The Scottish Health Survey

Obesity

Topic Report

A National Statistics Publication for Scotland

The Scottish Government

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Abbreviations used in the report

SHeS	Scottish Health Survey
BMI	Body Mass Index
WC	Waist circumference
WHR	Waist-hip ratio
WHtR	Waist-height ratio
SIGN	Scottish Intercollegiate Guidelines Network
NICE	National Institute for Clinical Excellence
NOO	National Obesity Observatory
WHO	World Health Organisation
CI	Confidence Interval
OR	Odds Ratio
CVD	Cardiovascular disease
ROC	Receiver Operator Curve
AUC	Area Under the Curve
DQI	Dietary Quality Index

Author's Acknowledgements

Our first thank you is to the over 29,000 men and women in Scotland who gave up their time voluntarily to take part in the surveys analysed here.

We are also grateful to the interviewers who conducted the surveys for the dedication and professionalism they applied to their work.

We would also like to thank Joan Corbett at the Scottish Centre for Social Research who answered many questions on the data. Also many thanks to Karen MacNee at the Scottish Government and Colin Fischbacher at the Scottish Public Health Observatory who gave valuable feedback on earlier drafts.

Responsibility for all analyses and conclusions lies with the authors.

Katherine Keenan, Ian Grant and Julie Ramsay.

INTRODUCTION

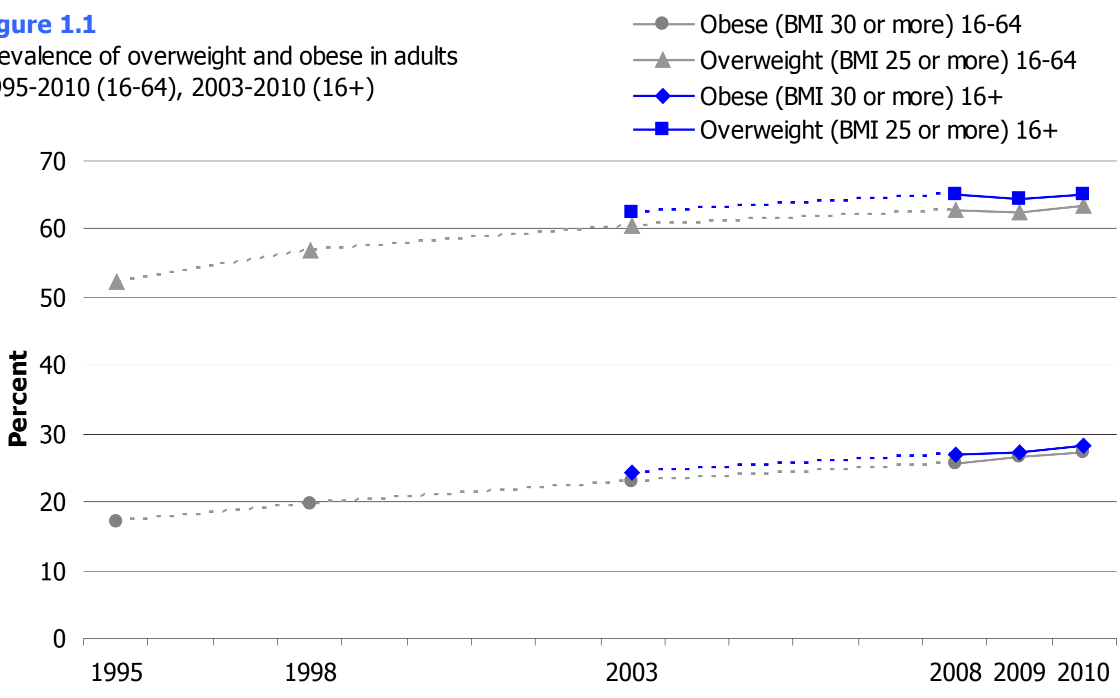
This topic report presents firstly an investigation into the most appropriate measure of adult obesity using Scottish Health Survey data, and secondly an investigation into the significant behavioural, socio-demographic and economic factors associated with adult obesity using data from the 2008, 2009, and 2010 surveys.

Background

Obesity is a leading preventable cause of death and disease worldwide. Global prevalence of obesity has more than doubled since 1980[1]. The WHO has called the situation an 'epidemic' and estimates that 1.5 billion adults are overweight or obese, and 500 million people obese[2]. Obesity increases the risk of type 2 diabetes, hypertension, cardiovascular disease, osteoarthritis and cancer, in turn increasing mortality risks[3]. Overweight and obesity is linked to many other health problems, such as stroke, liver and gall bladder disease, respiratory problems, sleep disturbance, sub-fertility, mental illness, and poor quality of life[4]. Globally, it is the 5th leading risk factor for death[5] and is strongly associated with other important risk factors, such as high blood pressure, high blood glucose and physical inactivity.

Scotland has one of the worst obesity records in the developed world, and one of the highest rates of all OECD and European countries[6]. Over the last 15 years, adult obesity in Scotland has risen significantly, from 17% of adults aged 16-64 in 1995 to 27% in 2010. If Scottish obesity follows the same trend as the US, it is predicted rates could reach 40% by 2030[7]. In 2010, 65% of adults aged 16 and over were overweight or obese (BMI≥25)[8].

Figure 1.1
Prevalence of overweight and obese in adults 1995-2010 (16-64), 2003-2010 (16+)



Obesity has a massive impact on population health and associated healthcare costs. The Scottish Public Health Observatory estimated that 47% of type 2 diabetes can be attributed to obesity, 36% of hypertension, 18% of myocardial infarction, 15% of angina and 12% of osteoarthritis[9]. The estimated cost to the NHS in Scotland of obesity and related illnesses in 2007/08 was in excess of £175 million[10].

Tackling and preventing obesity is a key public health priority in Scotland. Recent policy initiatives to address the problem in Scotland have included:

- The Scottish Government's *Healthy Eating, Active Living: An action plan to improve diet, increase physical activity and tackle obesity*[11].
- The Keep Well initiative[12].
- The Scottish Government's *Route Map* for tackling obesity[13].
- The Scottish Intercollegiate Guidelines Network (SIGN) national clinical guideline on obesity management[14].

The most important recent policy development is the publication of the *Obesity Route Map Action Plan*[13] which includes actions relating to energy consumption and active living. Food product reformulation, portion sizes, stocking policies, pricing, packaging, and advertising, will each be addressed by liaising with the food and drink industry, consumer groups, schools and the public sector, and using social marketing and licensing. Opportunities around transport, provisions for open space and sporting activities will be explored, as well as a focus on early life. A set of 16 indicators and associated desired outcomes to help monitor the progress of the Obesity Route Map's actions has also been published[15].

These policies draw on the 2007 Foresight *Tackling Obesities Report*, published by the UK Government Office for Science, which summarised evidence on the causes of obesity in the UK, describing how many inter-related behavioural and societal factors work together to put the population at risk of weight gain[4].

Such an important condition needs to be carefully monitored and measured. The Scottish Health Survey (SHeS) is the main instrument for measuring population levels of adult obesity. While body mass index (BMI) is the most widely used and understood measure, there is considerable academic debate about the usefulness of waist circumference (WC), waist-hip ratio (WHR), and waist-height ratio (WHtR). These are discussed in more detail in section 1.1.

Aims

The first aim of this topic report is to consider the various measures of adult overweight and obesity in the Scottish Health Survey and decide which are most appropriate for:

a) monitoring long-term trends
b) gaining an understanding of the factors most associated with obesity and the groups most at risk of obesity-related disease

The 5 measures available in the SHeS - BMI, WC, WHR, WHtR and the WHO combined measure were discussed and compared. This was done partly through a literature review of existing evidence and guidance. Secondly, each of the measures' associations with CVD, type 2 diabetes, high cholesterol and hypertension were investigated using SHeS data.

The second aim is to use the most suitable measure(s) of obesity to investigate factors that are significantly associated with adult overweight/obesity in the Scottish population. Although the relationship between obesity and age, sex, and some socio-economic variables has been described in the annual reports in 2009 and 2010, multivariable regression analysis has not been done since the 2008 report. This makes use of the wealth of data on lifestyle, socio-economic and demographic factors collected in the SHeS, which may interact to affect the distribution of obesity.

1 MEASUREMENT OF OBESITY

1.1 EVIDENCE FROM PREVIOUS STUDIES

Obesity is commonly defined as a condition of excess or abnormal accumulation of body fat (or adipose tissue) to such an extent that it impairs health[3]. At the most fundamental level, obesity is a result of energy imbalance. When energy intake from food and drink exceeds energy expenditure over a prolonged period, the excess energy is turned into body fat.

For reasons of ease and cost, most large-scale epidemiological studies use measurements of body weight and dimensions (anthropometry) to reflect body fat, rather than collect them using densitometry or imaging techniques. Obesity measures aim to capture levels of fat tissue that put an individual at increased risk of disease. The thresholds for the level at which an amount of body fat is considered clinically dangerous (and therefore a person is 'overweight' or 'obese') have developed through statistical associations between body weight/size and the risk of mortality and developing particular non-communicable diseases, such as type 2 diabetes and cardiovascular disease (CVD). In some cases, country and disease-specific cut-offs have been developed[16].

The anthropometric measures for adults available in SHeS are:

- Body mass index (BMI)
- Waist circumference (WC)
- Waist-hip ratio (WHR)
- WHO combined classification of disease risk
- Waist-height ratio (WHtR)

1.1.1 Body Mass Index

Calculated as weight adjusted for height (a ratio of weight to height):

Weight (kg) / height (m^2)

resulting in an index value that can be grouped as follows:

BMI (kg/m^2)	**Classification based on WHO recommendations[3]**
Less than 18.5	Underweight
18.5 to less than 25	Normal
25 to less than 30	Overweight
30 to less than 35	Obese: mild
35 to less than 40	Obese: moderate
40+	Obese: extreme (morbidly obese)

BMI is a proxy measure of total body fat, rather than fat distribution. It is easily measureable, calculable and widely understood. BMI≥25 is a strong predictor of all-cause mortality[17], and cardiovascular risk[18]. However, despite extensive use, it has long been acknowledged as a crude measure[3]. The main limitation is that it does not distinguish between fat mass and lean mass, resulting in classification bias in the youngest and oldest age groups. Research in the US population comparing the diagnostic performance of BMI-defined obesity with body fat defined obesity suggested that BMI can misclassify obesity in up to 50% of individuals with particularly poor performance in young men and older people[19].

For young people, BMI can overestimate obesity and associated disease risk. Young people (particularly young men) are more likely to have a high lean muscle mass, increasing their weight, leading to them being classified as overweight, when it may be that they are at lower risk due to their fitness level.

On the other hand, using BMI among elderly and non-Caucasian populations can lead to an underestimation of obesity, because at any given BMI, these groups have more body fat than younger or Caucasian populations[20]. With age the proportion of lean mass naturally decreases, and fat mass increases, so at any given BMI an older person will have a higher percentage body fat than a younger person. On the other hand, older people tend to be shorter due to secular trends in height, and spine shrinkage, so BMI may be biased upwards. It is not known how much these opposing biases work to cancel one another out.

An evidence review from the National Institute of Clinical Excellence (NICE) found no accepted definition of appropriate cut-offs in older people[21]. Asian populations have a substantial risk of obesity-related disease at 'healthy' BMIs, so there is an ongoing debate about appropriate lower cut-offs[22].

Studies have found that fat distribution, in particular abdominal obesity (sometimes referred to as central or visceral obesity) can vary within a narrow band of BMI, and is relevant for predicting disease risk[16]. The WHO[3] NICE[21] and the National Obesity Observatory (NOO)[23] all recommend that surveys supplement BMI with measures designed to capture abdominal obesity, such as waist circumference or waist-hip ratio.

1.1.2 Waist circumference (WC)

The following cut-offs are recommended by the WHO:

	Risk of metabolic complications in adults<70[3,16]	
	Increased	**High**
Men	≥94cm	≥102 cm
Women	≥80cm	≥88 cm

The cut-offs are based on relative risks for metabolic disorders, such as type 2 diabetes and CVD at different waist circumferences found in a random population sample in the Netherlands[24]. As with BMI, it has been suggested that alternative (lower) cut-offs are appropriate for Asian populations[18]. Another study found that risk associated with WC would be better captured if more categories for WC were used to differentiate between different classes of obese, as with BMI[25]. A high WC indicates visceral fat (fat stored within the abdominal cavity, packed between the organs) which is understood to be more harmful than subcutaneous fat (fat stored just beneath the skin).

WC is a simple measure, is unrelated to height, and is an appropriate index of both abdominal fat and total body fat [20]. It is as least as good as BMI for measuring total body fat, and some studies suggest it could replace BMI in clinical settings[26]. It is harder to collect accurately than BMI as it requires use of a tape measure, removal of clothes, which may be intrusive, and must be measured at a specific place on the body.

A European prospective study with over 300,000 participants found that WC predicted mortality independently of BMI[27]. A recent WHO evidence review of cross-sectional and prospective studies concluded that WC was more strongly associated with CVD, CVD risk factors and type 2 diabetes than BMI[16], although the evidence was slightly stronger for diabetes. Meta-analysis also suggests that WC is a better predictor of all-cause mortality, and could replace BMI and WHR entirely[28]. People within normal ranges of BMI but with excess abdominal fat can still be at increased risk of cardiovascular disease and type 2 diabetes[16]. There is some evidence that WC predicts disease better in women than men[29].

WC should be interpreted carefully in the elderly because older adults tend to store more fat around the middle, and carry more visceral fat than younger people with the same WC[30]. There is ongoing debate about appropriate cut-offs for the over 70s, but in general the thresholds should be higher[31]. In addition, lifestyle factors such as drinking and smoking are associated with greater abdominal obesity within Scotland[32] and elsewhere[33,34].

