elderly[24, 25], but our data suggest that conventional BMI criteria alone may be insufficient. The mis-match between BMI and WC with age may also contribute to the apparently adverse impact of 'normal weight' on mortality, reported in various studies.[6, 7, 26, 27] A serious problem lies in the very small numbers of older adults, as low as 10-15%, who now have a BMI in the 'normal'/'healthy' range (Figure 3). It is possible that a significant proportion of these older, normal-weight individuals have in fact lost weight[11], and specifically muscle mass through illness and inactivity. The HSE and SHS did not include questions about recent weight loss, which would provide valuable evidence on this.

To explain the disconnect between age-specific distributions of WC and BMI, more detailed measures of body composition are needed. Rising WC could indicate either a gain in total body fat[13], or a redistribution of body fat towards a more central, intra-abdominal, preponderance.[28] WC ceases to be a linear indicator of body fat when above an upper limit of about 130cm, when the abdominal apron of fat hangs below the waist. This was not a major factor in the present study: only 0·6 % of subjects had a WC above 130cm. When the range of body fat or BMI is wide, then WC is likely to reflect mainly variations in total body fat. When the range in body fatness is small, then WC is likely to be a stronger indicator of intra-abdominal fat mass.[29] In the present survey datasets, there were substantial ranges in BMI and WC, so the major influence on WC is likely to be variation in total body fat. The adverse metabolic health impacts of rising WC include both those of elevated total body fat and a more central fat distribution, but the former mechanism is more amenable to preventive action. Unintentional weight loss, even in overweight and obese people, is associated with poor health outcomes, probably related to undiagnosed illness and loss of lean body tissue as well as body fat.[30] More detailed characterisation of body composition, and information on changes in weight, are therefore urgently required within future population surveys.

Strengths and Limitations

There are many limitations to analyses of cross-sectional survey data of this kind, but this study has many strengths from which to develop hypotheses. The numbers of subjects studied was very large. The response rates (published elsewhere [15, 16]) were high (~70%), and quality of data-completeness

was high, so the samples can be considered at least broadly representative of the general populations. The methods used in the Scottish and English surveys were essentially the same, so comparisons between the countries are likely to be valid. The 1994-96 SHS did not include data for individuals above 65 years of age, which limits interpretation, although the similarities between Scottish and English data overall allows some confidence in drawing general conclusions. A combined analysis of data from both countries was not performed because of lack of participants aged above 65y in 1994-96 SHS. The HSEs of 1994, 1995 and 1996 offered greater numbers to characterise the 1994-96 population than the single 1995 SHS. Participants without a WC measurement had slightly higher BMI, but in both the 1994-96 and 2008-10 surveys (data not shown), which makes this unlikely to affect data interpretation.

Over the 14-year period studied, change in distributions of BMI and WC in Scotland and England were very similar, allowing the general conclusion that overweight and obesity are increasing, with more older people affected, and the BMI category 18·5-25 dwindling to the point where it needs better characterisation before assuming that it represents 'normal' or healthful body composition. There were mostly only minor differences between countries, perhaps with generally greater WC in Scotland then England (Table 3, Fig 3). We have not sought to explain these national differences.

Conclusions

Overweight and obesity are rising, and peaking later in life. Within the 14 years study period (1994-96 to 2008-10) the distributions of BMI and WC have changed such that more young people enter adult life already obese, and more older people have adverse body composition. Almost 40% of all UK adults now become obese, and many older people with normal BMI(18·5-25) actually have elevated WC. The continuing rise of WC into older age groups is evidence of continued body fat accumulation and/or redistribution into older age, a major emerging public health concern. The use of BMI alone as a measure for adiposity in this age group may be misleading. Using WC might better identify adverse changes in body composition.

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Conflict of interest

The authors have no conflicts of interest to declare

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Supplementary information

Supplementary information is available at International Journal of Obesity's website

References

1. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of Obesity and Trends in the Distribution of Body Mass Index Among US Adults, 1999-2010. *Jama-J Am Med Assoc* 2012; **307**(5)**:** 491-497.

2. Han TS, Sattar N, Lean M. ABC of obesity. Assessment of obesity and its clinical implications. *BMJ* 2006; **333**(7570)**:** 695-8.

