Household Wealth and the Metabolic Syndrome in the Whitehall II Study

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OBJECTIVE — The metabolic syndrome is more common in socially disadvantaged groups. Inequalities in household wealth are currently widening and may contribute to the increasing prevalence of the metabolic syndrome.

RESEARCH DESIGN AND METHODS — This was a cross-sectional analysis of 1,509 women and 4,090 men (aged 45.2–68.9 years) of an occupational cohort study of 20 civil service departments located in London, U.K. Components of the metabolic syndrome were measured in 1997–1999 and defined using a modified World Health Organization definition.

RESULTS — Own income, household income, and wealth were each strongly and inversely associated with the metabolic syndrome in both sexes ($P_{trend} < 0.001$). Within each group of household wealth, the prevalence of the metabolic syndrome was higher in men than in women. Sex differences became smaller with decreasing household wealth, with the prevalence of the metabolic syndrome rising from 12.0 and 5.7% in the wealthiest men and women, respectively, to corresponding values of 23.6 and 20.1% in the poorest group. The odds ratio (95% CI) associated with each decrease of one category in household wealth was 1.25 (1.03–1.50) in men and 1.69 (1.18–2.41) in women, adjusting for age, household members, occupational grade, education, father's social class, personal and household income, ethnic group, smoking, alcohol intake, diet, and physical activity.

CONCLUSIONS — Household wealth, a measure of assets accumulated over decades and generations, is strongly and inversely associated with the metabolic syndrome. Future research should explore the potential mechanisms by which wealth inequalities are associated with the metabolic syndrome.

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The prevalence of the metabolic syndrome has risen rapidly in parallel with the global obesity epidemic (1,2) and now affects up to a quarter of men and women in the U.S. and Europe (2,3). Prospective studies using agreed upon (4,5), although differing, diagnostic criteria have shown that the rate of fatal and nonfatal cardiovascular events is greatly elevated in individuals with the metabolic syndrome (6–9). Although the definition and prognostic value of the metabolic syndrome are still a matter of debate (10), its high prevalence and associated morbidity and mortality make it an increasingly important public health problem. The prevalence of the metabolic syndrome, like that of diabetes, is higher in socially disadvantaged groups (11–16) and is of particular interest as it may provide clues about influences on the social gradient in cardiovascular and other common chronic diseases (17). Conventionally, education, occupation, and, to a lesser extent, income (18) have been studied, yet economists clearly distinguish between income and wealth, a distinction not commonly made in the health field. Inequalities in income and wealth are high in Britain and the U.S. (19), and inequalities in wealth have continued to increase. Wealth reflects the accumulation of personal and intergenerational assets over time and is more unequally distributed among the population (20,21). It provides information about population differences in past and long-term financial security and may thus be a better summary measure of potentially modifiable factors, such as excess caloric intake, poor nutrition, cardiorespiratory fitness, or psychosocial stress that influence obesity, low-grade inflammation and metabolic disturbances, compared with income alone or other indicators of social disadvantage. On the background of increasing prevalences in obesity, the metabolic syndrome, and widening inequalities in wealth, it is important to understand which factors underlie socioeconomic differences in this common disorder and the current demographic trend.

In the present study we investigated *1*) whether the prevalence of metabolic syndrome and its components differs according to household wealth and *2*) to what extent behavioral, economic, social, and educational differences contribute to this association in men and women of the Whitehall II study.

RESEARCH DESIGN AND METHODS

The target population for the Whitehall II study was all London-based office staff, aged 35–55 years, working in 20 civil service departments. The cohort consisted of 10,308 participants (6,895 men and 3,413 women) at the first phase in 1985 (22). A total of 6,552 participants completed the phase 5 screening examination (1997–1999) and of these 5,599 (4,090 men and 1,509 women aged 45.2–68.9 years) had information on each component of the metabolic syndrome as well as household wealth. Participants were predominantly white European (91.5%), 2.8% were Afro-Caribbean, 4.3% South Asian, and 1.4% reported other ethnic origins. Each

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Abbreviations: HOMA, homeostasis model assessment; WHO, World Health Organization.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.
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phase of the Whitehall II study has received ethical approval from the research ethics committee of University College London Hospitals.

