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Metabolic syndrome and arterial stiffness: The Health 2000 Survey

Kalle Sipilä[b,*], Teemu Koivistoinen[a,b], Leena Moilanen[c], Tuomo Nieminen[d], Antti Reunanen[e], Antti Jula[e], Veikko Salomaa[f], Risto Kaaja[g], Tiit Kööbi[a,b], Katriina Kukkonen-Harjula[h], Silja Majahalme[i], Mika Kähönen[a,b]

[a]*Department of Clinical Physiology, Medical School, University of Tampere, FI-33014 Tampere, Finland*
[b]*Department of Clinical Physiology, Tampere University Hospital, FI-33521 Tampere, Finland*
[c]*Department of Medicine, Kuopio University Hospital, 70211 Kuopio, Finland*
[d]*Department of Clinical Pharmacology, Medical School, University of Tampere, FI-33014 Tampere, Finland*
[e]*Department of Health and Functional Capacity, National Public Health Institute, FI-00300 Helsinki, Finland*
[f]*Department of Epidemiology and Health Promotion, National Public Health Institution, FI-00300 Helsinki, Finland*
[g]*Department of Obstetrics and Gynaecology, Helsinki University Central Hospital, FI-00029 Helsinki, Finland*
[h]*UKK Institute for Health Promotion Research, FI-33501 Tampere, Finland*
[i]*Appleton Heart Institute, Appleton, WI 54911, USA*

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Abstract

Metabolic syndrome and its components have been associated with arterial stiffness and cardiovascular disease. The objective of this study was to examine the independent influences of metabolic syndrome, its components, and other cardiovascular risk factors on arterial stiffness as well as to compare 2 definitions for metabolic syndrome (National Cholesterol Education Program [NCEP] and International Diabetes Federation [IDF]) in their ability to identify subjects with arterial stiffness. The study population consisted of 401 Finnish men and women aged 45 years and older who participated in a substudy of the Finnish population–based Health 2000 Survey. Pulse wave velocity (PWV) measured by whole-body impedance cardiography was used as a marker of elevated arterial stiffness. In multivariate models, systolic blood pressure, age, waist circumference, and fasting blood glucose ($P \leq .001$ for all) were independent determinants for PWV. In the models including metabolic syndrome instead of its components, the NCEP and IDF definitions were similarly associated with PWV ($P \leq .01$ for both), the other independent determinants being age, sex ($P < .001$ for both) and plasma C-reactive protein concentration ($P = .016$ and $P = .005$ in models containing the NCEP and IDF definitions, respectively). Systolic blood pressure, age, waist circumference, and fasting blood glucose level were independently associated with increased arterial stiffness. Metabolic syndrome determined increased arterial stiffness independently of other known cardiovascular risk factors. The NCEP and IDF definitions did not differ in their ability to identify subjects with increased arterial stiffness.

1. Introduction

Metabolic syndrome is a cluster of cardiovascular risk factors such as central obesity, hypertension, dyslipidemias, and glucose intolerance. It has been shown to be a predictor of type 2 diabetes mellitus [1], coronary heart disease [2], and mortality [3-5]. Metabolic syndrome has various definitions. The National Cholesterol Education Program (NCEP) Adult Treatment Panel III proposed their widely used clinical definition for metabolic syndrome in 2001 [6]. Recently, the International Diabetes Federation (IDF) also published a worldwide definition of metabolic syndrome [7]. These definitions have 2 basic differences. First, the IDF definition has a significantly lower cutoff point for waist circumference than the NCEP definition. Second, the IDF definition makes the presence of increased waist circumference mandatory for diagnosis, whereas the NCEP definition considers waist circumference as important as the other components.

Arterial stiffness has been a strong independent predictor of coronary events and cardiovascular mortality in several

* Corresponding author. Department of Clinical Physiology, Tampere University Hospital, FI-33520 Tampere, Finland. Tel.: +358 3 311 65302; fax: +358 3 311 65511.
E-mail address: kalle.sipila@uta.fi (K. Sipilä).