1.1.3 Waist-hip ratio: (WHR)

WHR is a ratio of waist to hip circumference:

waist circumference (cm) / hip circumference (cm)

The following are commonly used cut-offs: [35][36]

	Increased risk of metabolic complications
Men	≥0.95 [37]
Women	≥0.85

WHR is often used as an alternative to WC as an indicator of abdominal obesity, but is more complicated to interpret because the increased risk associated with high WHR can be due to both abdominal fat and/or smaller hips and legs. Hip circumference is a measure of body stature and frame, not just adiposity, and there is evidence that large hip circumference is associated with longevity[38].

In prospective studies, WHR is a better predictor of mortality in older people than BMI[39], and is a good independent predictor of myocardial infarction and CVD-related mortality[40],[41].[42] Studies have found that a smaller hip circumference (for a given waist circumference or BMI) is associated with increased risk of diabetes and/or CVD[38,43]. Many experts suggest lower cut-offs for non-European populations[16].

WHR is even less practical than WC to collect. Two measures rather than one are needed, and to collect it accurately the interviewee should wear as few clothes as possible, and the interviewer needs to touch the subject on the waist and hips. This could be considered intrusive and same-sex interviewers may be needed. In the SHeS currently the measurement is carried out by a trained nurse.

1.1.4 WHO combined classification of disease risk (WHO combined measure)

As studies have shown that high WC, within categories of BMI identifies those at increased risk [44], the WHO (and NICE and SIGN, in turn) suggest that combining WC & BMI into one measure may be more accurate. The classifications below were used in the 2009 annual report and refer to relative risk of obesity-related disease.

		Type 2 diabetes, hypertension and CVD risk relative to normal weight and waist circumference		
BMI Classification	BMI (kg/m²)	'Normal' WC Men WC<94cm Women WC<80cm[45]	'High' WC Men WC 94-102 cm Women WC 80-88 cm	'Very high WC' Men WC≥102 cm Men WC≥88 cm
Underweight	<18.5	No increased risk	No increased risk	No increased risk
Normal weight	18.5-<25	No increased risk	No increased risk	Increased[46]
Overweight	25-<30	No increased risk	Increased	High
Obese				
Mild	30-<35	Increased	High	Very high
Moderate	35-<40	Very high	Very high	Very high
Extreme	40+	Extremely high	Extremely high	Extremely high

Grouping together all those at increased risk (or higher) is more specific than BMI≥25 because it reclassifies people who have BMI 25-30 but normal waist circumference as 'no increased risk'.

The WHO combined measure and BMI were compared by charting them together (figures 2 and 3). The figures for women using the two measures are very similar but men have a lower proportion at risk according to the WHO combined measure. 16% of men are classed as overweight according to their BMI but are not at increased risk according to the WHO combined measure because their waist circumference is not raised. These are likely to represent those people with higher levels of lean muscle mass. Only 4% of women fall into this category, suggesting that there are far fewer women with high BMI due to lean muscle mass and the vast majority of women with BMI≥25 are at increased risk of disease.

Using the WHO combined measure rather than BMI has implications for headline statistics. For example, when measured using BMI≥25, men are significantly more likely to be classified as overweight or obese than women (70% vs. 63%), However, when the WHO combined measure is used the proportion of men at increased risk of disease is 60% and for women the figure is 63% (with no significant difference between sexes). It is also notable that for the higher categories of risk, women have higher prevalence than men.

Figure 1.2
Comparison of BMI and WHO combined measure of disease risk, men

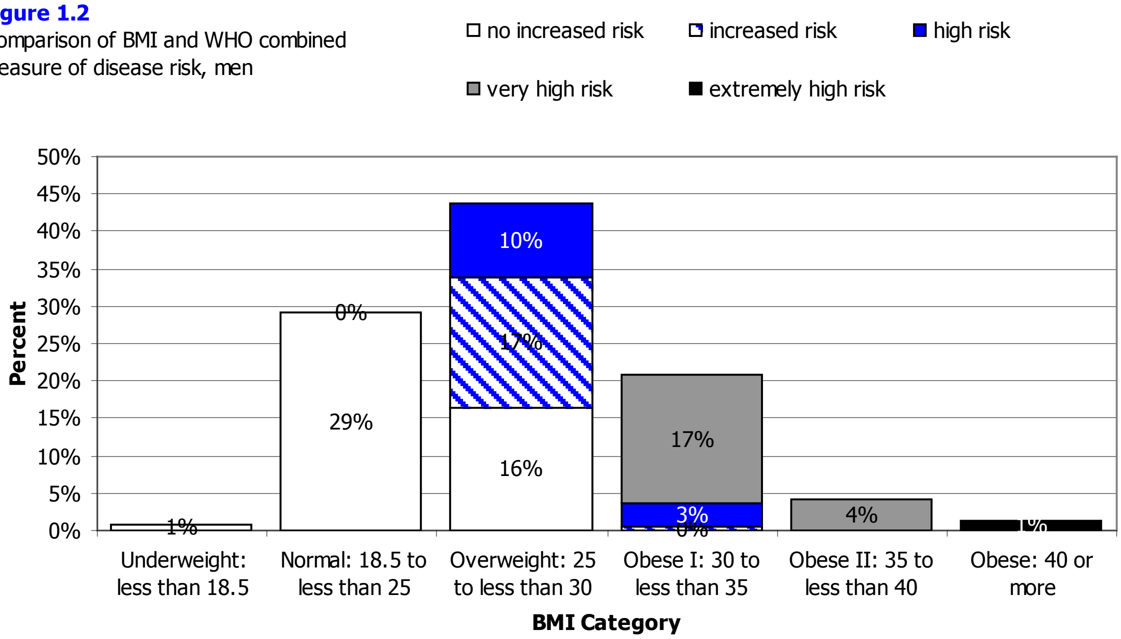
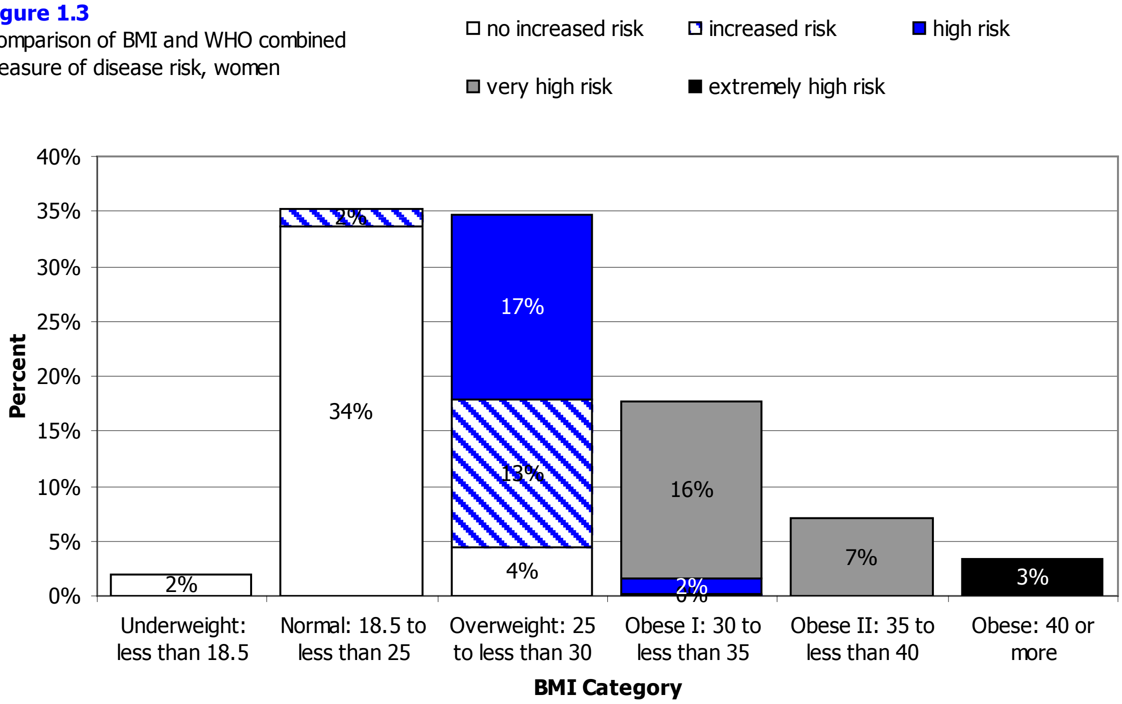


Figure 1.3
Comparison of BMI and WHO combined measure of disease risk, women



1.1.5 Waist-height ratio: (WHtR)

WHtR is a ratio of waist circumference to height:

waist circumference (cm) / height (cm)

The suggested universal cut-off is 0.5, where 0.5 and over indicates increased risk[47]. In this sense it is an alternative to BMI ≥25 or the WHO combined measure 'increased risk or higher'. Some studies suggest that the cut-off should vary with age, suggesting 0.55 for 40-50 year olds, and 0.6 for the over 50s[48].

WHtR is a useful, simple screening tool and its simplicity may be helpful for population wide public health messages. The same cut-off can be used for both sexes, all ethnic groups, and both adults and children, with the simple health message *'Keep your waist circumference to less than half your height'* [47].

As an alternative to BMI, WC, or WHR for measuring obesity, there is limited evidence. Studies suggest that it is better at predicting metabolic risk in non-obese or pre-obese subjects[49], and in clinical populations performed better than BMI or WHR[48].

1.1.6 Summary of measures discussed

Measure	**Data needed**	**Good predictor of disease / mortality**	**Disadvantages**
Increased risk or higher			
BMI≥25	Height, weight	Yes	Misclassification at lower BMI, does not take into account fat distribution
WHtR	Waist, height	Yes	Waist data more difficult to collect, limited use in studies
WHO Combined (increased risk or higher)	Waist, height, weight	Not known	More data needed
Higher risk			
BMI≥30	Height, weight	Yes	Does not take into account fat distribution
High WC	Waist	Yes	Data more difficult to collect
WHR	Waist, hip	Yes	Data more difficult to collect
WHO Combined (high risk)	Waist, height, weight	Not known	More data needed, almost the same as BMI≥30

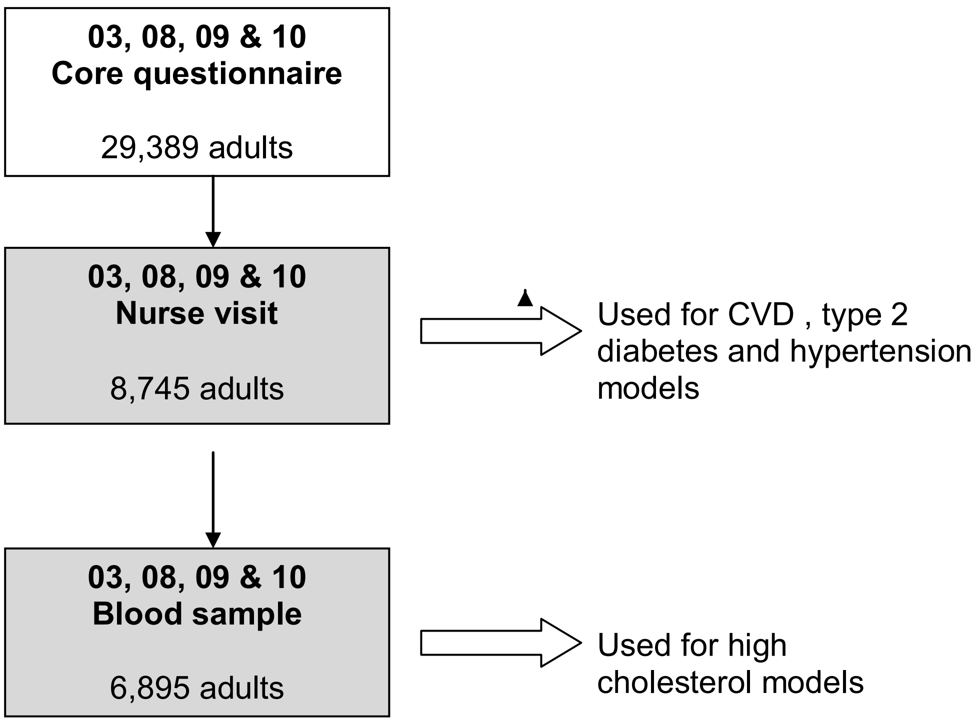
1.2 METHODOLOGY

1.2.1 Overview of data

The Scottish Health Survey (SHeS) was established in 1995 to provide data on the health of the population living in private households. It was repeated in 1998 and 2003, and has been run annually since 2008. Height and weight measurements were collected from all adults interviewed in the survey, excluding pregnant women. In 1995, 1998 and 2003, all adults were offered a nurse visit during which waist and hip circumference measures as well as blood samples where respondents gave permission. From 2008 onwards, the nurse visit was only offered to a subset of respondents.

The SHeS has a core and modular structure where a core set of questions is asked of all adults, and some modules of questions asked of a proportion of the sample. Questions about sedentary behaviour and frequency of eating certain foods were asked only in 2008 and 2010. The data is weighted to ensure it is representative, with different weights for people with a nurse visit, blood sample or answering sedentary behaviour/diet questions. All analyses were performed on individuals aged 16 or over. More details can be found in the technical reports for the 2008, 2009 and 2010 surveys [50,51,52].

Figure 1.4
Data used for comparing measures of obesity, combining data from 2003, 2008, 2009 & 2010 surveys



1.2.2 Methods used for comparing measures of overweight/obesity

In order to see how well different measures predicted disease, a series of logistic regression models was run for 4 different health outcomes: any cardiovascular disease (CVD); type 2 diabetes; high cholesterol and hypertension. Age-adjusted models were run for each outcome, for each measure of overweight/obesity, separately for men and women. The predictive power of the various obesity measures for each disease was assessed by the mean of the area under the receiver operating characteristic (ROC) curve, also known as the C statistic[53]. The C statistic ranges from 0.5 to 1, and the closer to 1, the better the measure.

In addition, the independent effect of BMI, WC and WHR on the outcomes in both men and women was investigated[54]. The combined 2003, 2008, 2009 and 2010 SHeS survey data were used and models were survey weighted. To make a fair comparison, the analysis was restricted to those with valid weight, height, waist and hip measures, and values on all the variables in the model. For the outcome of high cholesterol it was further restricted to those with a valid blood sample.