Measurements

Metabolic syndrome. The metabolic syndrome and its components were defined using a modified World Health Organization (WHO) definition (Appendix) (4), which includes the presence of diabetes, impaired glucose tolerance, and impaired fasting glucose or insulin resistance, plus at least two of the following: obesity, dyslipidemia, or hypertension. This definition varies from standard WHO recommendations in two ways: first, insulin resistance was defined using the homeostasis model assessment (HOMA) score instead of the euglycemic clamp technique; and second, the criterion of microalbuminuria was omitted because of a lack of urine samples. Our study is in line with the European Group for the Study of Insulin Resistance, whose modified definition of the metabolic syndrome also does not include microalbuminuria and with other studies using HOMA scores to assess insulin resistance (3,9,15).

At the phase 5 screening examination, height, weight, waist and hip circumferences, blood pressure, and glucose and lipid levels were measured, as described previously (12,23,24). Whole body insulin resistance in the fasting state was assessed using the HOMA for insulin resistance (25).

Socioeconomic indicators and health-related behavior. Information on demographic, socioeconomic, and behavioral variables was obtained from the self-completed questionnaires administered at phase 1 (childhood social class and adult employment grade) or phase 5 (all other variables). Childhood social class was based on father's occupation and grouped according to the Registrar General's Classification; the original six categories were collapsed into four (12). Education level was based on the highest educational qualification achieved and classified into four groups: higher education, advanced secondary qualifications, ordinary secondary qualifications, or no academic qualification. On the basis of salary and work role, the civil service defines a hierarchy of employment grades, and participants were assigned to one of three levels: unified grades 1–7 (high employment grades), executive officers (middle grades), and clerical and support staff (lower grades) (26).

Smoking status distinguished never-smokers from previous and current smokers. Alcohol intake was based on consumption during the week before the interview and was grouped into five categories based on sensible drinking recommendations (27). Physical activity distinguished participants with no vigorous physical activity, those with <1.5 and ≥1.5 h of vigorous physical activity per week (28). A healthy diet indicator (scored 0–3) was constructed as previously reported (29).

Income and wealth. All financial indicators were derived from phase 5 questionnaires. Precoded categories were collapsed to form four groups in descending order. Annual personal income included the "amount received annually from salary or wages, pensions, benefits, and allowances before deduction of tax"; categories were ≥£50,000, £25,000–49,999, £15,000–24,999, and <£15,000. Annual household income included the "total annual household income from any source, including personal income"; categories were ≥£60,000, £40,000–59,999, £20,000–39,999, and <£20,000. Household wealth included the "amount of money the respondent would have if s/he cashed in all household assets and paid off all debts"; categories were ≥£500,000, £100,000–499,999, £40,000–99,999, and <£40,000.

Statistical analysis

Prevalences or mean levels of metabolic syndrome components and socioeconomic characteristics were estimated for each household wealth category, and tests for linear trend were carried out. Logistic regression was then used to calculate age-adjusted odds ratios (ORs) and 95% CIs for the metabolic syndrome across all socioeconomic indicators, separately for men and women, using the most advantaged groups as reference categories and testing for linear trend. Adjusted analyses were performed in several steps: adjusting for age or age and number of household members; additionally including behavioral and demographic factors; and also adding all other socioeconomic variables first separately and then jointly to the model. Analyses were performed using STATA 8.0 (release 8.0, 2003; StatCorp, College Station, TX).

RESULTS — Participants with greater wealth were significantly more likely to be married or cohabiting, have greater personal and household income, have higher education, employment grade, and father's social class, and have a greater number of household members (Table 1). Likewise, insulin resistance, obesity, dyslipidemia, and the metabolic syndrome were all linearly and significantly associated with household wealth in both men and women ($P_{trend} < 0.002$ in each case) (Table 1) and with lowest prevalences in the wealthiest group (Table 1). A significant trend for diabetes was shown in men, but not in women, whereas the reverse was true for hypertension. Impaired glucose tolerance and fasting glucose did not differ significantly by household wealth in men or women and by use of binary or continuous glucose measures. Within each group of household wealth, the prevalence of having the metabolic syndrome was higher in men than in women (Table 1). This difference became smaller with decreasing household wealth; prevalence rose from 12.0 and 5.7% in the wealthiest men and women, respectively, to corresponding values of 23.6 and 20.1% in the poorest group.