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patient groups [8-11]. It can be evaluated by measuring pulse wave velocity (PWV) along the arterial tree. The individual components of metabolic syndrome have been previously associated with increased arterial stiffness and higher PWV values [12,13]. Hypertension in particular has been linked to increased arterial stiffness [14]. Metabolic syndrome as a whole, mostly according to the NCEP criteria, has also been associated with arterial stiffness [13,15-18]. The NCEP and the IDF criteria have been compared in few studies so far. Both definitions have been similarly associated with coronary heart disease [19] and mortality [20]. To our knowledge, these criteria have not been compared regarding their ability to identify subjects with increased arterial stiffness.

The aim of this study was to evaluate the relationships among metabolic syndrome, its individual components, and arterial stiffness. Furthermore, we set out to discover whether the NCEP and the IDF definition can identify subjects with increased arterial stiffness similarly. We also intended to test the applicability of the whole-body impedance cardiography (ICG_{WB}) method for measuring PWV in a large epidemiological study.

2. Methods

2.1. Study population

We studied a subpopulation of a large Finnish cross-sectional health examination survey (the Health 2000 Survey) carried out in 2000-2001 [21]. The overall study cohort was a two-stage stratified cluster sample (8028 persons) representing the entire Finnish population aged 30 years and older. To study cardiovascular disease (CVD) and diabetes more thoroughly, a supplemental study was carried out (sample size, 1867; participation rate, 82%). The subjects, a subpopulation of the Health 2000 Survey, in the supplemental study were 45 years and older, and the study was executed in the catchment areas of the 5 Finnish university hospitals because specialized equipment was required. In the catchment areas of Tampere and Turku university hospitals, 401 individuals (176 men and 225 women; mean age, 58 years; range, 46-76 years) participated in the supplemental study and underwent the ICG_{WB} measurements. These individuals were selected to be our study group.

Waist circumference was not measured in the supplemental study; therefore, the Health 2000 Survey parameters were used to define the presence of metabolic syndrome. All the other measurements and laboratory tests used in the present study were collected from the data of the supplemental study. The mean time interval between the Health 2000 Survey and the supplemental study was 1 year and 4 months (range, 10-23 months). The mean ($\pm$SD) change in body weight during this time was 0.52 ($\pm$3.43) kg. Because this change was not clinically significant, it is likely that change in waist circumference was not clinically significant either. Because most of the women in our study population had reached menopause, we did not analyze premenopausal and postmenopausal women separately. To evaluate a possible conflicting influence of concomitant diseases on the associations between the risk factors and PWV, we also created a smaller sample excluding subjects with CVD and diabetes. Subjects with previous myocardial infarction or stroke, or with diagnosed diabetes, coronary heart disease, cardiac insufficiency, cardiac arrhythmia, hypertension, arterial stenosis, or thrombosis in a lower limb or other CVD were excluded. The subjects who had fasting plasma glucose concentration of 7 mmol/L or higher or who had 2-hour glucose value of 11.1 mmol/L or higher in the oral glucose tolerance test were excluded. From this smaller sample, we also excluded subjects who were on antihypertensive medication or statins. After these additional exclusions, 200 individuals free of CVD and diabetes remained with available PWV data.

2.2. Metabolic syndrome

We used 2 different criteria to define metabolic syndrome. According to the NCEP definition [6], a person has metabolic syndrome if at least 3 of the following criteria are met: waist circumference greater than 102 cm for men and greater than 88 cm for women; triglycerides, 1.7 mmol/L or greater; high-density lipoprotein (HDL) cholesterol, less than 1.03 mmol/L for men and less than 1.29 mmol/L for women; systolic blood pressure, 130 mm Hg or higher, and diastolic blood pressure, 85 mm Hg or higher; and fasting glucose, 5.6 mmol/L or higher. The fasting glucose threshold of the NCEP criterion was modified in 2004 [22].

According to the IDF definition [7], a person has metabolic syndrome if waist circumference is increased ($\geq$94 cm for men and $\geq$80 cm for women) and at least 2 of the following factors are present: triglycerides, 1.7 mmol/L or greater, or specific treatment of this lipid abnormality; HDL cholesterol, less than 1.03 mmol/L in men and less than 1.29 mmol/L in women, or specific treatment; systolic blood pressure 130 mm Hg or higher or diastolic blood pressure 85 mm Hg or higher, or treatment of previously diagnosed hypertension; fasting plasma glucose, 5.6 mmol/L or higher, or previously diagnosed type 2 diabetes mellitus. The IDF definition has ethnicity-specific cutoff points for waist circumference.