1.2.3 Predictors: measures of overweight/obesity

Measures of increased risk or higher:

- **Body mass index:** 25 or over
- **WHO combined measure:** all increased risk and over
- **Waist/height ratio:** age 16-39 >0.5, age 40-49 > 0.55, age 50 and over >0.6.

Measures of higher risk:

- **Body mass index:** 30 or over
- **Waist circumference:** High WC classed as ≥88 cm for women, ≥102 cm for men.
- **Waist-hip ratio:** High WHR defined as ≥0.85 for women, ≥0.95 for men
- **WHO combined measure:** all high risk and over

Outcomes- diseases/health risk factors

Any CVD: classified as a binary variable based on a series of questions on whether participants had suffered from any of the following conditions: angina, heart attack, stroke, heart murmur, irregular heart rhythm and 'other heart trouble'.

Type 2 diabetes: The interview makes no distinction between type 1 and type 2 diabetes. Using a similar method to the 2003 survey[55], and other studies[56], individuals were classed as type 1 diabetics if they were under 30 when first diagnosed, and were using insulin therapy at the time of interview. The remainder were classed as type 2 diabetics. Those with missing data on either question were coded as missing. Using this method, there is the potential for some type 2 diabetics to be classified as type 1, especially since there has been a global trend to earlier onset of type 2 diabetes[57]. However the 2009 Scottish diabetes survey report indicates the misclassification would be negligible since only 0.4% of adult type 2 diabetics were aged under 30[58].

High cholesterol: total cholesterol ≥ 5 mmol/l.

Hypertension: This was classified into a binary of normotensive vs normotensive treated /hypertensive/ hypertensive untreated as used in the 2009 annual report[59].

1.2.4 Limitations

There were some limitations to this statistical analysis. It would be preferable to measure the disease outcomes by linking prospectively to medical records, to more accurately identify disease cases and to rule out any reverse causality of disease and weight. Comparison of the models would have been more straightforward if they were modelled as continuous variables in a linear regression, rather than logistic. While this is possible for blood pressure and high cholesterol, it was not for CVD or type 2 diabetes. ROC AUC analysis has been criticised for being relatively insensitive to small differences, and to remedy this we could have used more complex alternative methods, such as the relative integrated discrimination improvement (RIDI) to discriminate between the measures.[60]

1.3 COMPARISON OF MEASURES OF OBESITY USING SHES DATA

1.3.1 Correlation between obesity measures

Within the combined 03, 08, 09 & 10 surveys, the most strongly correlated measures were WC & WHtR (r=0.92) and BMI and WHtR (r=0.86). Of the measures that were completely independent of one another, BMI and WC were more strongly correlated (r=0.82) than BMI and WHR(r=0.43) See appendix A for full correlation coefficients.

Figure 1.5
Scatterplot of BMI and waist circumference values

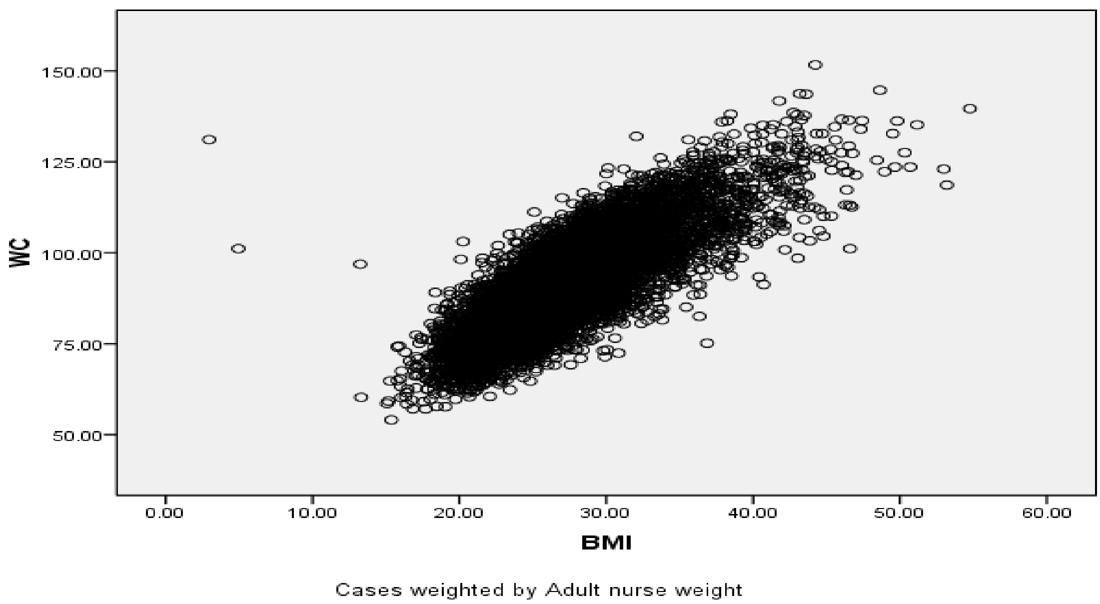
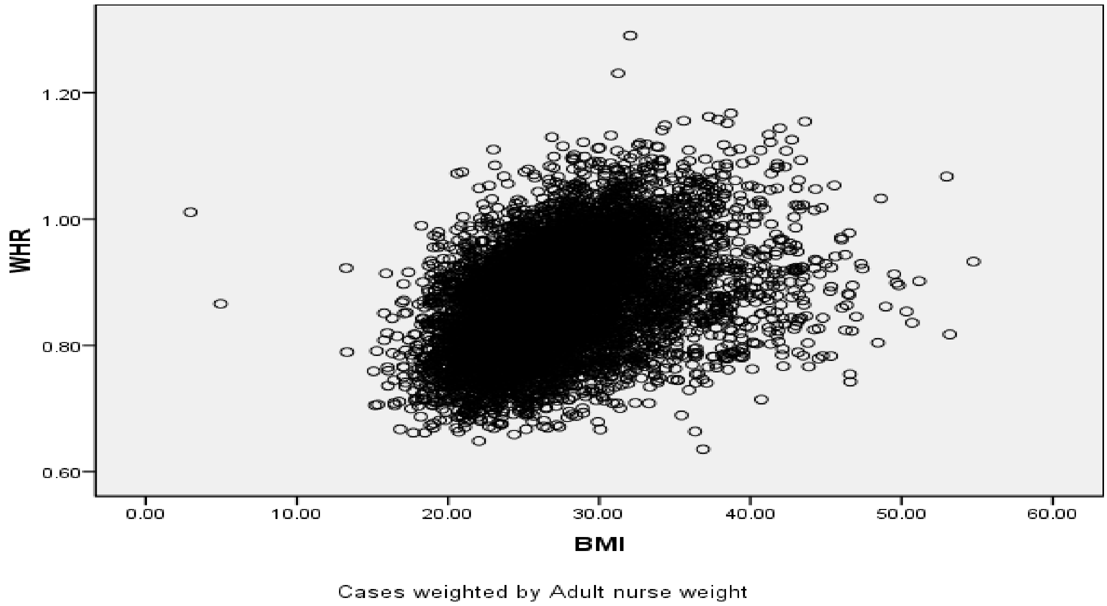


Figure 1.6
Scatterplot of BMI and waist/hip ratio values



1.3.2 Associations of measures of obesity with health risk factors

Characteristics of the Sample

The most common risk factors were hypertension (37%) and high cholesterol (68%), followed by CVD (18%), and type 2 diabetes (5%). The largest differences in prevalence by exposure status are for type 2 diabetes and hypertension, reflecting the importance of weight gain as a risk factor for those illnesses. Those with BMI ≥30 have three to four times higher prevalence of type 2 diabetes than those with BMI<30, whereas rates of hypertension are approximately double in those with BMI≥25 compared to those with BMI<25. The mean age of the sample for analysis was 50.3 years, compared to 50.5 years in the unrestricted sample.

Figure 1.7
Prevalence of Cardiovascular Disease (CVD),
by different measures of overweight and obesity

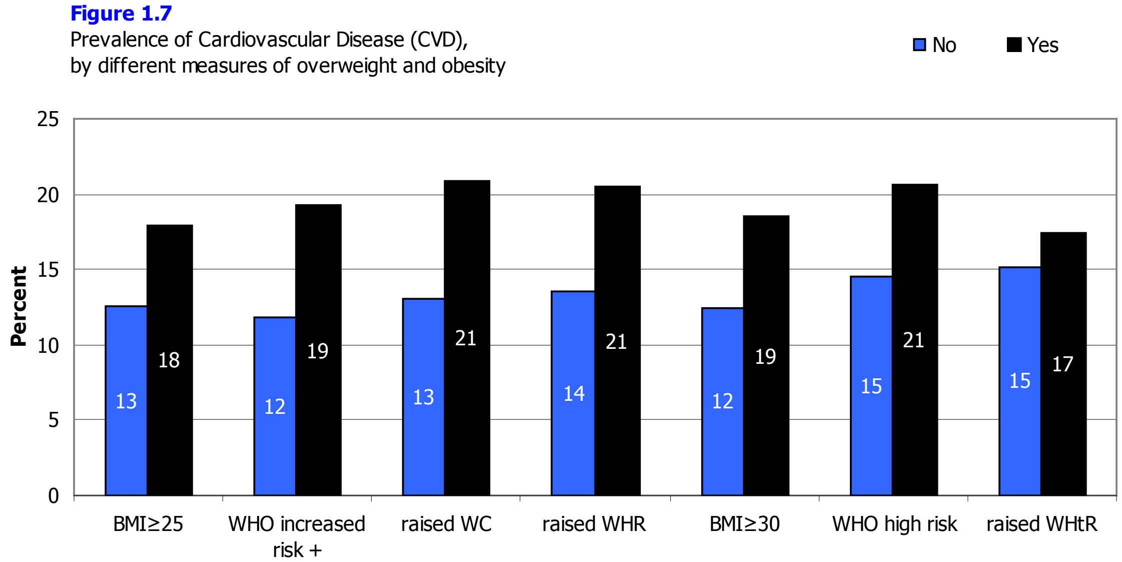


Figure 1.8
Prevalence of Type 2 Diabetes,
by different measures of overweight and obesity

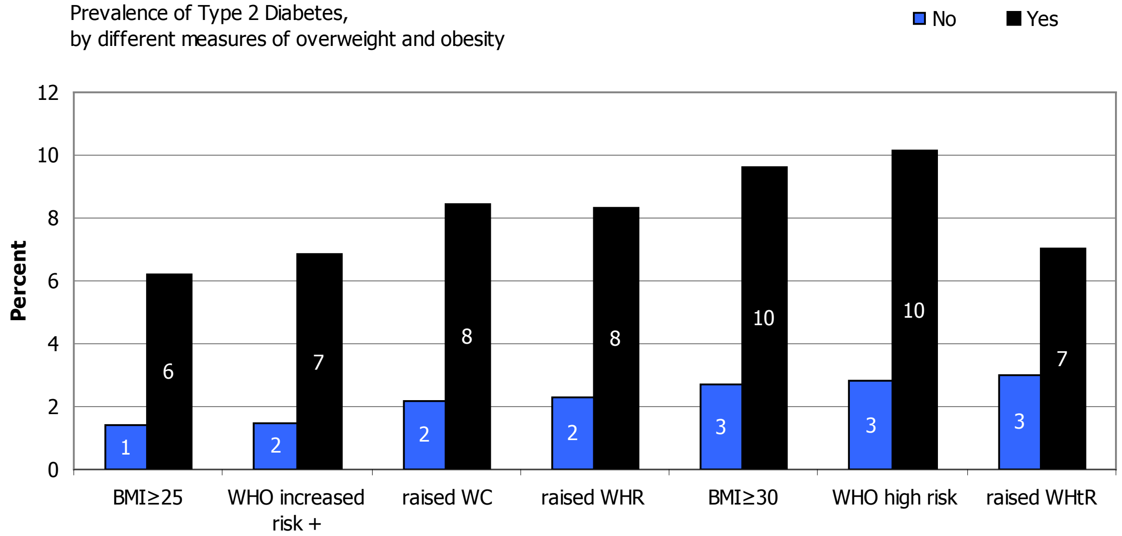


Figure 1.9
Prevalence of Hypertension,
by different measures of overweight and obesity