In logistic regression analysis, the odds of having the metabolic syndrome increased linearly across groups of decreasing household wealth for both sexes, after adjustment for age and number of household members (Table 2). Compared with the wealthiest group, men and women in the lowest category of household wealth had ORs (95% CI) of 2.26 (1.43–3.57) and 4.12 (1.57–10.8), respectively, for having the metabolic syndrome (P value for trend across groups < 0.001 in both cases). Likewise, men and women with the lowest personal income were more likely (OR [95% CI]) to have the metabolic syndrome (1.41 [1.05–1.90] in men and 1.70 [0.71–4.07] in women), compared with the most privileged group, as were those with the lowest household income (1.54 [1.11–2.14] in men and 3.43 [1.54–7.62] in women), those in the lowest employment grades (1.64 [1.20–2.24] in men and 1.91 [1.17–3.12] in women), and women from the most disadvantaged childhood social classes (1.71 [0.97–3.00]), with $P_{trend} \leq 0.02$ in all cases (Table 2). No significant differences were observed for childhood social class in men or educational group in either sex.

The association between household wealth and the metabolic syndrome was

Table 1—*Metabolic syndrome components and socioeconomic characteristics across groups of household wealth, adjusted for age and number of household members*

		Household wealth category				
	n	≥£500,000 (~$900,000)	£100,000–499,999	£40,000–99,999	<£40,000 (~$72,000)	*P**
Men (*n*)	4,090	252	2,833	671	334	
Diabetes (%)	4,089	2.6	4.5	7.1	10.3	<0.001
Impaired glucose tolerance (%)	3,415	13.6	12.5	11.4	14.2	0.795
Impaired fasting glucose (%)	3,415	2.3	3.6	4.0	2.6	0.983
Insulin resistance (%)	3,792	19.7	21.8	25.8	29.4	0.001
Obesity (%)	3,556	55.6	58.6	65.5	69.7	<0.001
Dyslipidemia (%)	4,089	27.4	31.5	34.7	38.5	0.002
Hypertension (%)	4,090	23.0	28.2	32.8	28.2	0.106
Metabolic syndrome (%)	4,090	12.0	15.0	18.3	23.6	<0.001
Fasting glucose (mmol/l)†	3,836	5.13	5.09	5.08	5.06	0.145
Postchallenge glucose (mmol/l)†	3,426	5.75	5.73	5.66	5.64	0.877
HOMA score†	3,792	1.59	1.65	1.72	1.81	0.006
Higher education (%)	3,941	73.0	42.3	25.8	28.9	<0.001
Personal income ≥£25,000 (%)	4,079	75.3	55.1	35.8	32.6	<0.001
Personal income <£15,000 (%)	4,079	3.1	17.3	27.8	32.9	<0.001
Household income ≥£60,000 (%)	3,554	40.1	18.1	4.4	3.8	<0.001
Household income <£20,000 (%)	3,554	2.0	14.2	26.9	35.0	<0.001
Administrative grade (%)	4,090	76.9	47.6	16.9	14.4	<0.001
Father's social class I/II (%)	2,838	82.9	67.9	70.0	64.3	0.048
Married/cohabiting	4,080	87.6	84.6	75.5	72.0	<0.001
Partner in paid work	2,507	74.3	71.3	68.7	68.9	0.213
No. of household members	4,090	2.54	2.43	2.12	1.94	<0.001
Women (*n*)	1,509	85	787	385	252	
Diabetes (%)	1,509	5.3	4.8	7.9	6.3	0.109
Impaired glucose tolerance (%)	1,255	10.1	13.8	14.4	15.3	0.409
Impaired fasting glucose (%)	1,255	2.5	1.2	1.4	2.5	0.841
Insulin resistance (%)	1,380	17.7	18.1	24.3	30.8	<0.001
Obesity (%)	1,355	17.7	30.0	37.1	46.5	<0.001
Dyslipidemia (%)	1,509	12.9	15.3	21.8	23.9	0.001
Hypertension (%)	1,509	21.3	24.8	27.7	39.3	<0.001
Metabolic syndrome (%)	1,509	5.7	9.0	14.4	20.1	<0.001
Fasting glucose (mmol/l)†	1,390	4.89	4.88	4.92	4.93	0.194
Postchallenge glucose (mmol/l)†	1,258	5.94	5.92	5.93	6.10	0.358
HOMA score†	1,380	1.35	1.41	1.58	1.70	<0.001
Higher education (%)	1,393	68.1	35.0	17.3	15.2	<0.001
Personal income ≥£25,000 (%)	1,498	50.7	30.9	11.9	7.2	<0.001
Personal income <£15,000 (%)	1,498	30.4	39.3	54.7	57.1	<0.001
Household income ≥£60,000 (%)	1,333	57.3	13.9	3.2	2.1	<0.001
Household income <£20,000 (%)	1,333	7.4	25.5	51.6	64.6	<0.001
Administrative grade (%)	1,509	71.0	22.1	2.3	0.8	<0.001
Father's social class I/II (%)	988	85.7	69.7	60.6	53.8	<0.001
Married/cohabiting	1,505	67.6	63.2	50.6	46.7	<0.001
Partner in paid work	645	90.5	93.8	89.7	89.3	0.560
No. of household members	1,509	2.15	1.58	1.29	1.32	<0.001