2.3. Pulse wave velocity

Pulse wave velocity was measured by ICG_{WB} using a commercially available circulation monitor device (CircMon B202, JR Medical, Tallinn, Estonia). Subjects were first interviewed and then electrodes (Blue Sensor type R-00-S; Medicotest, Ölstykke, Denmark) were applied while subjects were in the supine position for at least 15 minutes before the 10-minute PWV measurements. A pair of electrically connected current electrodes was placed on the distal part of the extremities just proximal to the wrists and ankles. Voltage-sensing electrodes were placed proximally to the current electrodes, with a distance of 5 cm

Table 1
Clinical and laboratory parameters of the study cohort (n = 400) with and without metabolic syndrome (MetS) according to 2 definitions (NCEP, IDF)

	MetS by NCEP definition			MetS by IDF definition		
	Yes (n = 156-162)[a]	No (n = 227-238)[a]	*P*	Yes (n = 175-182)[a]	No (n = 208-218)[a]	*P*
Age (y)	59.5 ± 7.7	57.6 ± 7.9	.017	59.5 ± 7.6	57.4 ± 8.0	.009
Sex (men, %)	44	44	.883	46	43	.555
Current smoking (%)	24	23	.748	24	23	.689
BMI (kg/m^2)	29.3 ± 3.9	25.6 ± 3.7	<.001	29.0 ± 3.8	25.5 ± 3.9	<.001
Waist circumference (cm)	101.5 ± 11.2	89.2 ± 10.8	<.001	100.9 ± 10.8	88.5 ± 11.0	<.001
Heart rate (beats/min)	64.9 ± 10.1	63.3 ± 10.7	.133	64.6 ± 9.7	63.4 ± 11.1	.260
HDL cholesterol (mmol/L)	1.4 ± 0.4	1.7 ± 0.5	<.001	1.4 ± 0.4	1.7 ± 0.5	<.001
LDL cholesterol (mmol/L)	3.6 ± 0.9	3.3 ± 0.9	.008	3.5 ± 0.9	3.3 ± 0.9	.028
Total cholesterol (mmol/L)	5.7 ± 1.0	5.5 ± 0.9	.213	5.6 ± 1.0	5.6 ± 0.9	.429
Triglycerides (mmol/L)	1.7 ± 0.8	1.2 ± 0.5	<.001	1.7 ± 0.8	1.1 ± 0.5	<.001
Fasting glucose (mmol/L)	6.3 ± 1.7	5.5 ± 0.7	<.001	6.2 ± 1.6	5.5 ± 0.7	<.001
CRP (mg/L)	4.1 ± 5.6	2.2 ± 3.0	<.001	4.0 ± 5.4	2.1 ± 2.8	<.001
SBP (mm Hg)	142.3 ± 19.5	129.1 ± 18.4	<.001	140.2 ± 19.3	129.6 ± 19.1	<.001
DBP (mm Hg)	85.1 ± 9.2	81.0 ± 9.7	<.001	85.0 ± 8.7	80.1 ± 10.0	<.001
PP (mm Hg)	57.2 ± 15.4	48.2 ± 11.8	<.001	55.3 ± 15.4	48.9 ± 12.1	<.001

Values are means ± SD except values for sex and smoking, which are percentages. SBP indicates systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure.
[a] Variation of n is caused by the fact that some values are missing for some subjects.

between the centers of the electrodes. With this electrode configuration, the recorded heart-synchronous changes in impedance reflect the weighted sum of the pulsatile plethysmograms of the vessels between the electrodes, ie, almost the whole vascular system. The foot of the whole-body impedance cardiogram coincides with pulse transmission in the aortic arch, making it possible to estimate the beginning of pulse wave transmission in the arterial system. Similarly, with voltage sensing electrodes applied to any distal region between the current electrodes, pulse-related impedance changes can be recorded. In this study, the distal impedance plethysmogram was recorded from a popliteal artery at knee joint level. The active electrode was placed on the lateral side of the knee joint and the reference electrode on the calf, the distance between the electrodes being about 20 cm. The time difference between the feet of these impedance plethysmograms, recorded from the aortic arch and popliteal artery, was measured. The time resolution of the CircMon recordings was 5 milliseconds. The evaluation of the ICG_{WB} method and PWV measurement using ICG_{WB} has been described in detail previously [23,24]. Reproducibility values of the PWV measurements by ICG_{WB} (2.42 m/s) and Doppler ultrasound (2.17 m/s) are similar [24].