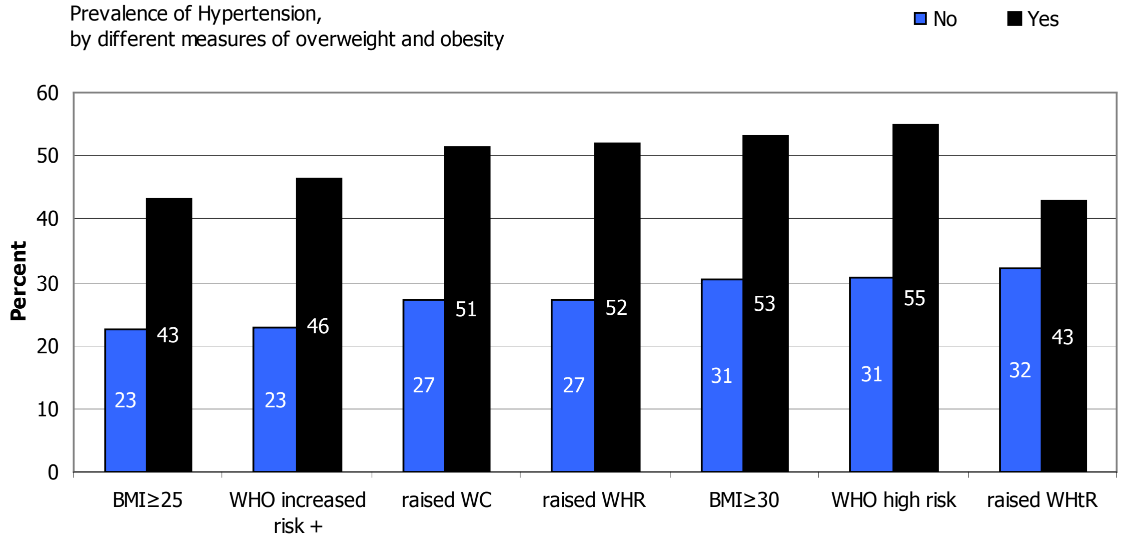
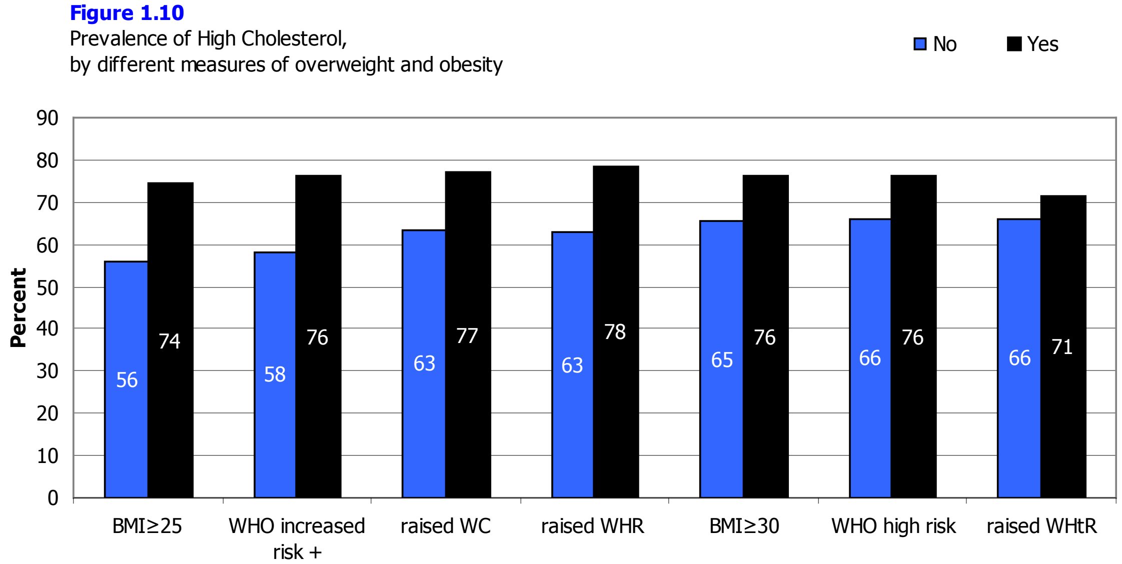


Figure 1.10
Prevalence of High Cholesterol,
by different measures of overweight and obesity



1.3.3 Results of Logistic Regression analysis

The outcome with the smallest odds ratios, and weakest associations after age-adjustment was CVD. This could be because there are other risk factors at play with CVD, such as smoking, which dilute the association. Secondly, the severity of some CVD conditions, eg. heart attack may produce a selection bias whereby those with CVD are less likely to be respondents of SHeS. Therefore the full association between obesity and CVD may not be captured in a cross-sectional sample and a longitudinal sample of linked data may be more appropriate. The calculated C statistics (interpreted as the higher, the better) were all exactly the same for men, and very similar for women, suggesting no significant difference between the obesity measures in their ability to predict CVD. The remainder of the discussion concentrates on associations with the other outcomes.

The strongest effects were seen for type 2 diabetes in women, where age-adjusted odds ratios (ORs) ranged from 2.69-5.31, and hypertension in women, where age-adjusted ORs ranged from 2.17-3.58. Women at increased risk (or higher) according to the WHO combined measure had odds of having type 2 diabetes 5.3 time higher than women of healthy weight and waist size. Men with BMI≥25 had odds 2.8 times higher of having high cholesterol than men of normal weight.

There is no clear pattern of one measure having a stronger effect, the effects varied by sex and outcome. For type 2 diabetes, the association between excess fat and disease was stronger for women than men. In women, less specific measures (measures of overweight including obesity) had a stronger effect. For example, women with BMI≥25 were significantly more likely to have type 2 diabetes compared with those with BMI<25 (OR 5.21) whilst the odds ratio for women with BMI≥30, whilst still significant, was smaller (OR 3.17) In men more specific measures (eg. BMI≥30) produced stronger effects than less specific measures. Men with BMI≥30 were significantly more likely to have type 2 diabetes than those with BMI<30 (OR 2.85) The comparable odds ratio for men with BMI≥25 was 2.16.

For high cholesterol, the strongest effects were seen for men, particularly for less specific measures. Men with BMI≥25 had odds of having high cholesterol 2.8 times higher than those with BMI<25.

For hypertension, the odds ratios were higher for women on every measure, and the strongest effects were observed for BMI≥30 and the WHO combined measure (high risk). The AUC (C statistics) for all measures, all outcomes, in both sexes, are all significantly different from 0.5, and ranged between 0.66 and 0.82, suggesting that all of the models are useful predictors. The ROC curves were plotted and showed that in most cases, there is very little difference in the predictive value of the different obesity measures. The only significant difference between the C statistics was for type 2 diabetes in men, where BMI≥30

and waist-height ratio were significantly better predictors than BMI ≥25.
Tables 1.1 -1.4

The further adjustments shown in table 1.5 give an overall picture of the independent contribution of BMI, WC & WHR to the association between obesity and disease. The results varied considerably by disease and sex (shown in appendix D) , suggesting that future studies should consider these factors when choosing an appropriate measure.

CVD: After adjustment for the other variables, BMI≥30 has the smallest reduction in effect, and was still a significant predictor. The association between WC or WHR and CVD disappeared on adding any of the other variables.

Type 2 diabetes: Once again, BMI≥30 was the strongest independent predictor, as the effect and significance was least reduced on adding WC and WHR. However, all of the measures were independently significant predictors, WHR the weakest and least significant.

High cholesterol: WHR was the strongest independent predictor, and was strongly statistically significant after controlling for BMI and WC. The independent effect was stronger in women - after adding BMI and WC, 89% of the effect of WHR remained. The effect and significance of WC reduced on adding BMI or WHR, and disappeared on adding them both.

Hypertension: BMI≥30 was the strongest independent predictor, 70% of the effect remained after adding WC and WHR.

Except for high cholesterol, controlling for WHR makes the smallest reductions to the odds of the main variable, suggesting that overall, WHR is the least powerful independent predictor. However, for high cholesterol, WHR performed best independently. **Table 1.5**

1.3.4 Discussion and Conclusion

The literature review describes how BMI, WC, WHR and WHtR are all proxy measures for the underlying concept(s) of excess fat of which there are 2 elements - total body fat, and fat distribution. Guidelines from WHO, SIGN, and NICE suggest it is important to measure both aspects, as both are independent indicators of health[3,14,16,21,2361]. Studies show that total body fat is well captured by BMI and WC, fat distribution is well captured by WC or WHR[20]. However, BMI is less complex and more efficient to collect than WC or WHR, and WHR is more complicated to interpret.

The first issue is the relative usefulness of the measures for measuring risk from excess fat. There is considerable controversy over which is the single most useful measure for obesity - WC, WHtR or combined BMI/WC have all been suggested as alternatives to the traditional BMI.

There is convincing evidence from previous studies that BMI, WC & WHR are positively associated with CVD risk, diabetes, hypertension, all-cause mortality and some cancers (colorectal and post-menopausal breast)[16]. There is far less evidence for WHtR. In some cross-sectional studies, measures of abdominal obesity (either WC or WHR) better predict CVD and type 2 diabetes [16,41,62,]. Where studies investigate the independent effect of the measures, results vary according to the outcome, gender, age and are often contradictory.

Statistical analysis with ROC AUC analysis in the SHeS suggested that all the measures discussed are good predictors of obesity-related disease, but provided little evidence to distinguish between them. The findings are in line with meta-analysis studies which found that despite differences between BMI, WC and WHR as discriminators of cardiovascular risk factors and diabetes incidence, the differences were small and not statistically significant[63,64]. A recent study using a large sample of UK wide data also found little difference between AUC estimates for BMI, WHR and WC[42]. After mutual adjustment for other obesity measures, BMI≥30 was the best independent predictor of CVD, type 2 diabetes and hypertension, because it was strongly associated with the outcomes, and a considerable amount of the association remained after adjustment for WC and WHR. However WHR was the best predictor of high cholesterol, much better than BMI. It had the highest odds ratio, and remained the strongest independent predictor after adjusting for BMI and WC.

This suggests that within the SHeS the best overall measure of obesity-related risk is BMI≥30, but measures of abdominal fat (particularly WHR, confirming results from previous studies [41,42,65,,]) are also strong independent predictors. The results for CVD contradict a recent study using SHeS data which found that WHR was the strongest predictor of CVD mortality, much better than BMI [42]. However, that study differed in that it used prospective data and focused on cardiovascular mortality. As discussed earlier, CVD prevalence may not be best captured using a cross-sectional study.

The second issue concerns whether combining BMI and WC is more discriminatory than using them individually. The strength of the WHO combined measure is that is provides information about different levels of risk, while taking into account total weight and level of abdominal fat. As a binary measure, using the cut-off of ‘high risk’, it is virtually identical to BMI≥30, and there is very little to be gained from using it in such a way. However, using the cut-off of increased risk (or higher) is a good, more specific alternative to BMI≥25, as it removes people who have high lean muscle mass from the ‘at risk’ group. The combined measure could replace BMI≥25 to capture increased risk from excess fat. However, it does require more data which is harder and more expensive to collect.

The final issue is about the usefulness of the measures for two purposes - measuring trends over time, and investigating the causes of obesity. Here practical considerations must take over. Using BMI-based measures yields larger samples in the SHeS, as waist and hip based measures are only collected from a sub-sample at every survey. This is because waist and hip measures have traditionally been collected by a trained nurse which is more expensive, whereas weight and height can be collected by the interviewer with minimal personal intrusion (no need to remove clothes, or hold the tape next to the body)[66]. Larger sample sizes are essential to detect change over time, and allow sub-group analysis for statistical modelling to investigate the causes of obesity. Given that BMI performed well as an independent indicator of disease and health risk, it is valid choice. However, the analysis also showed that indicators of abdominal obesity were strong predictors of poor health, independent of BMI, so where possible WC or WHR should be also be reported, or combined with BMI.

In summary the analysis validates BMI≥30 as an indicator of obesity, but this should be combined with or supplemented by a measure of abdominal obesity (WC or WHR) where practical.

Based on these findings, chapter 2 investigates the factors associated with overweight and obesity using the WHO combined measure for increased risk, and the factors associated with obesity using BMI ≥30.

Table 1.1: Estimated odds ratios and ROC area under the curve estimates for doctor-diagnosed CVD, by measure of overweight and/or obesity

Aged 16 and over *2003/2008/2009/2010*

Measures	Men Base (weighted) **3109**		Women Base (weighted) **3725**	
	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)
Measure of increased risk				
BMI≥25	0.97 (0.81-1.16)	0.75 (0.73-0.77)	1.50 (1.29-1.74)**	0.71 (0.68-0.73)
WHO combined (increased risk +)	1.21 (1.03-1.42)	0.75 (0.73-0.77)	1.53 (1.32-1.78)**	0.71 (0.68-0.73)
High WHtR	1.30(1.12-1.52)*	0.75 (0.73-0.78)	1.25 (1.10-1.43)**	0.70 (0.68-0.73)
Measure of high risk				
High WC	1.28 (1.11-1.49)*	0.75 (0.73-0.77)	1.44 (1.27-1.65)**	0.71 (0.69-0.73)
High WHR	1.21 (1.06-1.39)*	0.75 (0.73-0.77)	0.95 (0.84-1.07)	0.70 (0.67-0.72)
BMI≥30	1.29 (1.10-1.52)*	0.75 (0.73-0.77)	1.31 (1.16-1.48)**	0.71 (0.68-0.73)
WHO combined (high risk)	1.32 (1.12-1.56)*	0.75 (0.73-0.77)	1.35 (1.19-1.53)**	0.70 (0.68-0.73)

*P<0.01 **P<0.001

Table 1.2: Estimated odds ratios and ROC area under the curve estimates for type 2 diabetes, by measure of overweight and/or obesity

Aged 16 and over				*2003/2008/2009/2010*
Measures	**Men** Base (weighted) **3111**		**Women** Base (weighted) **3728**	
	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)
Measure of increased risk				
BMI≥25	2.16 (1.57-2.98)**	0.76 (0.73-0.79)	5.21 (3.35-8.06)**	0.79 (0.76-0.82)
WHO combined (increased risk +)	2.17 (1.64-2.87)**	0.77 (0.73-0.80)	5.31 (3.55-7.92)**	0.79 (0.76-0.82)
High WHtR	2.31 (1.76-3.01)**	0.78 (0.75-0.81)	3.24 (2.53-4.14)**	0.79 (0.76-0.82)
Measure of high risk				
High WC	2.69 (1.99-3.65)**	0.78 (0.75-0.82)	3.25 (2.52-4.19)**	0.78 (0.75-0.82)
High WHR	1.95 (1.45-2.63)**	0.77 (0.74-0.80)	2.69 (2.12-3.42)**	0.78 (0.75-0.82)
BMI≥30	2.85 (2.16-3.78)**	0.79 (0.76-0.83)	3.17 (2.54-3.96)**	0.79 (0.75-0.82)
WHO combined (high risk)	2.84 (2.13-3.79)**	0.79 (0.76-0.82)	3.09 (2.49-3.48)**	0.78 (0.75-0.82)

*P<0.01 **P<0.001

Table 1.3: **Estimated odds ratios and ROC area under the curve estimates for high cholesterol, by measure of overweight and/or obesity**