3. Hendriks AM, Gubbels JS, De Vries NK, Seidell JC, Kremers SP, Jansen MW. Interventions to promote an integrated approach to public health problems: an application to childhood obesity. *J Environ Public Health* 2012; **2012:** 913236.

4. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007-2008. *JAMA* 2010; **303**(3)**:** 242-9.

5. Hughes VA, Roubenoff R, Wood M, Frontera WR, Evans WJ, Fiatarone Singh MA. Anthropometric assessment of 10-y changes in body composition in the elderly. *Am J Clin Nutr* 2004; **80**(2)**:** 475-82.

6. Janssen I. Morbidity and mortality risk associated with an overweight BMI in older men and women. *Obesity (Silver Spring)* 2007; **15**(7)**:** 1827-40.

7. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA* 2005; **293**(15)**:** 1861-7.

8. Stevens J, Cai JW, Pamuk ER, Williamson DF, Thun MJ, Wood JL. The effect of age on the association between body-mass index and mortality. *New Engl J Med* 1998; **338**(1)**:** 1-7.

9. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA* 2013; **309**(1)**:** 71-82.

10. Health and Social Care Information Centre LS. Statistics on Obesity, Physical Activity and Diet: England, 2013. 2013.

11. Locher JL, Roth DL, Ritchie CS, Cox K, Sawyer P, Bodner EV *et al.* Body mass index, weight loss, and mortality in community-dwelling older adults. *J Gerontol a-Biol* 2007; **62**(12)**:** 1389-1392.

12. Han TS, Tajar A, Lean MEJ. Obesity and weight management in the elderly. *Brit Med Bull* 2011; **97**(1)**:** 169-196.

13. Lean ME, Han TS, Deurenberg P. Predicting body composition by densitometry from simple anthropometric measurements. *Am J Clin Nutr* 1996; **63**(1)**:** 4-14.

14. Visscher TLS, Seidell JC, Molarius A, van der Kuip D, Hofman A, Witteman JCM. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obesity* 2001; **25**(11)**:** 1730-1735.

15. Mindell J, Biddulph JP, Hirani V, Stamatakis E, Craig R, Nunn S *et al.* Cohort profile: the health survey for England. *Int J Epidemiol* 2012; **41**(6)**:** 1585-93.

16. Lean ME, Katsarou C, McLoone P, Morrison DS. Changes in BMI and waist circumference in Scottish adults: use of repeated cross-sectional surveys to explore multiple age groups and birth-cohorts. *Int J Obes (Lond)* 2012.

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

18. Lean MEJ, Han TS, Morrison CE. Waist Circumference as a Measure for Indicating Need for Weight Management. *Brit Med J* 1995; **311**(6998)**:** 158-161.

19. Ding J, Kritchevsky SB, Newman AB, Taaffe DR, Nicklas BJ, Visser M *et al.* Effects of birth cohort and age on body composition in a sample of community-based elderly. *Am J Clin Nutr* 2007; **85**(2)**:** 405-10.

20. Eiben G, Dey DK, Rothenberg E, Steen B, Bjorkelund C, Bengtsson C *et al.* Obesity in 70-year-old Swedes: secular changes over 30 years. *Int J Obes (Lond)* 2005; **29**(7)**:** 810-7.

21. Droyvold WB, Nilsen TI, Kruger O, Holmen TL, Krokstad S, Midthjell K *et al.* Change in height, weight and body mass index: Longitudinal data from the HUNT Study in Norway. *Int J Obes (Lond)* 2006; **30**(6)**:** 935-9.

22. Stenholm S, Simonsick EM, Ferrucci L. Secular trends in body weight in older men born between 1877 and 1941: the Baltimore Longitudinal Study of Aging. *The journals of gerontology. Series A, Biological sciences and medical sciences* 2010; **65**(1)**:** 105-10.

23. Lean MEJ, Han TS, Seidell JC. Impairment of health and quality of life in people with large waist circumference. *Lancet* 1998; **351**(9106)**:** 853-856.

24. Etman A, Burdorf A, Van der Cammen TJM, Mackenbach JP, Van Lenthe FJ. Socio-demographic determinants of worsening in frailty among community-dwelling older people in 11 European countries. *J Epidemiol Commun H* 2012; **66**(12)**:** 1116-1121.