2.4. Waist circumference, body mass index, blood pressure, and smoking

Waist circumference was measured with subjects in the standing position by using the standards created for population health studies [25]. Height and weight were measured and body mass index (BMI) was calculated. In the Health 2000 Survey, blood pressure was measured from the right arm with a mercury sphygmomanometer (Mercuro 300, Speidel & Keller, Juningen, Germany). The first measurement was taken after subjects had rested at least 5 minutes in the sitting position. Korotkoff's first phase was used as the sign of systolic blood pressure and the fifth phase as the sign of diastolic pressure. The measurement was repeated 2 minutes after the first measurement. The average of the 2 measurements was used in the analysis. In the supplemental study, blood pressure was measured from the right arm after at least 10 minutes' rest. The measurement was taken 3 times with 1- to 2-minute intervals. The automatic Omron M4 manometer (Omron Matsusaka, Japan, and Omron Healthcare Europe, Hoofddorp, the Netherlands) was used in these measurements. The average of the 3 measurements was used in the analysis. Pulse pressure was calculated as the difference between the average systolic and the average diastolic blood pressure. Current smoking was evaluated with a questionnaire. Those who were currently smoking were defined as smokers and the rest of the subjects as nonsmokers. The smoking data used in the present study were collected from the Health 2000 Survey data.

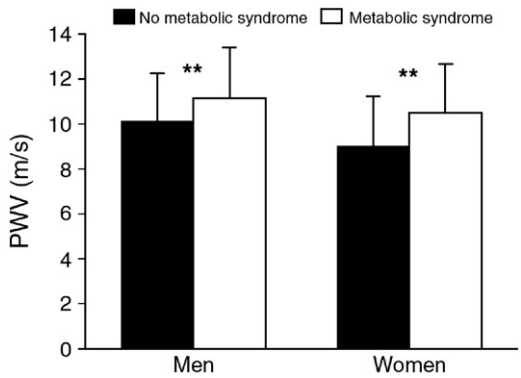

Fig. 1. PWV (mean and SD) in men and women with or without metabolic syndrome, according to the NCEP definition. **P < .01. The pattern is essentially the same using the IDF definition.

Table 2
Univariate correlations between cardiovascular risk factors and PWV in the whole cohort (n = 393-401) and in the healthy subsample (n = 197-200)

	Whole cohort		Subsample	
	r	*P*	*r*	*P*
Age (y)	0.510	<.001	0.518	<.001
BMI (kg/m^2)	0.238	<.001	0.274	<.001
Waist circumference (cm)	0.343	<.001	0.353	<.001
HDL cholesterol (mmol/L)	−0.161	.001	−0.255	<.001
LDL cholesterol (mmol/L)	0.062	.217	0.208	.003
Total cholesterol (mmol/L)	0.028	.577	0.120	.090
Triglycerides (mmol/L)	0.199	<.001	0.174	.014
Fasting glucose (mmol/L)	0.341	<.001	0.252	<.001
CRP (mg/L)	0.226	<.001	0.214	.003
SBP (mm Hg)	0.627	<.001	0.694	<.001
DBP (mm Hg)	0.392	<.001	0.496	<.001
PP (mm Hg)	0.619	<.001	0.642	<.001
HR × PP	0.627	<.001	0.664	<.001

SBP indicates systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; PP, pulse pressure.

2.5. Laboratory tests

Venous blood samples were drawn from the antecubital vein after an overnight fast. HDL cholesterol, total cholesterol, triglyceride, and glucose concentrations were determined enzymatically (Roche Diagnostics, Mannheim, Germany, for HDL; Olympus System Reagent, Hamburg, Germany, for total cholesterol, triglyceride, and glucose) with a clinical chemistry analyzer (Olympus, AU400, Hamburg, Germany). C-reactive protein (CRP) concentrations were determined by a chemiluminescent immunometric assay (Immulite, Diagnostic Products, Los Angeles, CA). Low-density lipoprotein (LDL) cholesterol was calculated with the Friedewald formula.

