Prevalence of the Metabolic Syndrome and Its Components

Findings from a Finnish general population sample and the Diabetes Prevention Study cohort

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OBJECTIVE — To assess the prevalence of the metabolic syndrome (MetS) in two independent Finnish study cohorts.

RESEARCH DESIGN AND METHODS — The prevalence of the MetS by modified World Health Organization criteria was analyzed in different categories of glucose tolerance in a cross-sectional, population-based sample of 2,049 individuals (FINRISK) aged 45–64 years and in 522 participants of the Finnish Diabetes Prevention Study (DPS) with impaired glucose tolerance (IGT).

RESULTS — In the FINRISK cohort, the MetS was present in 38.8% of the men and 22.2% of the women. The prevalence was 14.4 and 10.1% in subjects with normal glucose tolerance, 74.0 and 52.2% in subjects with impaired fasting glucose, 84.8 and 65.4% in subjects with IGT, and 91.5 and 82.7% in subjects with type 2 diabetes in men and women, respectively. Among women, the prevalence of the MetS increased with increasing age. In the DPS cohort, the MetS was present in 78.4% of the men and 72.2% of the women with IGT.

CONCLUSIONS — The MetS was extremely common in middle-aged subjects The high prevalence in men was mostly due to their high waist-to-hip ratio. The prevalence of the MetS increased in both sexes with deterioration in glucose regulation. Approximately 75% of the subjects with IGT had the MetS. Because the syndrome includes the major risk factors for atherosclerotic vascular diseases and is the major antecedent for type 2 diabetes, concerted preventive action should be targeted to control all the features of the MetS.

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The prevalence of type 2 diabetes is rapidly increasing worldwide (1,2), primarily due to the global increase in obesity and sedentary lifestyles (3). Subjects with impaired glucose tolerance (IGT) are at increased risk of developing type 2 diabetes and form an important high-risk group for actions aimed at preventing the disease (4–7).

Subjects with abnormal glucose metabolism are at increased risk for cardiovascular disorders and often exhibit various cardiovascular risk factors (8). The clustering of cardiovascular risk factors has been called the metabolic syndrome (MetS). Currently there are four definitions: the criteria of the World Health Organization (WHO) consultation group (9), the criteria of the European Group for the Study of Insulin Resistance (EGIR) (10), the criteria of the National Cholesterol Education Program (NCEP) Expert Panel (11), and the criteria of the American Association of Clinical Endocrinologists (12).

Type 2 diabetes and IGT are closely associated with the MetS (13). Clustering of the risk factors associated with this syndrome predicts the development of manifest diabetes and cardiovascular disease (14–20) Prevention of type 2 diabetes should therefore aim to prevent and treat several components of the MetS simultaneously.

The aim of this study was to assess the prevalence and clustering of components of the MetS using the WHO criteria in two independent middle-aged Finnish study cohorts: the population-based FINRISK study cohort and the participants of the Finnish Diabetes Prevention Study (DPS).

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Abbreviations: DPS, Diabetes Prevention Study; EGIR, European Group for the Study of Insulin Resistance; FPG, fasting plasma glucose concentration; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; MetS, metabolic syndrome; NGT, normal glucose tolerance; OGTT, oral glucose tolerance test; WHO, World Health Organization; WHR, waist-to-hip-ratio.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

RESEARCH DESIGN AND METHODS

— The FINRISK survey took place in spring 1992 as part of the FINMONICA cardiovascular risk factor survey. The survey methods followed the WHO MONICA protocol (21) and are detailed elsewhere (22,23). In brief, a cross-sectional stratified random sample of 8,000 subjects aged 25–64 years from four regions of Finland was drawn from the national population register. A subsample of 3,300 individuals aged 45–64 years was formed to assess glucose metabolism; 3,201 of these subjects completed a postal questionnaire on medical history and made their first study visit. Clinical and metabolic characteristics related to blood pressure and dyslipidemia were analyzed in the present study. A total of 2,087 attended a second visit for a standard 75-g oral glucose tolerance test (OGTT) (24). Glucose status could be classified in 2,061 subjects, based on current use of diabetes medication ($n = 71$), fasting plasma glucose (FPG) value ($n = 88$), or OGTT value ($n = 1902$). After excluding type 1 diabetic patients ($n = 12$) from the assessment, 2,049 subjects were included in the further analysis of glucose tolerance and components of the MetS, representing 62% of the original 3,300 subjects.