25. Gobbens RJJ, van Assen MALM, Luijkx KG, Wijnen-Sponselee MT, Schols JMGA. Determinants of Frailty. *J Am Med Dir Assoc* 2010; **11**(5)**:** 356-364.

26. Flegal KM, Graubard BI, Williamson DF, Gail MH. Cause-specific excess deaths associated with underweight, overweight, and obesity. *JAMA* 2007; **298**(17)**:** 2028-37.

27. McGee DL. Body mass index and mortality: a meta-analysis based on person-level data from twenty-six observational studies. *Ann Epidemiol* 2005; **15**(2)**:** 87-97.

28. Han TS, Lean ME. Self-reported waist circumference compared with the 'Waist Watcher' tape-measure to identify individuals at increased health risk through intra-abdominal fat accumulation. *Br J Nutr* 1998; **80**(1)**:** 81-8.

29. Han TS, McNeill G, Seidell JC, Lean ME. Predicting intra-abdominal fatness from anthropometric measures: the influence of stature. *Int J Obes Relat Metab Disord* 1997; **21**(7)**:** 587-93.

30. Wannamethee SG, Shaper AG, Whincup PH, Walker M. Characteristics of older men who lose weight intentionally or unintentionally. *Am J Epidemiol* 2000; **151**(7)**:** 667-75.

Figure4. Prevalence by age of elevated WC (>80cm for women, >94cm for men) among individuals with BMI within the range 18.5-25 kg/m^2 in 2008-10. Data for Scotland and England combined.

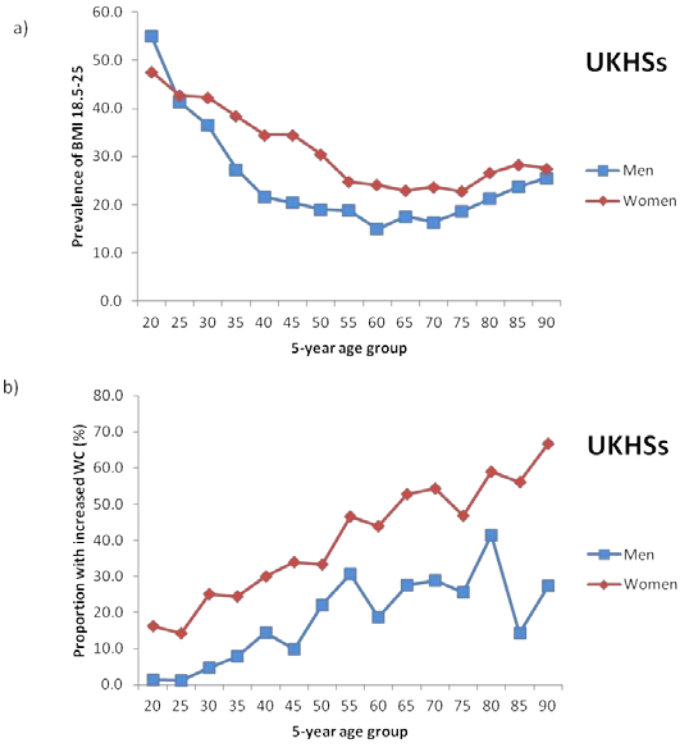
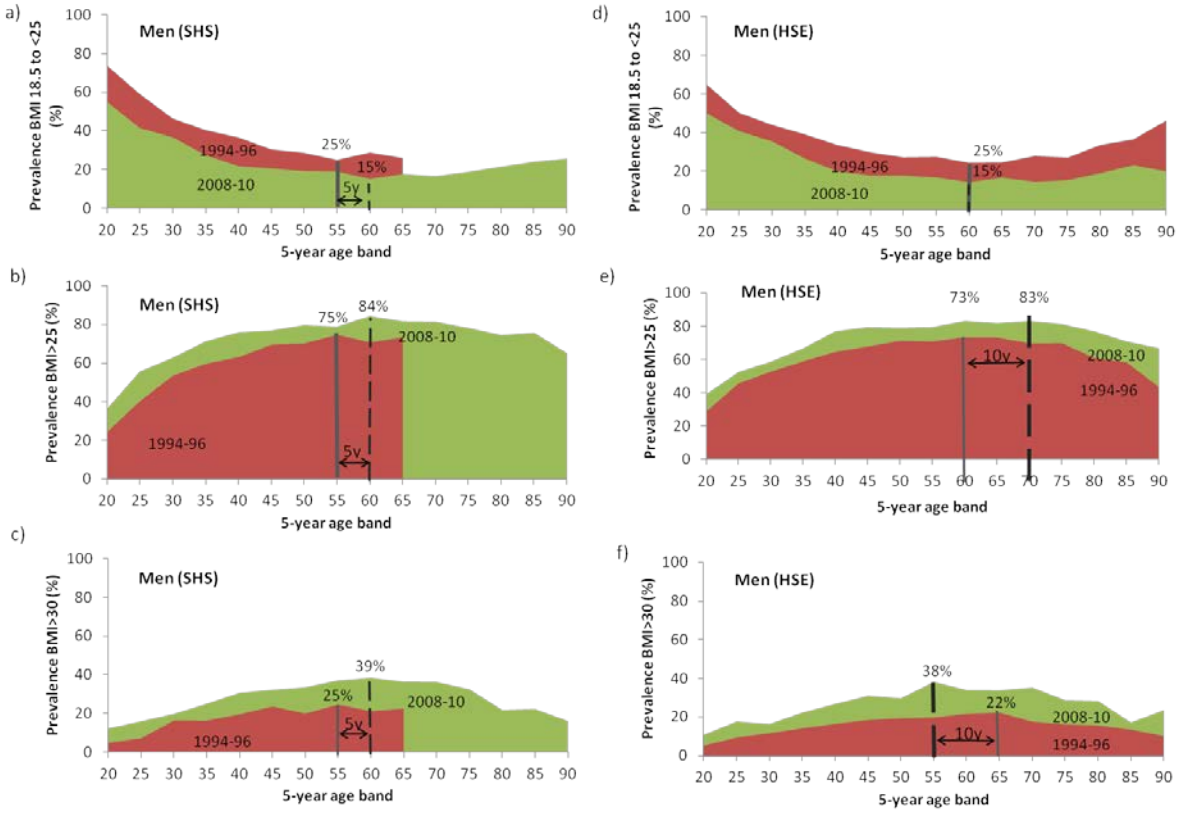