2.6. Statistical analyses

Statistical analyses were performed using SPSS for Windows (version 13.0; SPSS, Chicago, IL). The skewed distributions of triglycerides and CRP were corrected logarithmically before statistical analyses. Chi-square and *t*-test analyses were calculated to compare categorical and continuous variables between the metabolic syndrome groups, respectively. Pearson correlation coefficients were used to examine the association between cardiovascular risk factors and PWV. Stepwise linear regression analysis was performed for continuous and dichotomous variables to examine independent relationships among metabolic syndrome, its components, other cardiovascular risk factors, and PWV.

3. Results

The prevalence of metabolic syndrome obtained by using the NCEP and IDF definitions was, respectively, 41% and 47% in men and 40% and 44% in women. For one participant, the waist circumference measurement was missing and the presence of metabolic syndrome could not be assessed. By both definitions, the subjects with metabolic syndrome were older, had higher BMI, waist circumference, LDL cholesterol, triglycerides, fasting plasma glucose, CRP and blood pressure and lower HDL cholesterol ($P < .05$ for all) than the subjects who did not have the syndrome. Subjects with and without metabolic syndrome did not differ in sex, resting heart rate, total cholesterol levels, or smoking habits ($P > .1$ for all). Twenty-eight percent of the study population was on antihypertensive medication, and 11% used statins. Selected clinical and demographic values of the study population are given in Table 1.

Men had significantly higher mean PWV than women ($P < .001$). For both sexes, the mean PWV was significantly higher in subjects with metabolic syndrome (using both definitions; $P < .01$) than those without the syndrome (Fig. 1 illustrates the data obtained with the NCEP definition). There was no statistically significant difference in the mean PWV ($P > .1$) of current smokers and nonsmokers. Age, systolic blood pressure, diastolic blood pressure, pulse pressure, product of heart rate and pulse pressure, waist circumference, BMI, and levels of HDL cholesterol, triglycerides, CRP, and fasting plasma glucose correlated statistically significantly with PWV (Table 2). Correlations between risk factors and PWV remained essentially similar in the smaller group excluding subjects with CVD and diabetes with the exception that the plasma LDL cholesterol level correlated statistically significantly with PWV (Table 2).

A stepwise linear regression model was performed to examine the relationships between cardiovascular risk

Table 3
A linear regression model for the relationships between cardiovascular risk factors and PWV in the whole cohort (n = 390) and in the healthy subsample (n = 196)

Risk variable	Whole cohort			Risk variable	Subsample		
	$\beta \pm$ SE	*P*	R^2 change (%)		$\beta \pm$ SE	*P*	R^2 change (%)
SBP (mm Hg)	.05 ± .00	<.001	40	SBP (mm Hg)	.06 ± .01	<.001	48
Age (y)	.10 ± .01	<.001	11	Age (y)	.10 ± .01	<.001	12
Fasting glucose (mmol/L)	.27 ± .07	<.001	3	Waist circumference (cm)	.02 ± .01	.042	1
Waist circumference (cm)	.03 ± .01	<.001	1				
R^2 (%)	55%				61		

Initial stepwise regression models included age, sex, waist circumference, fasting plasma glucose, HDL cholesterol, systolic blood pressure, CRP, triglycerides, smoking and LDL cholesterol (only in the sub sample) as independent variables. β indicates regression coefficient; R^2 change, change in adjusted R^2 value after addition of the respective variable in to the model; R^2, adjusted R^2 value of the whole model.

Table 4
Linear regression model for the relationships between metabolic syndrome (MetS), using 2 different definitions, other cardiovascular risk factors and PWV in the whole cohort (n = 392) and in the healthy sub sample (n = 197)

Risk variable	Whole cohort			Risk variable	Subsample		
	$\beta \pm$ SE	P	R^2 change (%)		$\beta \pm$ SE	P	R^2 change (%)
Age (y)	.14 ± .01	<.001	26	Age (y)	.13 ± .02	<.001	26
MetS using the NCEP definition	.92 ± .20	<.001	4	MetS using the NCEP definition	.84 ± .25	<.001	5
Sex	−.82 ± .19	<.001	3	Sex	−.72 ± .23	.002	2
CRP (mg/L)	.52 ± .21	.016	0.8				
R^2 (%)	34				33		
Age (y)	.14 ± .01	<.001	26	Age (y)	.13 ± .02	<.001	26
Sex	−.80 ± .19	<.001	3	MetS using the IDF definition	.78 ± .24	.001	4
MetS using the IDF definition	.67 ± .20	.001	3	Sex	−.69 ± .24	.004	3
CRP (mg/L)	.60 ± .21	.005	1				
R^2 (%)	33				33		