The DPS was a randomized prospective controlled trial to assess the possibility of preventing type 2 diabetes by lifestyle intervention (25,26). The design of the DPS is described in detail elsewhere (27). Briefly, 522 overweight subjects (BMI ≥25 kg/m^2) aged 40–65 years and with IGT participated. The definition of IGT was based on the mean of two consecutive 2-h glucose values in OGTT (24). The Ethics Committee of Finland's National Public Health Institute approved the study protocol. All subjects gave written informed consent.

Both studies involved similar investigations, including a self-administered questionnaire, medical history, physical examination, and laboratory examinations. Those taking medication during the past week were recorded as being on medication. Blood pressure was measured from the right arm of the subject seated for 5 min before measurement. Systolic and diastolic blood pressure values were recorded as the mean of two measurements.

In FINNRISK, fasting and 2-h blood samples for plasma glucose were measured at the local laboratory by a hexokinase method. In the DPS, the plasma glucose concentrations during the OGTT were determined locally and confirmed at a central laboratory in Helsinki. All other blood samples in both studies were analyzed in the same central laboratory (National Public Health Institute, Helsinki). Cholesterol and triglyceride levels were determined by enzymatic assays (Boehringer Mannheim, Mannheim, Germany). HDL cholesterol was measured after dextran sulfate magnesium chloride precipitation of apo B–containing lipoproteins. Serum insulin was measured by a radioimmunoassay method (Pharmacia, Uppsala, Sweden). The intra-assay coefficient of variation (CV) for serum insulin was 5.3%, and the interassay CV was 7.6%.

Definitions of the MetS and its components

For the definition of the MetS, we used the WHO criteria (9) modified as follows: insulin resistance was defined by the top quartile distribution of fasting insulin among subjects without diabetes (10). Top quartile cutoff points were 9.42 and 9.80 mU/l for men and 8.20 and 9.75 mU/l for women in age-groups of 45–54 and 55–64 years, respectively. Different categories of glucose tolerance were calculated applying the WHO 1999 criteria (9) in venous plasma samples as follows: normal glucose tolerance (NGT): FPG <6.1 mmol/l and 2-h plasma glucose <7.8 mmol/l; impaired fasting glycemia (IFG): FPG 6.1–6.9 mmol/l and 2-h plasma glucose <7.8 mmol/l; impaired glucose tolerance (IGT): FPG <7.0 mmol/l and 2-h plasma glucose 7.8–11.0 mmol/l; diabetes: FPG ≥7.0 mmol/l or 2-h PG ≥11.1 mmol/l, or current use of diabetes medication. Subjects were considered to have obesity if waist-to-hip-ratio (WHR) was >0.90 in men and >0.85 in women and/or BMI was >30 kg/m^2. Subjects were considered to have hypertension if blood pressure was ≥140/90 mmHg or if they were taking antihypertensive medication. Subjects were considered to have dyslipidemia if plasma triglyceride was ≥1.7 mmol/l and/or HDL cholesterol was <0.9 mmol/l for men and <1.0 mmol/l for women, or if they were using lipid-lowering medication.

A subject was considered to have the MetS if they had either NGT with insulin resistance, IFG, IGT, or diabetes and two or more of the following features: obesity, hypertension, or dyslipidemia.

Statistical analysis

The data were analyzed using statistical software (SPSS version 11.5; SPSS, Chicago, IL). Continuous numerical variables are presented as means ± SD unless otherwise indicated. The analysis included independent samples two-tailed *t* test for equality of means between sexes for variables distributed normally. Fasting serum insulin, 2-h serum insulin, and triglycerides were skewed, and the Mann-Whitney *U* test was used for them. The χ^2 test was used to analyze the dependency of categorical variables.