Figure 5a shows the prevalence of 'normal' BMI (18.5-25). Figure 5b shows the proportion of participants with elevated WC within this 'normal' weight BMI with age. Data are presented combined for the two countries but split by sex.

420

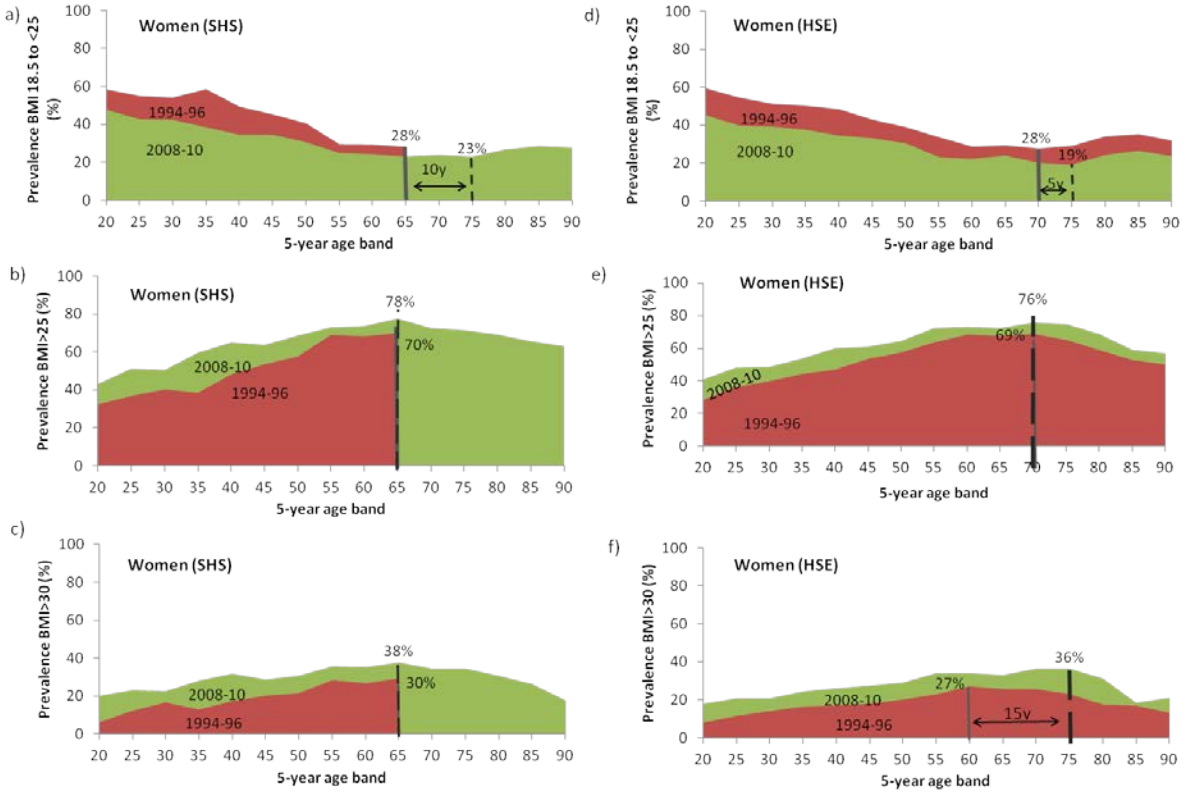
Figure1. Prevalences by age of BMI 18.5-24.9, BMI >25, and BMI>30 among men in 1994-96 & 2008-10 for Scotland (a-c) and England (d-f).