*χ^2 tests for trend. †Geometric mean in participants without diabetes; P_{trend} based on log-transformed normalized variables.

attenuated little after adjustment for behavioral and demographic factors and only slightly more after considering all other socioeconomic factors either separately or combined (Table 3). In fully adjusted models, the odds of having the metabolic syndrome were 25% greater ($P = 0.02$) in men and 69% greater ($P = 0.004$) in women for each decrease in category of household wealth (P value for sex interaction = 0.08), adjusting for occupational grade, education, father's social class, personal and household income, ethnic group, smoking status, alcohol intake, diet, and physical activity (Table 3).

CONCLUSIONS— In this study, household wealth was strongly and inversely associated with the prevalence of the metabolic syndrome in both men and women. This association remained strong after adjustment for several other socioeconomic indicators over the life course, including personal and household in-

Table 2—*Age-adjusted ORs for the metabolic syndrome across the categories of income, wealth, and other socioeconomic indicators*

	n (men/ women)	OR (95% CI)	
		Men	Women
Household wealth*	(4,090/1,509)		
≥£500,000		Reference	Reference
£100,000–499,999		1.27 (0.87–2.26)	1.59 (0.62–4.09)
£40,000–99,999		1.61 (1.06–2.47)	2.71 (1.04–7.07)
<£40,000		2.26 (1.43–3.57)	4.12 (1.57–10.8)
P trend		<0.001	<0.001
Household income*	(3,588/1,373)		
≥£60,000		Reference	Reference
£40,000–59,999		1.16 (0.87–1.56)	2.41 (1.04–5.60)
£20,000–39,999		1.16 (0.87–1.53)	2.51 (1.15–5.49)
<£20,000		1.54 (1.11–2.14)	3.43 (1.54–7.62)
P trend		0.02	0.003
Personal income	(4,580/1,859)		
≥£50,000		Reference	Reference
£25,000–49,999		0.83 (0.63–1.09)	0.89 (0.35–2.29)
£15,000–24,999		1.01 (0.78–1.42)	1.30 (0.54–3.12)
<£15,000		1.41 (1.05–1.90)	1.70 (0.71–4.07)
P trend		<0.001	0.009
Adult grade	(4,643/1,905)		
Administrative		Reference	Reference
Professional/executive		1.32 (1.11–1.56)	1.56 (0.95–2.57)
Clerical/office support		1.64 (1.20–2.24)	1.91 (1.17–3.12)
P trend		<0.001	0.009
Education	(4,385/1675)		
Higher education		Reference	Reference
Advanced secondary		1.11 (0.92–1.36)	0.96 (0.59–1.57)
Ordinary secondary		1.05 (0.85–1.30)	1.47 (0.97–2.22)
No academic qualifications		1.09 (0.76–1.56)	1.26 (0.80–2.00)
P trend		0.5	0.1
Father's social class	(3,211/1,233)		
I and II		Reference	Reference
III nonmanual		1.09 (0.82–1.44)	0.88 (0.45–1.73)
III manual		1.27 (1.02–1.60)	1.46 (0.95–2.24)
IV and V		1.13 (0.81–1.60)	1.71 (0.97–3.00)
P trend		0.08	0.02

*Adjusted for age and number of household members.