RESULTS

— The clinical and metabolic characteristics of the 3,201 subjects are presented in Table 1. The men had higher waist circumference, WHR, diastolic blood pressure, LDL cholesterol, and triglycerides but lower HDL cholesterol than the women. There was no marked sex difference in the proportion of those having BMI >30 kg/m^2. However, in terms of abdominal obesity, 78.1% of the men had WHR >0.9, whereas only 23.6% of the women had WHR >0.85. The prevalences of hypertension and dyslipidemia were significantly higher in men.

Drop outs

The men who failed to attend ($n = 602$, 39.1%) the second visit for the glucose tolerance assessment were slightly younger (53.5 vs. 54.7 years) and slimmer. Nevertheless, the prevalences of obesity (77.5 vs. 80.0%; $P = 0.252$), hypertension (65.1 vs. 66.6%; $P = 0.560$), and dyslipidemia (50.2 vs. 48.0%; $P = 0.40$) were similar in nonattenders and attenders. In contrast, the female nonattenders ($n = 550$, 33.1%) had significantly higher systolic blood pressure (145.8 vs. 140.7 mmHg; $P < 0.001$), higher prevalences of obesity (39.0 vs. 33.4%; $P = 0.026$), hypertension (63.8 vs. 55.2%; $P = 0.001$), and dyslipidemia (30.9 vs. 25.1%; $P = 0.013$).

Prevalence of insulin resistance and disturbances in glucose metabolism

Insulin resistance in subjects with NGT was present in 10.8% of the men and 15.1% of the woman. The prevalence of disturbances in glucose metabolism by sex and age-group is presented in Table 2.

Table 1—*Clinical and metabolic characteristics of the FINRISK cohort* (n = *3,201) by sex*

	Men	Women	*P*
n	1,538	1,663	—
Age (years)	54.2 ± 5.9	54.5 ± 6.1	0.257
BMI (kg/m^2)	27.6 ± 3.8	27.4 ± 4.9	0.123
Waist circumference (cm)	97.8 ± 10.8	84.2 ± 11.9	<0.001
WHR	0.95 ± 0.07	0.81 ± 0.07	<0.001
Systolic blood pressure (mmHg)	144 ± 19	142 ± 21	0.098
Diastolic blood pressure (mmHg)	88 ± 11	84 ± 11	<0.001
Total cholesterol (mmol/l)	6.02 ± 1.04	5.98 ± 1.10	0.251
HDL cholesterol (mmol/l)	1.25 ± 0.33	1.51 ± 0.35	<0.001
LDL cholesterol (mmol/l)	3.94 ± 0.93	3.82 ± 0.98	0.001
Triclycerides (mmol/l)	1.96 ± 1.30	1.45 ± 0.92	<0.001
BMI (kg/m^2)			
<25.0	25.2	35.4	<0.001
25.0–29.9	49.8	38.3	<0.001
≥30	25.0	26.3	0.445
WHR >0.9 in men and >0.85 in women	78.1	23.6	<0.001
Hypertension	66.0	58.1	<0.001
Dyslipidemia	48.8	27.0	<0.001

Data are means ± SD or percent. Hypertension: systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or use of oral antihypertensive medication. Dyslipidemia: triglycerides ≥1.7 mmol/l or HDL cholesterol <0.9 in men or <1.0 mmol/l in women or use of lipid-lowering medication.

Abnormal glucose metabolism was found in 34.9% of the men and 21.3% of the women. The men had significantly higher prevalences of IFG and diabetes than the women. Diabetes was found in 10.1 and 6.8% of the men and women, respectively, whereas according to the questionnaires only 37.2% of the subjects with diabetic blood glucose values were aware of the condition.