a, d-age at minimum prevalence of BMI 18.5-24.9 in 1994-96 (solid) vs. 2008-10 (dotted); b, c, e, f- age at maximum prevalence of BMI>25 or BMI>30 in 1994-96 (solid) vs. 2008-10 (dotted)

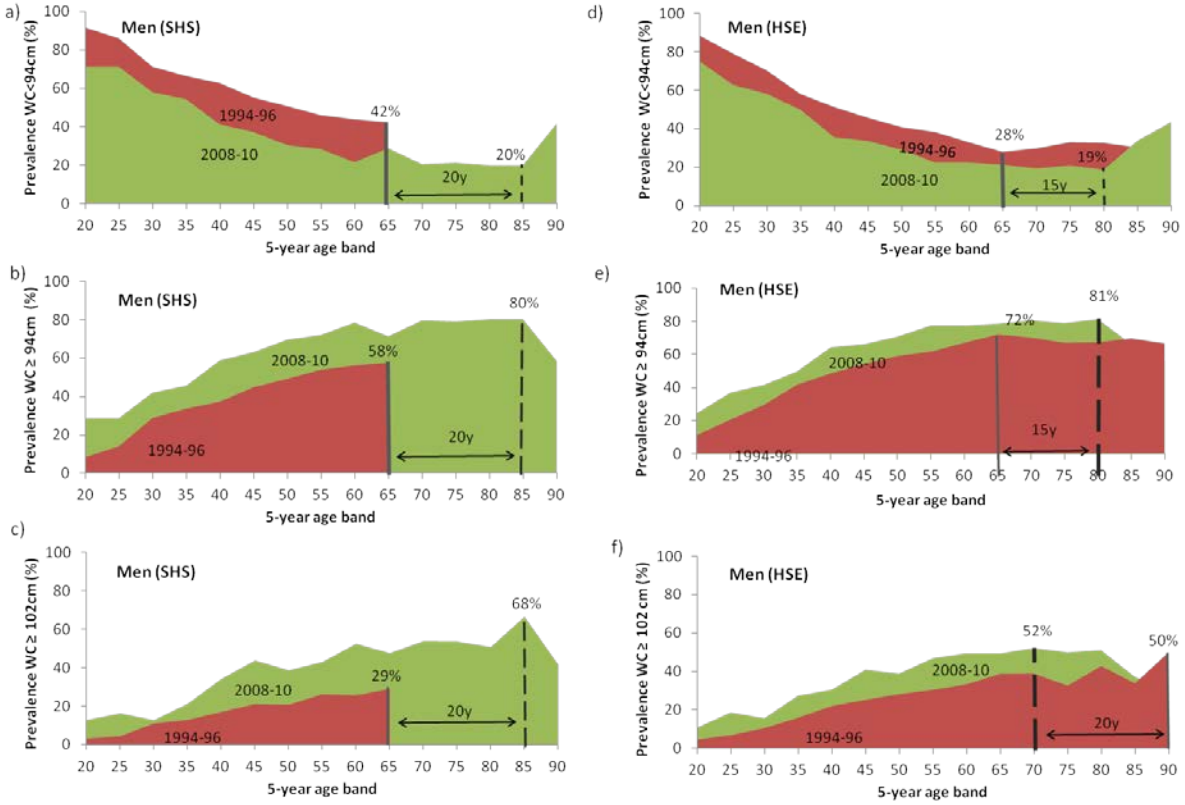
421

Figure2. Prevalences by age of BMI 18.5-24.9, BMI >25, and BMI>30 among women in 1994-96 & 2008-10 for Scotland (a-c) and England (d-f).