come, ethnic group, marital status, smoking, alcohol intake, diet, and physical activity. Although insulin resistance, obesity, and dyslipidemia followed the same pattern, a significant and linear trend for diabetes was shown in men only, and impaired glucose tolerance and fasting glucose were not significantly associated with wealth in either sex. The lack of associations with glucose measures in the context of significant differences in HOMA-insulin resistance, a combination of glucose and insulin, suggests that factors associated with wealth affect glucose metabolism largely through their influence on insulin sensitivity and levels. The greater levels of obesity of less wealthy men and women are likely to have contributed to the development of insulin resistance and dyslipidemia in this group, and prevention and management of this most commonly observed modifiable risk factor is paramount for reducing inequalities in metabolic risk.

The prevalence of the metabolic syndrome also differed significantly by household and personal income and adult employment grade in both sexes and by father's social class in women; however, these associations were attenuated and did not remain statistically significant in multivariate analyses. Social inequalities in the metabolic syndrome have been shown in several studies using different indicators of socioeconomic position across the life course, including childhood and adult social position and education (12–16,30). In contrast, we are aware of only one study reporting that limited household income is associated with a greater risk of the metabolic syndrome in a sex-specific manner (18), and in no previous study has the role of wealth in socioeconomic differences in metabolic risk been considered. Socioeconomic indicators such as education, income, and occupation are limited in their ability to capture the complex forces that dominate social structure (31). Although income and wealth are related, their distributions and definitions differ (21), and household wealth was only weakly correlated with personal or household income in this study (correlation coefficients 0.25 and 0.34, respectively). Whereas this may partly reflect measurement error of wealth, associations between wealth and the metabolic syndrome remained strong after adjustment for other factors measured with greater precision. Inequalities in wealth are greater than those of income and have continued to widen (20). Household wealth includes not only income and savings but also all marketable assets and thus captures the accumulation of personal and intergenerational capital and assets from all household members over time. Continuing material security associated with wealth may benefit health through a sense of protection, autonomy, and prestige, and this may also contribute to the established link between material assets such as car or house ownership and health (32). The stronger associations between wealth and the metabolic syndrome suggest that wealth may be a better, or more comprehensive, indicator of actual socioeconomic situation and associated long-term material and psychological security, living conditions, and life choices affecting health, compared with other socioeconomic measures considered in this study. Corresponding with one earlier report of sex differences in the association between household income and the metabolic syndrome (18), we found some evidence for the influence of household wealth being stronger in women, compared with men. Despite significant sex differences in the distribution of all socioeconomic variables, with higher proportions of women in the more disadvantaged groups (all P values $<$ 0.001, data not shown), behavioral and socioeconomic factors accounted for only some of this difference in fully adjusted models. Future studies exploring why women may be more susceptible to the

Table 3—*ORs for the metabolic syndrome associated with each decrease in one category of household wealth, before and after adjustments*

Household wealth	OR (95% CI)*	
	Men	Women
Age-adjusted model	1.32 (1.11–1.56)	1.81 (1.35–2.43)
Model 1: age + number of household members	1.32 (1.11–1.56)	1.89 (1.40–2.54)
Model 2: model 1 + behavioral and demographic factors†	1.29 (1.08–1.54)	1.67 (1.21–2.29)
Model 2 + household income	1.25 (1.04–1.50)	1.57 (1.12–2.21)
Model 2 + personal income	1.25 (1.05–1.50)	1.67 (1.21–2.32)
Model 2 + occupational grade	1.26 (1.05–1.52)	1.84 (1.30–2.60)
Model 2 + education	1.29 (1.08–1.54)	1.66 (1.19–2.32)
Model 2 + father's social class	1.28 (1.07–1.51)	1.54 (1.11–2.15)
Fully adjusted model‡	1.25 (1.04–1.51)	1.63 (1.14–2.35)

*Includes 2,188 men and 714 women with complete information on all covariates. †Behavioral and demographic factors include smoking, alcohol intake, diet, physical activity, marital status, and ethnic group. ‡Includes household wealth, age, number of household members, behavioral and demographic factors, household and personal income, occupational grade, education, and father's social class.

influence of economic disadvantage than men could help to identify the underlying mechanisms through which unequal access to economic resources influences metabolic and ultimately cardiovascular risk.