Prevalence of the MetS and its features

In the FINRISK glucose tolerance study cohort, the overall prevalence of the MetS was significantly higher among men: 38.8% of the men and 22.2% of the women fulfilled the modified WHO criteria for the MetS. The prevalence of the various components was also significantly higher in men: obesity was observed in 79.8 and 33.2%, hypertension in 66.1 and 54.9%, and dyslipidemia in 52.4 and 29.0% of the men and women, respectively. The higher prevalence of obesity among men was due to abdominal obesity: 79.1 vs. 21.8% ($P < 0.001$) of the men and women had high WHR, while 26.5 vs. 24.5% ($P = 0.355$) had BMI >30 kg/m^2. If obesity had been defined only by BMI >30 kg/m^2, the prevalence of the MetS would have been 28.9% in men and 20.6% in women ($P < 0.001$).

The prevalence of the MetS and its components was separately assessed in the 45- to 54-year and 55- to 64-year age-groups, and the results are presented in Table 2. Age had no significant effect on the already high prevalence of the MetS and obesity among men, unlike among women. Elevated systolic blood pressure in both sexes, lower HDL cholesterol in

Table 2—*Prevalence (%) of MetS and its components in the glucose tolerance study subgroup* (n = *2,049) of the FINRISK cohort by sex and age-group*

	Men			Women			
	45–54 years	55–64 years	*P*	45–54 years	55–64 years	*P*	*P* between sexes
n	427	509	—	535	578	—	—
MetS	36.2	41.4	0.116	16.5	27.9	<0.001	<0.001
NGT with insulin resistance	12.2	9.5	0.194	15.1	15.0	0.977	<0.004
IFG	14.5	12.4	0.337	5.8	3.6	0.089	<0.001
IGT	8.9	13.8	0.021	6.9	12.6	0.001	0.226
Diabetes	7.5	12.6	0.104	5.2	8.3	0.042	0.005
Obesity	77.6	81.9	0.104	26.9	39.4	<0.001	<0.001
BMI >30 kg/m^2	26.5	26.5	0.984	19.6	29.4	<0.001	0.355
Abdominal obesity	76.9	80.9	0.134	18.3	25.1	0.006	<0.001
Hypertension	60.7	71.5	<0.001	43.2	66.5	<0.001	<0.001
Systolic blood pressure ≥140 mmHg	46.6	62.3	<0.001	34.0	59.5	<0.001	<0.001
Diastolic blood pressure ≥90 mmHg	44.3	42.1	0.459	24.9	26.5	0.539	<0.001
Use of antihypertensive medication	15.0	20.6	0.010	11.0	21.1	<0.001	0.225
Dyslipidemia	51.7	53.0	0.712	21.1	36.8	<0.001	<0.001
Low HDL cholesterol (men <0.9 women <1.0 mmol/l)	9.4	14.0	0.029	4.7	6.4	0.229	<0.001
Triglycerides ≥1.7 (mmol/l)	44.7	45.6	0.799	15.7	29.6	<0.001	<0.001
Use of lipid-lowering medication	3.5	5.0	0.285	0.9	4.0	0.004	0.046

Obesity: BMI >30 kg/m^2 or WHR >0.9 in men and >0.85 in women. Abdominal obesity: WHR >0.9 in men and >0.85 in women. Hypertension: systolic ≥140 mmHg or diastolic blood pressure ≥90 mmHg or use of antihypertensive medication. Dyslipidemia: triglycerides ≥1.7 mmol/l or HDL cholesterol <0.9 in men and <1.0 mmol/l in women or use of lipid-lowering medication.

Table 3—*Prevalence (%) of MetS and its components by WHO criteria in men and women in the FINRISK subgroup (n = 2,049) by glucose tolerance status*

	NGT (n = 1,482)			IFG (n = 177)			IGT (n = 218)			Diabetes (n = 172)		
	Men	Women	*P*	Men	Women	*P*	Men	Women	*P*	Men	Women	*P*
n	607	875	—	125	52	—	108	110	—	96	76	—
MetS	14.4	10.1	0.019	74.0	52.2	0.007	84.8	65.4	<0.001	91.5	82.7	0.084
Obesity	75.4	25.5	<0.001	80.8	46.2	<0.001	92.6	57.3	<0.001	93.1	81.6	0.013
Hypertension	61.9	49.9	<0.001	72.0	69.2	0.711	75.9	76.4	0.940	78.1	76.4	0.778
Dyslipidemia	44.7	22.0	<0.001	55.3	39.0	0.074	69.0	52.6	0.018	76.9	69.4	0.282

Obesity: BMI >30 kg/m^2 or WHR >0.9 in men and >0.85 in women. Hypertension: systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or use of oral antihypertensive medication. Dyslipidemia: triglycerides ≥1.7 mmol/l or HDL cholesterol <0.9 in men and <1.0 mmol/l in women or use of lipid-lowering medication.

men, and higher triglycerides in women were significantly more common in the 55- to 64-year age-group.