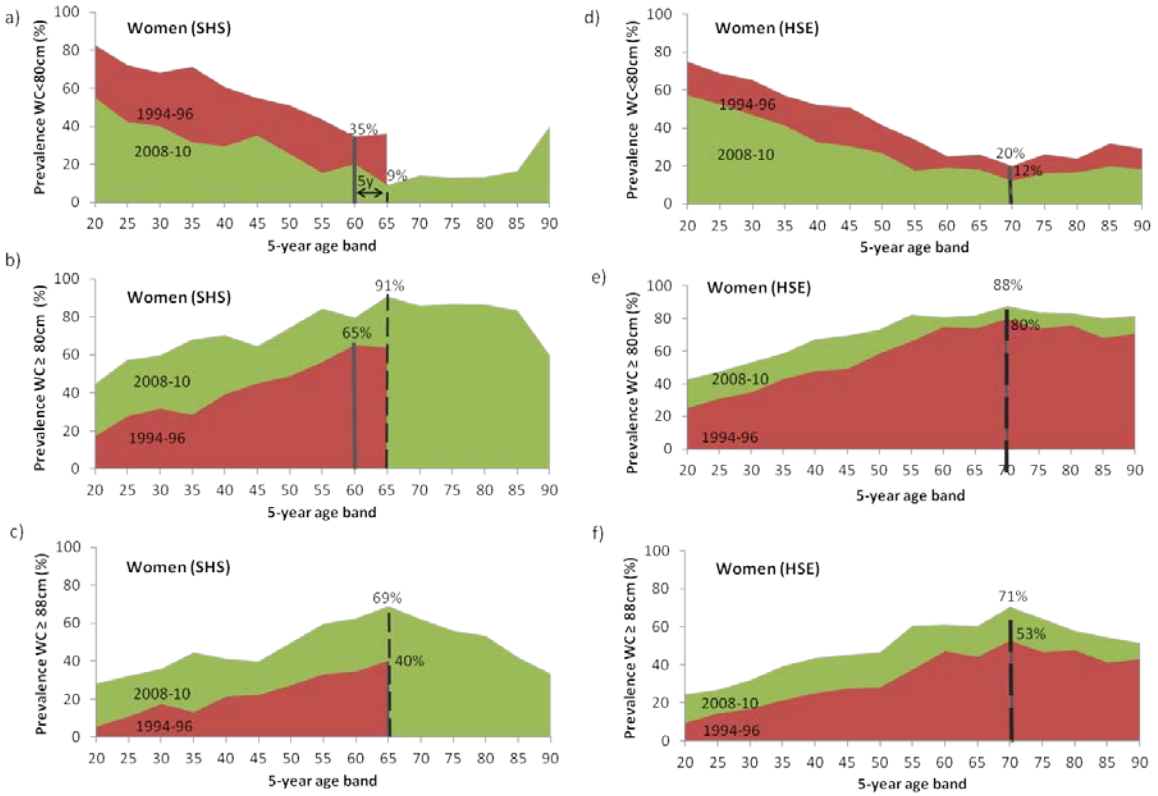
a, d-age at minimum prevalence of BMI 18.5-24.9 in 1994-96 (solid) vs. 2008-10 (dotted); b, c, e, f- age at maximum prevalence of BMI>25 or BMI>30 in 1994-96 (solid) vs. 2008-10 (dotted)

Figure3. Prevalences by age of f WC<94cm, WC≥94cm, and WC≥102 among men in 1994-96 & 2008-10 for Scotland (a-c) and England (d-f).