To our knowledge, this is the first study to report on the association between the distribution of wealth and the metabolic syndrome. However, some limitations should be noted. All subjects are participants of the Whitehall II study, a large prospective occupational cohort of London civil servants, the majority of whom are white, nonmanual British office workers; our results may therefore not apply to other ethnic groups, manual social classes, the unemployed, or nonworking populations or other countries or parts of the world.

Different diagnostic criteria have been published for the definition of the metabolic syndrome (4,5), and its prevalence is difficult to compare because of differences in the definition used and population characteristics (33). In this study, the metabolic syndrome was based on the definition published by the WHO for epidemiological studies. Using the same definition, prevalences in European populations varied from 7 to 39% in men and from 5 to 24% in women (34). A greater prevalence in men of both the metabolic syndrome and obesity, compared with that in women, has been also reported in other studies using the standard WHO definition (35). The choice of diagnostic criteria may influence the association between wealth and the metabolic syndrome, and it is therefore reassuring that consistent associations were observed with several of its components.

All socioeconomic measures are based on participants' self-report, which for father's social class involved recall over a long period. Greater measurement error may lead to an underestimation of the relative influence of father's social class, compared with socioeconomic indicators measured contemporaneously, if recall is nondifferential with regard to metabolic syndrome status. Baseline employment grade was chosen instead of grade at phase 5 for the following reasons: *1*) because the number of participants with available information would be maximized; *2*) because reverse causality, in which baseline morbidity may simultaneously affect later employment grade through restriction of social mobility as well as development of the metabolic syndrome, would be minimized; and *3*) because grade at phase 5 reflects mobility for those who remained in the civil service but cuts short the trajectories of those who left the civil service to take up employment elsewhere. The relatively stronger association between household income and the metabolic syndrome in women indicates that adult employment grade may be a poorer marker of adult social position for women in the Whitehall II study than it is for men. However, our findings remained unchanged when partner's social class instead of women's own employment grade was used (data not shown). Wealth may be influenced by preexisting ill health; however, household wealth in this cohort has been shown to be the financial indicator less influenced by preexisting illness (36).

In summary, greater household wealth, a measure of assets accumulated over decades and generations, is associated with a decreased prevalence of the metabolic syndrome in both men and women in this occupational cohort of civil servants. This association is independent of several socioeconomic indicators, including personal and household income. Although, on average, people with lower household wealth exhibited more adverse health behaviors, such as smoking, unhealthy diet, and physical inactivity (data not shown), adjustment for those factors did not fully explain the observed association. A recent study from this cohort has shown that stress at work is an important risk factor for the metabolic syndrome (37). Future research exploring the potential biological and psychosocial mechanisms by which inequalities in wealth are associated with the metabolic syndrome may assist in the development of interventions aimed at reducing the burden of this highly prevalent disorder in socially and economically disadvantaged groups.

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P.P. and C.L. developed the study aim and design, wrote the initial draft and incorporated comments from all coauthors. P.P. undertook the analysis and is guarantor. All authors contributed to interpreting the results and writing the final version.

APPENDIX

For the modified WHO definition of the metabolic syndrome, one of the following must be present:

- Diabetes: fasting glucose ≥7 mmol/l (126 mg/dl) or postload glucose ≥11.1 mmol/l (200 mg/dl) or use of antidiabetic medication (oral or insulin)
- Impaired glucose tolerance: fasting glucose <7 mmol/l and postload glucose ≥7.8 mmol/l (140 mg/dl) and <11.1 mmol/l
- Impaired fasting glucose: fasting glucose ≥6.1 mmol/l (110 mg/dl) and <7 mmol/l and postload glucose <7.8 mmol/l
- Insulin resistance: HOMA score in the top sex-specific quartile (cutoff in men 0.926278 and cutoff in women 0.8481044), excluding participants with diabetes.

plus any two of the following:

- Obesity: waist-to-hip ratio >0.9 in men and >0.85 in women and/or BMI >30 kg/m^2
- Dyslipidemia: triglycerides ≥1.7 mmol/l (150 mg/dl) and/or HDL cholesterol <0.9 mmol/l in men (35 mg/dl) or <1.0 mmol/l (39 mg/dl) in women or use of lipid-lowering medication
- Hypertension: blood pressure ≥140/90 mmHg or use of antihypertensive medication.

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