Prevalence of MetS in different categories of glucose tolerance

The MetS was observed in 12.3% of the subjects with NGT, in 63.1% with IFG, in 75.1% with IGT, and in 87.1% with diabetes. The prevalence of the MetS and its components in different categories of glucose metabolism is presented in Table 3. In all categories men had a higher prevalence of obesity and dyslipidemia than women. The MetS clustered most often together with obesity in all categories of glucose tolerance in men. In women it clustered most often with hypertension in NGT, IFG, and IGT categories but with obesity in those with diabetes.

The DPS cohort

The clinical and metabolic characteristics of the 522 DPS subjects with IGT and overweight are presented in Table 4. Mean BMI was significantly higher in women than men, but WHR was significantly higher in men. Men had slightly higher diastolic blood pressure and FPG, but lower HDL cholesterol. Altogether, 78.4% of the men and 72.2% of the women fulfilled the criteria for MetS. Obesity was seen in 96.5 and 66.3%, hypertension in 62.9 and 60.9%, and dyslipidemia in 51.2 and 48.6% of men and women, respectively.

CONCLUSIONS — In the FINRISK cohort of people aged 45–64 years, ~40% of the men and ~20% of women fulfilled the modified WHO criteria for the MetS. Among women the prevalence of the MetS increased with increasing age. The high prevalence among men was closely associated with abdominal obesity. If we had used only BMI >30 kg/m^2 for the criteria of obesity instead of high WHR or high BMI, the prevalence of the MetS would have been lower (~30%) in men but would have stayed in the same range in women. Our study conforms with the range found in other studies on Caucasian people. In general the MetS is observed in 15–30% of middle-aged people in industrialized western countries (8,28–31).

Our FINRISK cohort represented 62% of the original randomized, age- and sex-stratified, population-based FINRISK study cohort. The prevalences of obesity,

Table 4—*Clinical and metabolic characteristics of the DPS subjects by sex*

	Men	Women	*P*
n	172	350	—
Age (years)	55.9 ± 7.1	54.8 ± 7.1	0.124
BMI (kg/m^2)	29.9 ± 3.6	31.9 ± 4.8	<0.001
WHR	0.99 ± 0.05	0.89 ± 0.06	<0.001
Systolic blood pressure (mmHg)	137 ± 17	138 ± 18	0.412
Diastolic blood pressure (mmHg)	87 ± 9	85 ± 10	0.045
FPG (mmol/l)	6.3 ± 0.8	6.1 ± 0.7	0.010
2-h plasma glucose (mmol/l)	8.8 ± 1.6	9.0 ± 1.4	0.146
Fasting serum insulin (mU/l)	15.6 ± 8.5	14.4 ± 7.0	0.315
2-h serum insulin (mU/l)	93.1 ± 60.9	96.3 ± 66.6	0.454
Total cholesterol (mmol/l)	5.5 ± 0.9	5.7 ± 0.9	0.027
LDL cholesterol (mmol/l)	3.6 ± 0,8	3.6 ± 0,8	0.464
HDL cholesterol (mmol/l)	1.10 ± 0.28	1.26 ± 0.28	<0.001
Triclycerides (mmol/l)	1.8 ± 0.9	1.7 ± 0.7	0.419
MetS	78.4	72.2	0.082
Obesity	96.5	86.3	<0.001
BMI >30 kg/m^2	45.3	59.1	0.004
WHR >0.9 in men and >0.85 in women	96.5	75.3	<0.001
Hypertension	62.9	60.9	0.647
Systolic blood pressure ≥140 mmHg	38.2	44.0	0.181
Diastolic blood pressure ≥90 mmHg	39.4	33.1	0.161
Use of antihypertensive medication	29.1	29.2	0.745
Dyslipidemia	51.2	48.6	0.599
HDL cholesterol: <0.9 in men and <1.0 mmol/l in women	22.7	17.8	0.183
Triglycerides ≥1.7 mmol/l	44.8	39.0	0.205
Use of lipid-lowering medication	5.8	5.4	0.857