a, d-age at minimum prevalence of BMI 18.5-24.9 in 1994-96 (solid) vs. 2008-10 (dotted); b, c, e, f- age at maximum prevalence of BMI>25 or BMI>30 in 1994-96 (solid) vs. 2008-10 (dotted)

Figure4. Prevalences by age of f WC<94cm, WC≥94cm, and WC≥102 among women in 1994-96 & 2008-10 for Scotland (a-c) and England (d-f).



a, d-age at minimum prevalence of BMI 18.5-24.9 in 1994-96 (solid) vs. 2008-10 (dotted); b, c, e, f- age at maximum prevalence of BMI>25 or BMI>30 in 1994-96 (solid) vs. 2008-10 (dotted)

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Figure5. Prevalence by age of elevated WC (>80cm for women, >94cm for men) among individuals with BMI within the range 18.5-25 kg/m^2 in 2008-10. Data for Scotland and England combined.

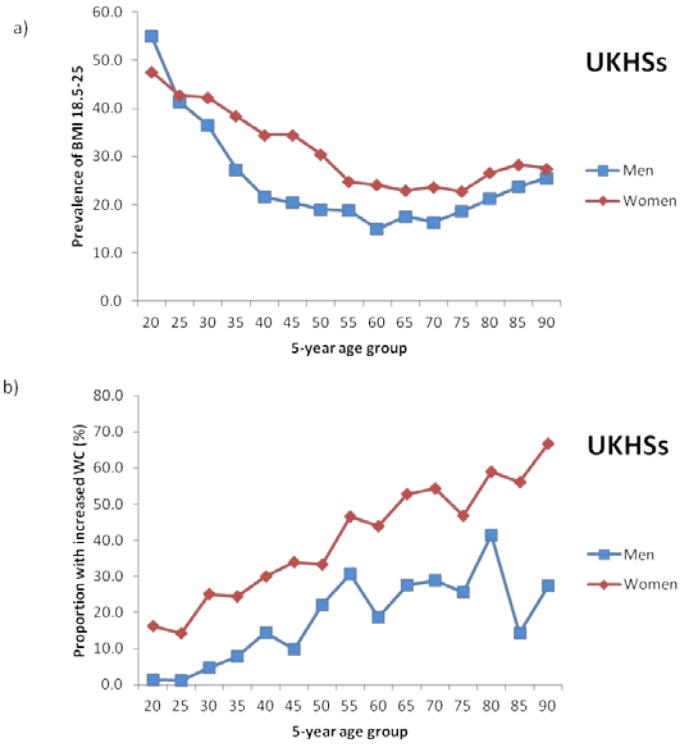

Figure 5a shows the prevalence of 'normal' BMI (18.5-25). Figure 5b shows the proportion of participants with elevated WC within this 'normal' weight BMI with age. Data are presented combined for the two countries but split by sex.

434 **Table 1. Numbers of participants with available records**

	1994	1995	1996	2008	2009	2010
England	15809	19788	20328	8215	8602	14112
Scotland	-	7932	-	8215	10138	9038
Total	15809	27720	20328	16430	18740	23150

	Overall '1994-96'	Overall '2008-10'
England	55925	30929
Scotland	7932	27391
Total	63857	58320

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436 **Table 2. Age bands with maximum prevalences of BMI and waist circumference**

	BMI>25				BMI>30			
	1994-96		2008-10		1994-96		2008-10	
	Max (%)	Age(y)	Max (%)	Age(y)	Max (%)	Age(y)	Max (%)	Age(y)
Scotland								
Men	74.5	55	84.3	60	24.6	55	38.5	60
Women	69.9	65	77.5	65	29.5	65	37.6	65
England								
Men	73.4	60	83.0	60-70	22.3	65	35.2	70
Women	68.7	70	75.6	70	27.2	60	36.4	70-75

	WC>80/94cm				WC>88/102cm			
	1994-96		2008-10		1994-96		2008-10	
	Max (%)	Age(y)	Max (%)	Age(y)	Max(%)	Age(y)	Max (%)	Age(y)
Scotland								
Men	57.6	65	80.0	80-85	28.8	65	66.7	85
Women	65.3	60	91	65	40.3	65	68.8	65
England								
Men	72.0	65	81.4	80	50.0	90	52.2	70
Women	80.0	70	87.9	70	52.7	70	70.5	70

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