Aged 16 and over *2003/2008/2009/2010*

Measures	Men Base (weighted) **2120**		Women Base (weighted) **2572**	
	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)
Measure of increased risk				
BMI≥25	2.80 (2.42-3.23)**	0.68 (0.66-0.71)	1.72 (1.52-1.95)**	0.75 (0.73-0.77)
WHO combined (increased risk +)	2.19 (1.89-2.53)**	0.66 (0.64-0.69)	1.87 (1.65-2.12)**	0.74 (0.72-0.76)
High WHtR	2.42 (1.07-2.83)**	0.68 (0.65-0.7)	1.71 (1.49-1.96)**	0.74 (0.72-0.76)
Measure of high risk				
High WC	2.13 (1.78-2.56)**	0.66 (0.64-0.69)	1.64 (1.43-1.91)**	0.74 (0.72-0.76)
High WHR	2.09 (1.76-2.49)**	0.66 (0.64-0.69)	1.76 (1.53-2.02)**	0.75 (0.73-0.77)
BMI≥30	2.00 (1.65-2.42)**	0.68 (0.65-0.70)	1.42 (1.21-1.67)**	0.75 (0.73-0.77)
WHO combined (high risk)	2.00 (1.62-2.46)**	0.66 (0.63-0.68)	1.39 (1.18-1.65)**	0.74 (0.72-0.76)

*P<0.01 **P<0.001

Table 1.4: Estimated odds ratios and ROC area under the curve estimates for hypertension, by measure of overweight and/or obesity

Aged 16 and over *2003/2008/2009/2010*

Measures	Men Base (weighted) **2835**		Women Base (weighted) **3587**	
	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)	Odds Ratio (95% CI)	ROC : Area under curve (95% CI)
Measure of increased risk				
BMI≥25	2.08 (1.78-2.43)**	0.76 (0.73-0.78)	2.96 (2.64-3.32)**	0.83 (0.82-0.86)
WHO combined (increased risk)	2.09 (1.83-2.38)**	0.76 (0.74-0.78)	3.20 (2.84-3.58)**	0.85 (0.83-0.86)
High WHtR	1.91 (1.68-2.18)**	0.76 (0.74-0.78)	2.53 (2.24-2.86)**	0.85 (0.82-0.85)
Measure of high risk				
High WC	2.43 (2.08-2.73)**	0.77 (0.74-0.79)	2.66 (2.19-3.24)**	0.84 (0.82-0.85)
High WHR	2.14 (1.88-2.43)**	0.76 (0.74-0.78)	2.17 (1.87-2.52)**	0.84 (0.82-0.85)
BMI≥30	2.43 (2.11-2.80)**	0.76 (0.74-0.78)	3.52 (3.00-4.11)**	0.85 (0.83-0.86)
WHO combined (high risk)	2.58 (2.21-3.01)**	0.76 (0.74-0.78)	3.58 (3.12-4.11)**	0.85 (0.82-0.86)

*P<0.01 **P<0.001

Table 1.5: Percentage reduction in odds ratios and significance level after adding alternative measures to the model, separately for each risk factor, both sexes combined [a]

Aged 16 and over *2003/2008/2009/2010*

Measure	Initial Odds Ratio and significance level	Age-adjusted, survey weighted models Significance level of main variable *P<0.05 **P<0.001			
		% of main effect remaining after adding following variables			
		+BMI≥30	+ High WC	+ High WHR	+ previous 2 variables
CVD					
BMI≥30	1.28**	-	70%	99%*	71%*
High WC	1.39**	53%		100%	61%
High WHR	1.07	60%	43%	-	40%
Type 2 diabetes					
BMI≥30	2.98**		60%**	81%**	58%**
High WC	2.84**	63%**		81%**	47%*
High WHR	2.28**	65%**	48%*		44%*
High cholesterol					
BMI≥30	1.69**		68%**	66%**	64%**
High WC	1.82**	55%*		47%*	8%
High WHR	1.87**	80%**	81%**		79%**
Hypertension					
BMI≥30	2.85**		73%**	85%**	71%**
High WC	2.48**	51%**		79%**	33%*
High WHR	2.05**	59%**	51%**		45%**

[a] The sex-specific results are shown in appendix D.

2. FACTORS ASSOCIATED WITH OBESITY

2.1 LITERATURE REVIEW

Although obesity is the result of energy imbalance at the individual level, many complex biological, psychological, cultural, social, environmental, and economic factors combine to determine each person's energy intake and expenditure. The UK Foresight report 'obesity system map' shows the immense complexity of these proximal and distal causes[4]. Attention has increasingly turned away from individual level responsibility for energy imbalance to consider the wider environmental determinants driving the energy in/energy out dynamic[67]. The focus on the 'obesogenic environment' takes into account how the built environment, availability and cost of types of food, food advertising and transport options combine to encourage excessive eating and discourage physical activity [68].

2.1.1 Energy intake: diet

The recent Lancet series suggested that the most powerful driver of recent increases in obesity is a rapid increase in the supply of affordable, processed food, which occurs alongside economic development[68]. Overall, calorie consumption in the UK and US has increased over time along with obesity[69]. However, at an individual level, diet composition is also important, with higher fat, lower carbohydrate diets linked to higher BMI [70,71]. This is because fat does not satisfy the appetite very efficiently, making you more likely to overeat, and contains twice as many calories per gram than carbohydrate. Studies in the US have found links between obesity and consumption of sweetened drinks[72], snack or 'fast' foods', low fibre foods, and energy dense products[73]. Low-cost food, which usually revolves around refined grains, with high levels of fats and sugar, may be a more consistent predictor of obesity than any single food group [74]. Larger portion sizes also play a role [75]. Eating away from home, skipping breakfast and eating less frequently was also associated with obesity [76].

2.1.2 Energy expenditure: Exercise and sedentary behaviour

A trend towards more sedentary lifestyles, through the decline in manual occupations, and rise in sedentary jobs, and increased use of mechanised transport, has long been linked to rising obesity in developed societies [77]. However, evidence is mixed. In the early 20th century, physical activity decreased, but was compensated for by decline in energy intake[68]. Some argue that a rapid decrease in physical activity was a key driver of increases in obesity in the UK until the late 80s [70]. Although detailed individual level studies often find no evidence that obese subjects are less active than their lean counterparts [78], self-reported survey data find that low physical activity and sedentary behaviour, such as increased time spent watching television or on the computer, are predictors of obesity [79,80,81]. Increased television watching is also associated with unhealthy dietary choices [82], with tendency to eat more energy, dense foods [83].

2.1.3 Socio-economic factors

The 2 major reviews find that in developed societies on the whole, low socio-economic status is more strongly associated with obesity in women, but not men [84,85]. The most recent review, including 333 cross-sectional studies, found that female obesity was most commonly associated with low education, area-level poverty/deprivation, and low occupational grade. Using most indicators, there was inconsistent or null association with socio-economic status in men, but in 50% of studies an inverse relationship with education[84]. In England, low education is associated with obesity in both sexes, but occupational class only associated in women [86]. Although in most developed countries the association in women has weakened since the 1980s, as obesity becomes more widespread, there is no evidence of inequalities reducing in Scotland [87]. The association may vary by ethnicity [88]. Suggested mechanisms for socio-economic status affecting obesity include the cheap cost and palatability of poor quality, energy-dense foods appealing to those with limited income [89], and area-level density of fast-food outlets [90]. Childhood socio-economic factors also influence adult obesity, diet and exercise habits [91]. One study investigating the mechanisms noted that male obesity was related to education and occupation even after adjustment for diet, physical activity, smoking and drinking [92].

2.1.4 Ethnicity and marital status

In the UK, South Asians and Africans have a higher prevalence of abdominal obesity than white Europeans [93], and higher prevalence of obesity and obesity related health conditions [94]. The mechanism for the increased prevalence is unclear.

Analysis from the SHeS 2008 shows that men in partnerships had higher odds of obesity than single men, independently of a range of other factors [95]. In the US, being married increases the risk of male obesity, independent of age and socio-economic factors, but has no effect for women [96]. For men, entering marriage is associated with weight gain, and dissolving marriage with weight loss [97]. BMI is often correlated within marriage, but analysis suggests this is more related to assortative mating than shared eating or exercise habits [98].

2.1.5 Lifestyle factors, health behaviours

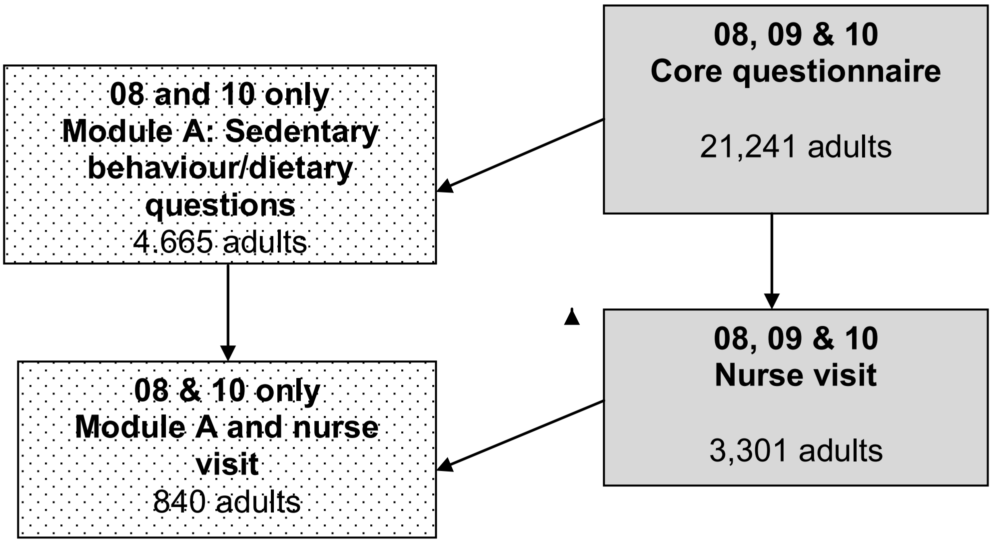
In Scotland, smokers tend to have lower BMIs than non-smokers, although smoking in women is linked to abdominal obesity [32]. As alcohol contains calories, it is expected that consumption can lead to weight gain. However, a systematic review of 31 publications provided inconclusive evidence. There is stronger evidence of a positive association among heavy drinkers, and in spirit drinkers [99].

2.1.6 Health conditions

Obesity is associated with increased risk of depression, bipolar disorder, and anxiety[100] although it is unclear on the direction of causation.

2.2 METHODOLOGY

Figure 2.1
Data used for exploring factors associated with obesity, combining data from 2008, 2009 & 2010 surveys



2.2.1 Methods for exploring factors associated with overweight and obesity

Firstly, every independent variable was cross-tabulated with the outcomes, and chi-squared tests of association performed. Where age-standardised tables were produced, the data were age-standardised separately by sex against the average of the mid-year population estimates from 2008, 2009 and 2010 [101]. Two multivariable models were run, an ordinal logistic regression model for the WHO combined measure, and a standard logistic regression for BMI≥30. For the WHO combined measure, the risk categories were combined resulting in 3 groups of risk: no increased risk, increased risk, and high risk and over (including very high risk and extremely high risk). The regression models were run separately for men and women, as the literature suggests gender-specific differences in the association of obesity with some risk factors [86,88].

In the ordinal logistic regression, coefficients are reported for each level of each dependent variable. A positive coefficient indicates an increase in the log odds of being in a higher category of risk of disease from excess fat (and a negative coefficient indicates a decrease). For example, if having a low level of physical activity has a coefficient of

0.8, it means low physical activity is associated with an increase of 0.8 in the log odds of being in a higher category of risk, when compared to those with high levels of physical activity, and when other variables in the model are held constant.

In the standard logistic regression, odds ratios are reported. This tells you the odds of the outcome when compared to the baseline category of that independent variable. For example, if low physical activity has an odds ratio of 2, it means that the odds of obesity are two times higher in those with low physical activity, compared to those with high physical activity, when all the other variables in the model are held constant.

The full process of model development and list of variables is described in appendix E. Significant interaction terms were included in the model and the stratum specific odds ratios reported.

When analysing obesity using BMI≥30, the combined 2008 and 2010 surveys were used, enabling exploration of associations with dietary habits and sedentary behaviour (these questions were not asked in 2009). Due to the small sample size of people with both waist measures and dietary information, it was not possible to do the same for the WHO combined measure. Therefore, when analysing this, to boost the sample size, the combined 2008, 2009 and 2010 surveys were used. Those with no valid weight measure, or BMI<18.5 were excluded, so that health issues associated with underweight did not confuse the associations.

Dietary quality was assessed using the modified version of the Dietary Instrument of Nutrition Education (DINE) questionnaire developed by the Imperial Cancer Research Fund's General Practice Research Group [102]. As more than 20 food and drink types were covered, the data was reduced into a single index of dietary quality, ranging from 0-100. The index was initially developed using the 2003 survey on behalf of the Food Standards Agency for Scotland [83]. More information about how the index is derived in available in the 2009 annual report chapter on diet [59].

2.2.2 Missing data

All analysis is based on complete cases; no multiple imputation was used. 17% of eligible sample were excluded because they had no BMI measure Predictors of missing BMI measures were explored, and the results presented in appendix C.

2.3 BIVARIATE ASSOCIATIONS WITH OVERWEIGHT AND OBESITY

2.3.1 Prevalence of risk categories (WHO combined measure) by age and sex

The proportion at risk increases with age in both men and women, peaking or levelling off at ages 55-64. By the age group 35-44, over half the population are at increased or high risk, and at ages 55-64, over three quarters of women are at increased or high risk. There are significantly more women than men at risk in the age groups 16-34. At every age, for both sexes (except 25-34 year old men), the proportion at high risk is larger than those at increased risk.