Obesity: BMI >30 kg/m^2 or WHR >0.9 in men and >0.85 in women. Hypertension: systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or use of oral antihypertensive medication. Dyslipidemia: triglycerides ≥1.7 mmol/l or HDL cholesterol <0.9 in men and <1.0 mmol/l in women or use of lipid-lowering medication.

hypertension, and dyslipidemia were similar in the men who did or did not attend the glucose tolerance study, which strengthens reliability of the results. In contrast, all the components were more prevalent in the female nonattenders of the glucose tolerance study, which could have caused underestimation of the prevalence of the MetS in women.

Impaired glucose regulation was closely associated with the syndrome. The prevalence of the MetS increased with established abnormalities in glucose metabolism from 12% in the subjects with NGT to 87% in those with manifest diabetes. The prevalence of the MetS was high and fairly similar in both study cohorts among those with IGT: 75% in the FINRISK and 73% in the DPS. The prevalence was higher among men in all categories of glucose tolerance and also increased with age, which is in accordance with previous studies. In the Finnish Botnia study, the MetS applying the WHO definition, was diagnosed in 10 and 15% of subjects with NGT, 42 and 64% of those with IFG or IGT, and 78 and 84% of those with type 2 diabetes in women and men, respectively (13). EGIR also found that the frequency of MetS by both WHO and EGIR definitions increased with age and was almost always higher in men than in women at a given age (31). In the Bruneck Study, the prevalence of insulin resistance syndrome in subjects aged 40–79 years was 66% in subjects with IGT and 84% among those with type 2 diabetes (32).

Different features of the MetS were surprisingly common in middle-aged individuals in the general population, especially in men. Obesity, hypertension, and dyslipidemia were all significantly more common among men. The high prevalence of obesity in men seemed to be due to their high WHR. Obesity, defined as high WHR (~78%), was clearly more common than obesity defined as BMI >30 kg/m^2 (~25%) in men, while both prevalences were quite similar in women (~25%). Over half of the men and women had hypertension, which is in accordance with the European cohorts published by EGIR (31). There were differences in the clustering of the components according to glucose status in men and women: whereas obesity was significantly more common among men than among women in all categories of glucose tolerance, the difference in the prevalence of hypertension and dyslipidemia between sexes declined with deteriorating glucose metabolism. The prevalence of dyslipidemia was more dependent on the presence of elevated triglycerides than of low HDL cholesterol.

In the FINRISK study, milder disturbances in glucose metabolism were quite common, especially in men: IFG or IGT was present in ~25% of the men and ~15% of the women. Around 10% had diabetes, but it was undiagnosed in over half of the cases.

Type 2 diabetes is preceded by a long period of milder disturbances in glucose metabolism (3). The Finnish DPS (26) and the Diabetes Prevention Program (33) in the U.S. have shown that the incidence of diabetes can be reduced by 58% with lifestyle changes in subjects with IGT. While the clustering of risk factors related to insulin resistance is an important predictor of the development of manifest diabetes, early ascertainment of the MetS in normal clinical consultation would prove useful for identifying those at risk.

In conclusion, the prevalence of the MetS in this Finnish setting was common in middle-aged subjects, especially men, and increased with age and worsening glucose metabolism. Our results support previous findings: the overall prevalence of MetS was ~30% in the population-based cohort and ~75% in subjects with IGT. The DPS study cohort, although comprised of volunteers for an intervention study, was quite similar to the IGT subjects in the Finnish general population. While prevention of type 2 diabetes also aims to minimize the associated vascular complications, preventive actions should focus on not only improving glucose tolerance but also on preventing and treating all components of the MetS.

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