Figure 2.2
Proportion at risk of obesity-related disease according to WHO combined measure, men

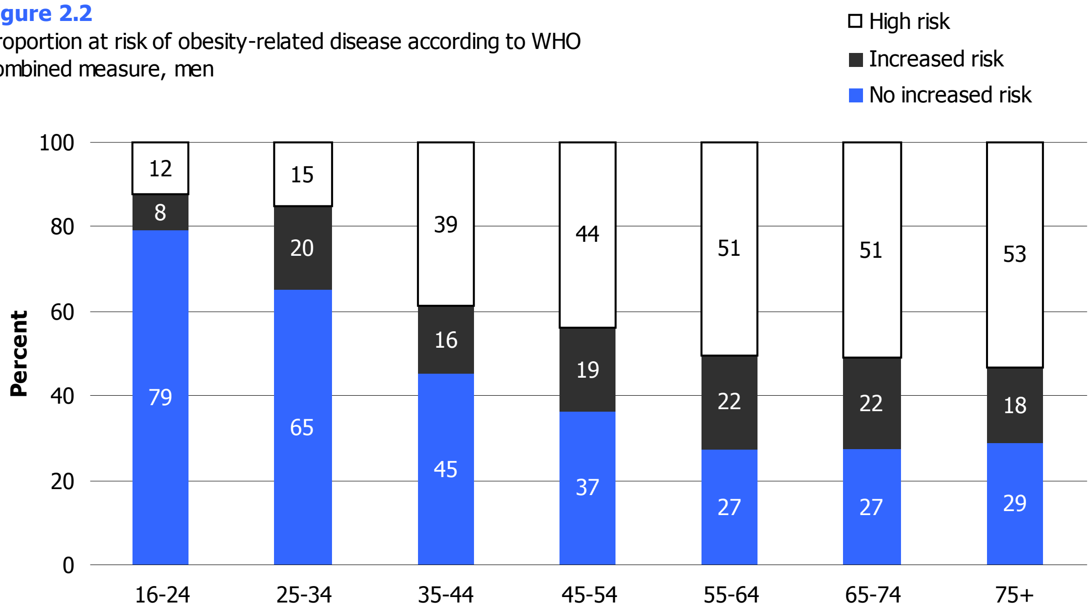
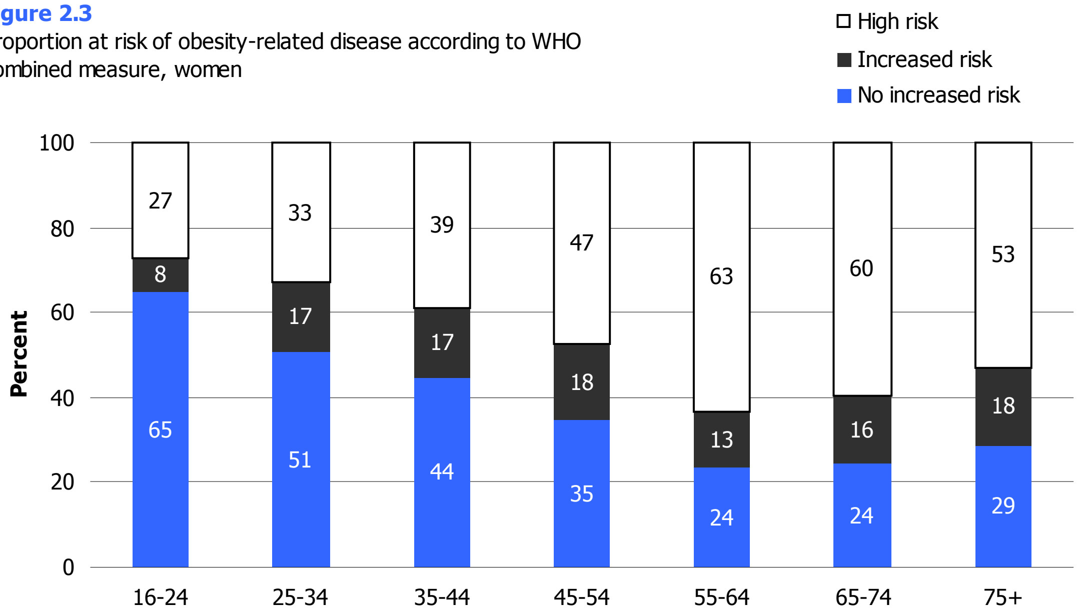


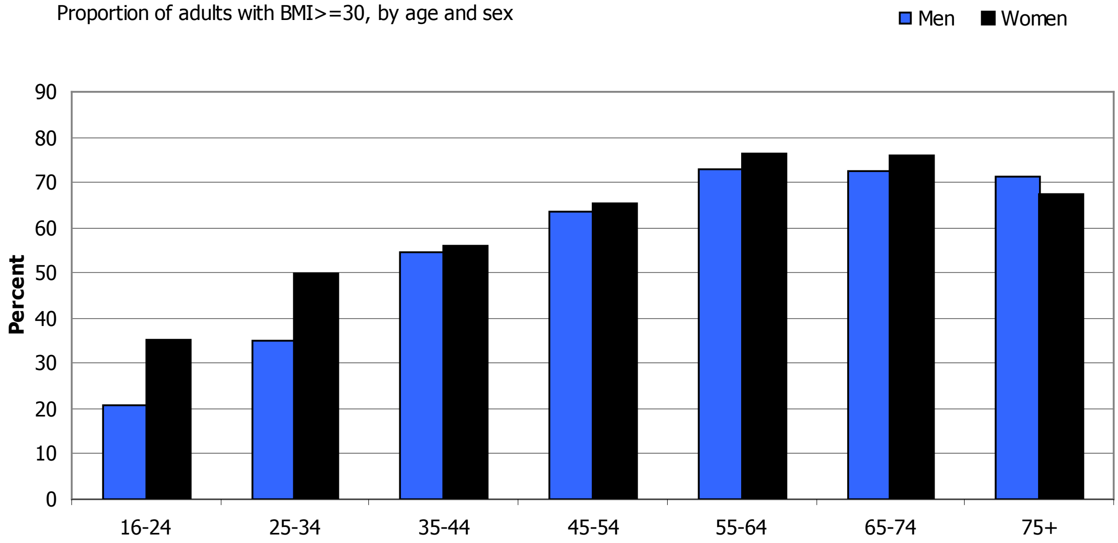
Figure 2.3
Proportion at risk of obesity-related disease according to WHO combined measure, women



2.3.2 Prevalence of BMI≥30 by age and sex

BMI≥30 increases significantly with age. peaking in the 55-64 age group in both sexes. The proportion of men and women with BMI≥30 is not significantly different overall, or within age groups, except among 16-24 year olds, where a higher proportion of women have BMI≥30 (16.9% vs. 9.2% for men).

Figure 2.4
Proportion of adults with BMI>=30, by age and sex



2.3.3 Factors significantly associated with the outcomes

The only factor which was not significantly associated with increased risk or BMI≥30 in men or women was mental health measured using WEMWBS. A number of factors were associated with increased risk and BMI≥30 regardless of sex: physical activity, area deprivation, low education, being unable to work, being married, not smoking or drinking, poor general health and long-standing illness. Others showed the same gendered patterns across both the WHO combined measure and BMI≥30: eating together and low occupational grade. In general the same factors were associated with men and women. The main exceptions were variables reflecting socio-economic status, such as income and occupational grade which were significant for women but not men.

Bivariate associations with BMI≥30, significant at the 5% level

Factors	BMI≥30, men	BMI≥30, women
Decreased physical activity	✓	✓
Increased screen time	✓	✓
Eating together more frequently	✓	X
Eating more than 5 portions fruit/vegetables a day	✓	X
Dietary Quality Index (DQI) quintiles	✓	✓
Increased area deprivation (SIMD)	✓	✓
No/other educational qualification	✓	✓
Low occupational grade	X	✓
Low income	X	✓
Economic activity- permanently unable to work	✓	✓
Not living in city	✓	✓
Being married	✓	✓
Ethnicity- white	✓	✓
Being an ex-smoker	✓	✓
Being a non-drinker	✓	✓
Bad or very bad general health	✓	✓
Mental health condition (GHQ score 4+)	X	✓
Long-standing limiting illness	✓	✓

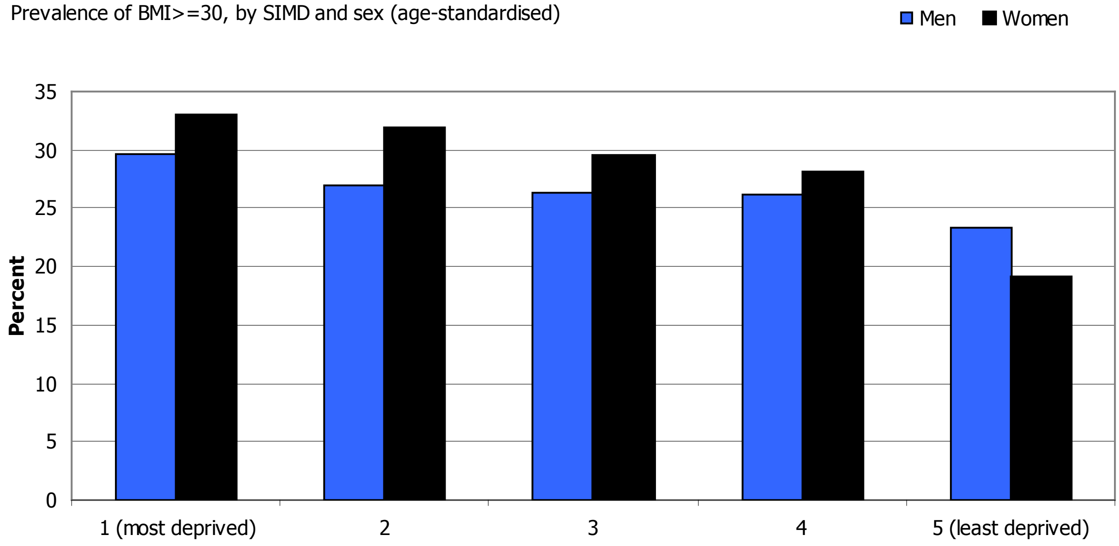
2.3.4 Socio-economic status

Educational qualifications, income, and Scottish Index of Multiple Deprivation (SIMD) were also considered. Obesity and overweight is generally higher in the most disadvantaged groups but the socio-economic status gradient is much clearer and steeper in women, than men.

Income was more strongly associated with obesity in women than men. The proportion of women at increased risk, or with BMI≥30 rose significantly as income decreased, peaking in quintile 4, whereas there was a much weaker association in men, with no clear pattern. For SIMD, in women, the proportion with BMI≥30 and at increased risk rises across deprivation quintiles. The proportion with BMI≥30 was approximately 50% higher in the most deprived quintile than the least deprived quintile (33% vs. 19%). Men had a similar pattern but the increase was less steep.

The education gradient was steeper among men than women. After age-standardisation, men with no qualifications were twice as likely to be in the high risk group than men with higher or standard grades (60% vs. 26%). Women with ‘other’ education or no qualifications were significantly more likely to be at increased risk or have BMI≥30, compared with those with higher levels of education.

Figure 2.5
Prevalence of BMI>=30, by SIMD and sex (age-standardised)



2.4 RESULTS OF MULTIVARIABLE MODELLING OF RISK FROM OVERWEIGHT AND OBESITY

2.4.1 Ordinal logistic regression for WHO combined measure

For both sexes physical activity had an inverse relationship with increase risk, i.e. those who had low levels of physical activity had higher levels of risk of obesity-related disease. Risk increased with age for both men and women. For men, being married or in a civil partnership was associated with a significantly higher risk when compared to single, separated, divorced or widowed men. For men, frequency of eating as a family was significantly associated with risk but once marital status was included in the model, this effect disappeared, suggesting that the two variables are associated. None of the socio-economic variables significantly predicted higher risk in men, but area-based deprivation (SIMD) was a significant predictor of higher risk in women. As area-level deprivation increased, the odds of women being in a higher category of risk increased. Compared with current smokers, those women who had never smoked and those who were ex-smokers had greater odds of being in a higher risk category. For women, the effect of smoking varied by education level. For women, having a non-limiting long-term illness had increased odds when compared to those with no long-term illness.

2.4.2 Logistic regression for BMI≥30

The factors significantly associated with BMI≥30 in men were age, physical activity, screen time, fruit and vegetable consumption, dietary quality, marital status, smoking and self-assessed general health. The odds of having BMI≥30 generally increased with age, peaking at age 55-64 before dropping for older age groups.
Men with low levels of physical activity had more than twice the odds of having BMI≥30 compared with those who met the physical activity recommendations. Those who had spent more time in front of a screen

also had higher odds. There was a dose-response relationship between physical activity and screen time, so that as activity increased, and sedentary behaviour decreased, the odds of obesity declined.

In line with the results for the WHO combined measure, men who were married or in a civil partnership had the highest odds of having BMI≥30. Men with good or very good self-assessed health had significantly lower odds than those with bad/very bad health. Being a non-smoker significantly increased the odds of obesity, but only among the less educated. (see table E1 in appendix E for full stratum-specific odds ratios). At higher levels of education, smoking had no significant effect.

Somewhat surprisingly, those men who ate 5 or more portions of fruit and vegetables per day had higher odds of having BMI≥30 than those who didn't and there was also an inverse relationship with dietary quality. These results should be interpreted with caution as the association with DQI was not uniform, only quintile 2 produced significantly higher odds than quintile 1.

Among women, the significant factors associated with BMI≥30 were age, physical activity, screen time, dietary quality, area-level deprivation, and self-assessed general health. In line with men, odds increased with age up to the age of 55-64 and low levels of physical activity and higher levels of screen time had higher odds of having BMI≥30.

In contrast to the men's results, increased dietary quality among women significantly reduced the odds of obesity. Also in contrast with men, area-based deprivation remained a significant independent predictor, not discounting any effect of deprivation that might be mediated by poor diet, lack of exercise or screen time. The effect of deprivation reduced when self-assessed general health was added to the model, but there was still a difference between the odds across deprivation quintiles.

The models suggested that the association between dietary quality varied with age and education. A model that took account of this fitted the data better than the one that did not, but there was no consistent pattern in results for dietary quality presented separately by age and education. Therefore for simplicity the final model chosen does not take account of these interactions. The implication however is that the relationship between dietary quality and obesity cannot be summarised in a single measure.

In summary, using either the WHO combined measure or the single cut-off of BMI≥30, increasing age and lower physical activity contributed to increased risk from excess fat in both sexes. For men, being in a partnership increased risk, and for women living in a deprived area increased risk independent of age, diet, and exercise factors. Where screen time and diet were considered, increasing screen time increased risk of BMI-defined obesity in both sexes. Diet quality had opposite effects on men and women. Being a current smoker reduced risk, but there is evidence that the effect was concentrated in those with low education.

Table 2.1 Ordinal regression coefficients for WHO combined level of disease risk (no risk/increased risk/high risk), by socio-demographic risk factors and sex

Aged 16 and over *2008/2009/2010*

Independent variables	Men			Women		
	Base (weighted) **1457**	Co-efficient	95% CI	Base (weighted) **1644**	Co-efficient	95% CI
Age			(p<0.001)			(p<0.001)
16-24	225	0		200	0	
25-34	235	0.51	-0.61,1.17	221	0.64	0.12,1.17
35-44	264	1.33	0.63,2.02	281	0.82	0.34,1.30
45-54	259	1.58	0.89,2.26	275	1.17	0.70,1.64
55-64	224	1.77	1.10,2.44	225	1.55	1.06,2.04
65-74	149	1.60	0.91,2.30	176	1.21	0.69,1.73
75+	99	1.60	0.87,2.32	129	0.67	0.09,1.25
Physical activity level		(p<0.001)				(p<0.001)
High	653	0		501	0	
Medium	412	0.55	0.21,0.82	529	0.57	0.12,0.34
Low	391	0.82	0.51,1.12	479	0.91	0.64,1.18
Marital Status		(p=0.001)			NS	
Married/civil partner	752	0				
Single	524	-0.41	-0.76,-0.07			
Separated	37	-0.75	-1.38,-0.12			
Divorced	92	-0.44	-0.83,-0.05			
Widowed	52	-0.74	-1.29,-0.18			
Scottish Index of Multiple deprivation		NS				(p<0.001)
5th (least deprived)				318	0	
4th				318	0.36	0.06,0.65
3rd				284	0.31	0.01,0.63
2nd				272	0.57	0.24,0.89
1st (most deprived)				314	0.65	0.31,1.00
Smoking [a]		NS				
Current smoker				378	0	
Never smoked				737	0.57	0.06,1.08
Ex occasional smoker				74	-1.56	-4.10,0.98
Ex-regular smoker				319	1.14	0.57,1.71
Long-term illness		NS				
No illness				869	0	
Limiting illness				407	0.18	-0.07,0.43
Non-limiting illness				232	0.39	0.13,0.65
Interactions		No significant interactions		Smoking* education	P=0.03	

[a] The effect of smoking in women varies by education level.

Table 2.2: Estimated odds ratios for BMI≥30, by associated risk factors and sex

Aged 16 and over, BMI >18.5 *2008/2010 combined*

Independent variables	Men			Women		
	Base (weighted)	Odds Ratio	95% CI	Base (weighted)	Odds Ratio	95% CI
	1406			**1730**		
Age		(p=0.001)			(p=0.002)	
16-24	99	0.25	0.09,0.69	137	0.61	0.36,1.04
25-34	197	0.61	0.35,1.07	244	0.63	0.41,0.98
35-44	246	0.97	0.62,1.53	343	1.27	0.89,1.82
45-54	266	1.0	[ref]	348	1.0	[ref]
55-64	265	1.10	0.72,1.72	295	1.39	0.95,2.03
65-74	218	0.66	0.41,1.10	244	1.22	0.83,1.81
75+	115	0.39	0.21,0.74	119	0.74	0.43,1.25
Physical activity level			(p<0.001)			(p<0.001)
High	591	1.0	[REF]	595	1.0	[REF]
Medium	408	1.85	1.31,2.61	605	1.94	1.44,2.61
Low	407	2.14	1.48,3.09	530	2.25	1.61,3.14
Screen time, hours per day		(p=0.02)			(p=0.05)	
<2 hours	397	1.0	[ref]	601	1.0	[ref]
2-4 hours	535	1.38	0.94,2.01	713	1.41	1.05,1.88
4+ hours	474	1.69	1.15,2.51	416	1.39	1.00,1.94
Consumption fruit/vegetables		(p=0.01)			NS	
<5 portions a day	1139	1.0	[ref]			
>5 portions a day	267	1.69	1.13,2.53			
Dietary Quality Index quintile [a]			(p=0.003)			(p=0.07)
1^{st}(lowest)	274	1.0	[ref]	275	1.0	[ref]
2^{nd}	297	2.49	1.57,3.94	317	0.73	0.49,1.09
3^{rd}	294	1.38	0.88,2.16	328	0.60	0.41,0.91
4^{th}	293	1.47	0.93,2.33	431	0.61	0.41,0.91
5^{th}	248	1.51	0.86,2.64	379	0.59	0.39,0.89
Scottish Index of Multiple deprivation		NS				(p=0.05)
5^{th} (least deprived)				303	1.0	[REF]
4^{th}				396	1.26	0.86,1.84
3^{rd}				336	1.44	0.98.2.13
2^{nd}				366	1.46	0.99,2.16
1^{st} (Most deprived)				329	1.60	1.08,2.35

Continued..

Table 2.2—Continued

2008/2010 combined

Independent variables	Men			Women		
	Base (weighted)	Odds Ratio	95% CI	Base (weighted)	Odds Ratio	95% CI
	1406			1730		
Marital Status		(p=0.01)			NS	
Single	382	0.56	0.37,0.85			
Married/civil partner	813	1.0	[ref]			
Separated	46	0.79	0.36,1.72			
Divorced	98	0.49	0.27,0.92			
Widowed	67	1.17	0.59,2.33			
Smoking [b]		(p=0.01)		NS		
Never smoked	578	6.89	3.05,15.56			
Ex occasional smoker	68	2.87	0.45,18.23			
Ex-regular smoker	392	2.86	1.35,6.08			
Current smoker	368	1.0	[ref]			
Self-assessed general health		(p=0.02)			(p<0.001)	
Good/very good	1076	0.61	0.41,0.93	1290	0.50	0.31,0.81
Fair	224	0.91	0.51,1.62	326	0.86	0.52,1.43
Bad/Very bad	106	1.0	[ref]	114	1.0	[ref]
Interactions	Smoking* education	(p=0.02)			No significant interactions	

[a] The effect of dietary quality on BMI-defined obesity in women varies by age and education.
[b] The effect of smoking in men varies by education level.

3. DISCUSSION AND CONCLUSION

The first part of the report investigated which was the most appropriate measure of obesity and overweight available in the SHeS.

For determining prevalence of overweight and obesity, the WHO combined measure was more specific than BMI≥25 and reduced classification bias. Where possible, this measure should be used to identify those at risk from overweight and obesity. However, the measure requires waist measurements, which can be more difficult to collect.

To identify obese individuals various measures (BMI≥30, high WC, high WHR, and combined BMI and WC) were compared for their ability to predict obesity-related health problems. When the predictive ability of each measure was compared using ROC AUC analysis, it was very difficult to tell the measures apart. BMI ≥30 was validated as a good independent predictor of obesity-related health risk. After mutual adjustment to determine the independent effect of BMI, WC and WHR, BMI≥30 was the strongest predictor for nearly all of the outcomes, independent of high WC and high WHR. It is also easier to collect than the other measures and yields larger sample sizes.

However, the measures of abdominal obesity (WC and WHR) should not be discounted, because they also predicted health problems independently of BMI, though the association was weaker. WHR emerged as a particularly strong predictor of high cholesterol, independently of the effects of high WC and high BMI. Therefore, where sample size allows, it is important to take into account abdominal obesity, either using the separate measures (WHR, WC) or by combining it with BMI.

The second part of the report used a cross-sectional sample from the 2008, 2009 & 2010 surveys to explore the factors independently associated with adult obesity in the Scottish population.

In the regression analysis, variables related to energy expenditure (physical activity, sedentary behaviour) were strongly associated with obesity, independent of socio-economic and dietary factors. The association with physical activity had a uniform effect by age, sex, socio-economic and socio-demographic factors. There was a dose-response relationship so that the odds of high BMI and high WC decreased as physical activity increased, even in those that do not meet physical activity recommendations. This confirms previous findings from the SHeS[95]. However, these results do not indicate a causal relationship, and it is possible that obesity leads to lower levels of physical activity.

Studies on the effect of screen time have tended to focus on child, rather than adult obesity. This study was able to explore the association in the Scottish adult population. The results suggest that independent of physical activity, increased screen time is associated with higher odds of BMI-defined obesity in both sexes, but was more strongly associated in men than women (P=0.02 vs. P=0.05). As with physical activity, there was a dose-response relationship in men.

Dietary factors had opposite effects on the odds of BMI-defined obesity in men and women. For women, low dietary quality was significantly associated with BMI≥30, but for men, higher dietary quality and eating at least 5 portions of fruit and vegetables had higher odds of having BMI≥30. As the results for men contradict evidence found elsewhere[68], they should be interpreted with caution. However, the results may be related to the measure itself, since an inconsistent association between DQI and obesity was found in previous analysis on the 2003 survey [83]. A composite index may not be the most appropriate instrument, as it is more difficult to interpret than individual food items. The DQI score is based on dietary recommendations from different organisations with the combined goals to increase consumption of fish, reduce red meat/processed meat, increase fibre-rich and starchy foods, reduce sugary and fatty foods, and increase fruits and vegetables[83]. It is not possible to adjust the DQI for total energy consumption and food groups are not calculated as a proportion of total calorie intake. For 'healthy' foods, there are no upper limits so those achieving the maximum points could be overeating simultaneously. For example, an individual would score the maximum points for starchy foods if they ate bread (any type), potatoes, rice, pasta or breakfast cereal at least 28 times a week (or 4 times a day).

However, there could also be issues with reporting on the DINE questionnaire. When frequency of eating fatty or sugary foods was entered into the model individually, (food types with a suggested link to obesity) there was still no significant association, either unadjusted or adjusted (analysis not shown). It is well established that self-reported dietary consumption is biased, particularly in obese subjects [103].

There are clear gender differences in the relationship between socio-economic status and obesity in Scotland, and further exploration of the causes and mediators of the disparity would be useful. Confirming results both within Scotland and in elsewhere[95,84], female obesity is consistently associated with area-level deprivation, independent of any effect mediated by diet, physical activity, screen time, or health behaviours such as smoking. There is almost certain to be some residual confounding by diet, especially given the limitations outlined above. The association between high income and male BMI-defined obesity found in the 2008 annual report was not replicated here, when using combined data from 2008, 2009 and 2010 combined[95]. This could be due to the relationship attenuating over time or a chance result with the smaller sample. The differences in male obesity by education level disappeared after adjustment for physical activity. In order to better understand the causal pathways and mechanisms for how socio-economic factors influences obesity, a different modelling approach, such as path analysis or structural equation modelling, could be employed. It is also important to try to separate individual effects from area-level effects.

The results confirm the importance of smoking habits for obesity patterns. Male never-smokers and ex-smokers had higher odds of BMI≥30, and the relationship was strongest in men with no qualifications. The difference in obesity prevalence between current and never smokers was large in men with no qualifications (18% vs 55%) but nonexistent in men with higher education (24% vs 23%). This extends recent analysis in Scotland which found that never smoking was associated with obesity in women, regardless of social class[104], to show that while never smoking is an important risk factor for men, it is socially patterned. The finding from previous studies that smoking increases abdominal adiposity[105], especially in women[32] was not replicated here using the high WC measure, but was when cross-tabulated against WHR.

It is important to note that this analysis does not provide evidence on causality and some of the associations seen could be bi-directional, such as physical activity and obesity. Moreover, the multivariable analysis also presents a picture of risk factors operating independently, whereas within Scotland, clustering of risk factors is common [106], which could further increase risk in individuals.

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APPENDIX A: CORRELATIONS BETWEEN MEASURES OF OBESITY IN THE SHES

Correlations

		WHR	WC	BMI	WHTR
WHR	Pearson Correlation	1.000	.780**	.432**	.685**
	Sig. (2-tailed)		.000	.000	.000
	N	7633.829	7634	7634	7634
WC	Pearson Correlation	.780**	1.000	.824**	.923**
	Sig. (2-tailed)	.000		.000	.000
	N	7634	7633.829	7634	7634
BMI	Pearson Correlation	.432**	.824**	1.000	.867**
	Sig. (2-tailed)	.000	.000		.000
	N	7634	7634	7633.829	7634
WHTR	Pearson Correlation	.685**	.923**	.867**	1.000
	Sig. (2-tailed)	.000	.000	.000	
	N	7634	7634	7634	7633.829

**. Correlation is significant at the 0.01 level (2-tailed).

Shared variance is calculated by squaring the Pearson correlation coefficient

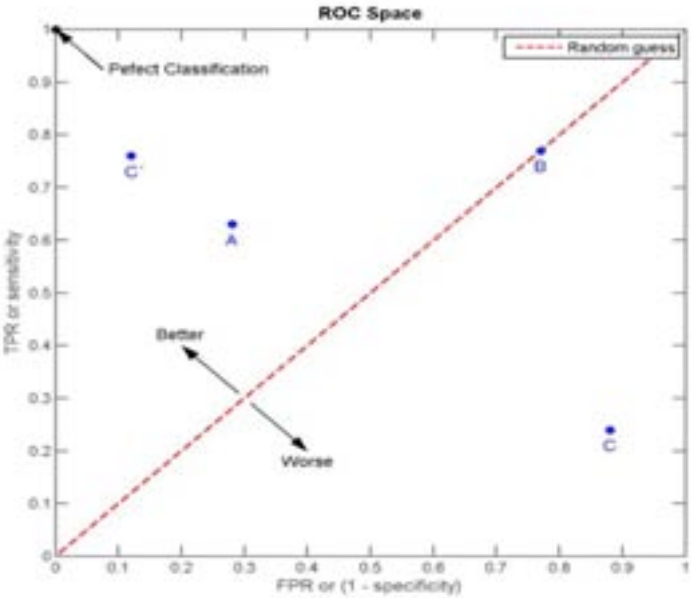
Shared variation-

BMI & WC = 0.824 x 0.824 = 0.678, 68% shared variance
BMI & WHR = 0.432 x 0.432 = 19 % shared variance
WC & WHR = 0.78 x 0.78 = 61% shared variance
BMI & WHTR= 0.685 x 0.685= 47% shared variance
WC & WHTR = 0.923 x 0.923 85% shared variance
WHR & WHTR =0.78 x 0.78 61% shared variance

APPENDIX B: RECEIVER OPERATOR CHARACTERISTIC (ROC) CURVE

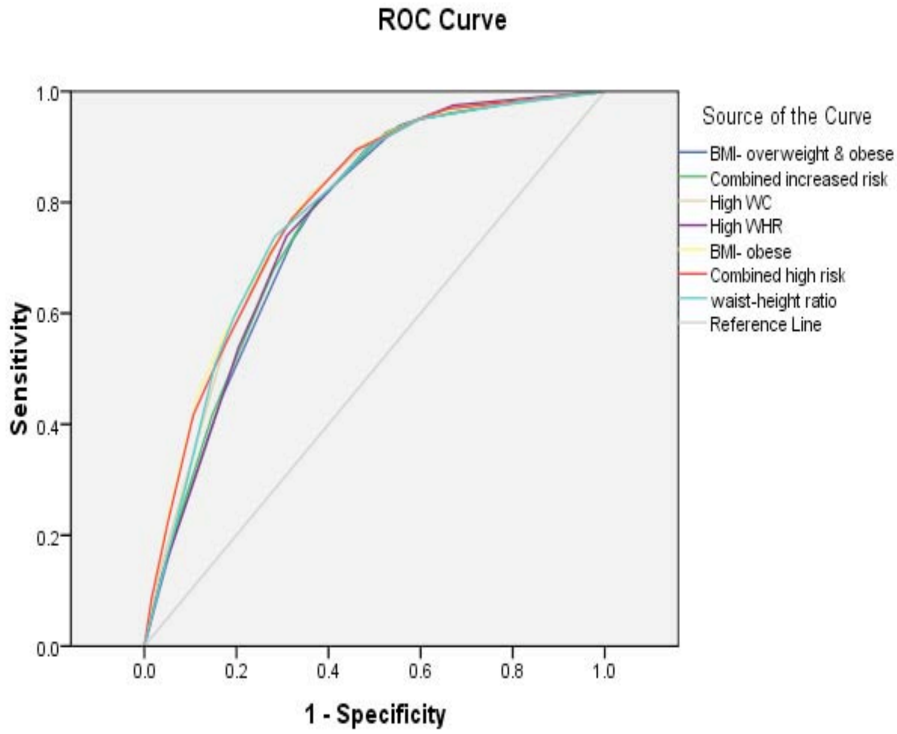
A ROC curve is a graphical plot of the sensitivity for a logistic regression model. It compares the predicted values from the model to the actual values in the data, and plots a curve comparing the true positive rate vs. false positive rate.

<u>Description of how to interpret the ROC space</u>



From a ROC curve, the area under the curve (AUC) can be calculated, also known as the C statistic. This enables comparison between logistic regression models fitted on the same data. C statistics indicate what proportion of the predicted model values match the values in the actual data, and range from 0.5 to 1. A 0.5 value means that the model is no better than a random guess (the red line above), and a value of 1 indicates perfect discrimination. The closer to 1, the better the fit of the model. C statistics have their own standard error and confidence intervals.

For example, the ROC curve for type 2 diabetes in men looked like this:



Diagonal segments are produced by ties.

The curve for every measure is far from the diagonal reference line, suggesting that all are good predictors. However the measures have similar predictive values (and therefore similar curves), with the only slight difference being between the red line (combined high risk) and dark blue line (WHR).

APPENDIX C: FACTORS ASSOCIATED WITH MISSING OBESITY MEASURES

Missing BMI measures

17% of the eligible sample had no valid BMI measure. Of those, 1.0% were pregnant, 8.5% refused, 5.3% measurement not attempted at the interviewer's judgement (due to excessive clothes, etc), and the remainder gave unusable measures. Older people, women, those with lower income, lower education, high area-level deprivation are all more likely to have missing BMI values. Lifestyle and health factors were also significantly associated - lower physical activity, poor self-assessed general health, low mental health, diabetes and hypertension. As many of these variables are associated with obesity, it is likely that the survey underestimates the full extent of obesity in Scotland, and that the associations between risk factors and weight is diluted. The proportion of those aged 75 and over who refused to have these measurements taken was not much higher than the average for all adults, however people aged 75 and over were the most likely to have not been measured due to physical difficulties with standing, which explains the lower response for this age group (data not shown).

Table C1: Factors associated with missing BMI measures

Aged 16 and over *2008,2009,2010*

	% Missing valid BMI measure	Total N for each category	Chi squared P value
Male	18.5	9245	<0.001
Female	14.5	11996	
Lowest income quintile	17.1	3201	<0.001 (linear trend
Highest income quintile	11.9	3777	by quintile P<0.001)
Most deprived quintile	19.8	4150	<0.001 (linear trend
Least deprived quintile	15.5	3778	by quintile P<0.001)
Low physical activity	23.4	7223	<0.001 (linear trend
Medium physical activity	14.5	6486	P<0.001)
High physical activity	12.1	7493	
V poor/poor general health	30.3	1707	<0.001 (linear trend P<0.001)
Fair general health	20.1	3946	
Good/V Good general health	14.4	15775	
Low mental wellbeing	51.1	1574	<0.001
Average mental wellbeing	13.9	17672	
Good mental wellbeing	14.1	1457	
Any diabetes	24.1	1258	<0.001
No diabetes	16.3	19983	
Any hypertension	10.5	1074	P=0.003
No hypertension	7.3	1735	

Missing waist/hip measures

98.2% of those asked gave valid waist measures; 1%) refused, the remainder gave invalid measures. Due to small numbers predictors of missing values were not investigated.

APPENDIX D: PERCENTAGE REDUCTION IN ODDS RATIOS FOR DIFFERENT OBESITY MEASURES

The KHB method (STATA command khb) was used.

This calculates the percentage reduction in the OR (effect) when other measures are added to the model and is an important improvement of previous methods which incorrectly compared odds ratios across similar models.

Table D1: Proportion reduction in effect of obesity measure on health problem, separately for CVD, type 2 diabetes, high cholesterol and hypertension, and by sex

Aged 16 and over with valid height, weight, waist and hip measures *2008/2009/2010*

Main variable	Initial OR and significance level	Age-adjusted, survey weighted models Significance level of main variable *P<0.05 **<0.001 % of main effect remaining after adding following variables			
		+BMI≥30	+ High WC	+ High WHR	+ previous 2 variables
Men, CVD					
BMI≥30	1.29*	-	58%	78%	55%
High WC	1.28*	61%	-	78%	41%
High WHR	1.21*	60%	42%	-	40%
Women, CVD					
BMI≥30	1.31*	-	99%	100%	99%
High WC	1.44*	0%		100%	0%
High WHR	0.95				
Men, T2D					
BMI≥30	2.85**	-	65%*	85%**	64%*
High WC	2.69**	54%*	-	87%**	43%
High WHR	1.95**	48%	38%	-	26%
Women, T2D					
BMI≥30	3.17**	-	63%	81%**	60%*
High WC	3.25**	65%*	-	77%**	44%*
High WHR	2.69**	77%**	65%*	-	42%*

Continued….

Table D1: continued

Main variable	Initial OR and significance level	Age-adjusted, survey weighted models Significance level of main variable *P<0.05 **<0.001 % of main effect remaining after adding following variables			
		+BMI≥30	+ High WC	+ High WHR	+ previous 2 variables
Men, high cholesterol					
BMI≥30	2.00**		42%	59%*	38%
High WC	2.13**	74%**		57%*	33%
High WHR	2.09**	77%**	65%**	-	65%**
Women, high cholesterol					
BMI≥30	1.42**		86%*	69%*	78%*
High WC	1.64**	34%		30%	0%
High WHR	1.76**	86%	93%	-	89%**
Men, hypertension					
BMI≥30	2.43**		47%*	76%**	55%*
High WC	2.38**	62%**		85%**	42%*
High WHR	2.14**	63%**	48%*	-	54%*
Women, hypertension					
BMI≥30	3.52**		82%**	88%**	81%**
High WC	2.67**	41%*		78%**	23%
High WHR	2.17**	62%**	61%**	-	54%**

APPENDIX E: DEVELOPMENT OF ORDINAL LOGISTIC AND LOGISTIC REGRESSION MODELS PREDICTING RISK FROM EXCESS FAT

Selection of variables for models

A combination of forward and backward selection was used. Firstly a basic age-adjusted model was run. Then variables were entered into the models in groups, after which backward selection was used to retain only those variables significant at the 5% level. The next set of variables was then added, backward selection performed again, and so on, until the model contains only significant variables. The combination of forward and backward selection means that it is possible to explore how adding new variables reduces the effect of previously added ones, but also means that the final model didn't contain any redundant information. In order to compare model fit and odds ratios, the models were re-run at every step restricted to participants with data on the variables found to be significant.

The models were adjusted for complex survey design. The variables that were significant in the final models were tested for interactions with one another, and separately with income, education and area-based deprivation.

Variables considered for inclusion in the models

The groups of variables added to the model were as follows:

<u>Group 1: Variables relating to diet, eating or exercise:</u>

- Portions of fruit or vegetables per day (More than 5 /less than 5)
- Dietary quality: DQI score (score 0-100 split into quintiles)
- Frequency of eating together as a family per week (excluding breakfast) (Never /1-2 time/3-4 times/5-6 times/7 times/more often/lives alone)
- Level of physical activity (high (30 minutes or more at least 5 days a week)/medium (30 minutes or more on 1 to 4 days a week) or low (fewer than 30 minutes of activity a week))
- Sedentary behaviour, measured as daily screen time averaged over weekends and weekdays((0-2 hours of TV per day/2-4 hours per day/ 4+ hours of TV). This excludes screen time at work.

<u>Group 2: Socio-economic status:</u>

- National Statistics Socio-economic Classification (NS-SEC) (categorised as: managerial and professional occupations, intermediate occupations, small employers and own account workers, lower supervisory and technical occupations and semi-routine occupations, as well as a category for people for whom the NS-SEC is not applicable, such as full-time students)
- Equivalised income (quintiles)
- Scottish Index of Multiple Deprivation (SIMD)- measures area-based deprivation and is highly spatially sensitive. (quintiles)
- Economic activity (full time education, paid employment/self employed/government training, looking for/intending to look for work,

permanently unable to work, retired, looking after home/family, doing something else)

- Highest educational qualifications attained (HNC/D , degree level or higher, Standard Grade or Higher Grade, other school level, no qualifications)

Group 3: Other demographic/geographic factors

- Ethnicity (white vs. other)
- Marital status (single, married/in civil partnership/living together, separated & divorced, widowed/surviving civil partner)
- Urban/rural residence (Large urban areas/other urban/accessible small towns/remote small towns/accessible rural/remote rural)

Group 4: Lifestyle factors

- Smoking (Never smoked cigarettes at all/Used to smoke cigarettes occasionally/Used to smoke cigarettes regularly/Current cigarette smoker)
- Drinking over the recommended weekly limits- 21 units for men, 14 for women (abstains/up to and including weekly limit/ over weekly limit)
- Drinking over the recommended daily limits- 4 units for men, 3 for women (abstains/up to and including weekly limit/ over weekly limit)
- Binge drinking: drinking twice over the recommended daily drinking limits in the last week- 8 units for men, 6 for women (abstains/did not drink last week/within limits/over limits).

Group 5: Health

- General self-assessed health - participants rated their health in general on a 5 part scale grouped into 3 categories ('very good' or 'good'/ 'fair'/ 'bad' or 'very bad').
- Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS): indicator of mental wellbeing, which comprises 14 positively worded statements with a five item scale ranging from '1 - None of the time' to '5 - All of the time'. The scores therefore range from 14 to 70. A participant was classified as having a low WEMWBS score if it was more than one standard deviation below the mean.
- General Health Questionnaire (GHQ-12): The General Health Questionnaire (GHQ-12) is a widely used standard measure of mental distress and psychological ill-health, consisting of 12 questions on concentration abilities, sleeping patterns, self-esteem, stress, despair, depression, and confidence in the previous few weeks. As the GHQ-12 measures deviations from people's usual functioning it cannot be used to detect chronic conditions. Responses to the GHQ-12 items were scored, resulting in an overall score between zero and twelve. A score of four or more indicates the presence of a possible psychiatric disorder.
- Long-standing illness (long term limiting illness/long-term non-limiting illness/no illness)

Tests for multicollinearity

Before running any model, all the independent variables were entered into a linear regression model to check for multicollinearity. The collinearity statistics did not indicate any particular problems, as all tolerance values were >0.1 and all variance inflation factors (VIFs) were less than 10. The alcohol variables were most strongly correlated- for BMI in men, the binge drinking variable had a VIF of 7.47- but this was still within acceptable limits.

Interaction effects- smoking and education in men, BMI≥30

Table E1: Stratum specific odds ratios for BMI≥30, men, according to smoking and education level†

Aged 16 and over, valid weight and height measures *2008/2010*

	Education level			
Smoking status	Degree/HND/HNC	Standard or higher grade	Other	No qualifications
Never smoked	1.00	2.36	1.17	**6.89***
Ex-occasional	0.92	2.84	5.31	2.87
Ex-regular	0.94	2.57	0.71	**2.87***
Smoker	1.00 [ref}	1.00 [ref}	1.00 [ref}	1.00 [ref}

*Significantly different from 1.0, P<0.05

† adjusted for age, physical activity, screen time, consumption fruit/vegetables, dietary quality, marital status and general health

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Scottish Health Survey (Print) ISSN 2042-1605
Scottish Health Survey (Online) ISSN 2042-1613

The Scottish Government

ISBN: 978-1-78045-471-9 (web only)
ISSN: 2042-1613

APS Group Scotland
DPPAS12134 (10/11)

ISBN 978-1-78045-471-9