Initial stepwise regression models included age, sex, CRP, smoking, metabolic syndrome, according to the NCEP or the IDF definition and LDL cholesterol (only in the subsample) as independent variables. β indicates regression coefficient; R^2 change, change in adjusted R^2 value after addition of the respective variable in to the model; R^2, adjusted R^2 value of the whole model.

factors as independent variables and PWV (Table 3). The initial stepwise regression model included age, sex, waist circumference, fasting plasma glucose, HDL cholesterol, triglycerides, systolic blood pressure, CRP, and smoking as independent variables. In that model, systolic blood pressure, age, fasting blood glucose, and waist circumference explained 55% (adjusted R^2, 55%) of the variation in PWV. When the same model was adjusted by replacing systolic blood pressure with pulse pressure or with the product of heart rate and pulse pressure (data not shown), the results remained essentially the same (adjusted R^2, 53% and 55%, respectively) with the exception that sex was also an independent determinant of PWV. We used the same linear regression model (LDL cholesterol included) for the smaller sample excluding subjects with CVD and diabetes (Table 3). Systolic blood pressure, age, and waist circumference explained 61% of the variation in PWV. Therefore, in this smaller healthier population, fasting plasma glucose was not an independent factor determining PWV.

Another stepwise linear regression model was performed by using metabolic syndrome (both definitions separately) and other known cardiovascular risk factors (age, sex, CRP, and smoking) as independent variables (Table 4). Age, metabolic syndrome (using the NCEP or the IDF definition), sex, and CRP were independent determinants for PWV (adjusted R^2, 34% and 33% in the models containing the NCEP and the IDF definition, respectively). When CRP was excluded from the models, the results remained essentially the same. The same linear regression model (including LDL as independent variable) was used for the smaller sample that excluded subjects with CVD and diabetes (Table 4). Age, metabolic syndrome, and sex explained 33% (using the NCEP or the IDF definition) of the variation in PWV.

4. Discussion

Metabolic syndrome and its individual components are risk factors for atherosclerosis and CVD [1-5]. Arterial stiffness is also related to CVD and atherosclerosis [26] and has been a strong independent predictor of coronary events and cardiovascular mortality in several patient groups [8-11]. In this study, we examined the relationships between arterial stiffness measured by PWV and single cardiovascular risk factors as well as metabolic syndrome as a whole. Our aim was also to compare 2 different definitions for metabolic syndrome (NCEP and IDF) in their relations with arterial stiffness.

Age, systolic blood pressure, diastolic blood pressure, pulse pressure, product of heart rate and pulse pressure, BMI, waist circumference, and triglyceride, HDL cholesterol, fasting plasma glucose, and CRP levels correlated statistically significantly with PWV. The univariate associations were thus significant between PWV and all the components of metabolic syndrome. The strongest correlation was observed between systolic blood pressure and PWV, which is not surprising considering that both are connected to arterial stiffness. As expected, age was strongly correlated with PWV. In all, these findings are well in line with previously published data [14,27]. LDL cholesterol has also been linked with arterial stiffness [28,29]. In a smaller sample excluding subjects with CVD and diabetes, we also found a significant correlation between LDL cholesterol and PWV.

The mean PWV was significantly higher in the subjects with metabolic syndrome than in those without the syndrome, regardless of the definition used. This is in line with previous studies using the NCEP definition [13,14,16-18]. To our knowledge, this is the first study to examine the relationships between metabolic syndrome and arterial stiffness by using the IDF definition. In our study, men had significantly higher mean PWV than women. The results of the Framingham heart study were in agreement with the present study, the difference in PWV being small but statistically significant [30]. On the other hand, several other studies have not reported significant differences between the sexes [31,32].

Although we did find that many individual risk factors were associated with arterial stiffness, only some of them

appeared in the final regression models as independent determinants of PWV. As expected, systolic blood pressure and age were the strongest factors determining arterial stiffness—a finding that is in agreement with previous data [33]. In our study population, waist circumference and fasting plasma glucose were also independent determinants of arterial stiffness, results consistent with those of previous studies [13-15,34]. When metabolic syndrome was included in the regression model instead of its components, it was found to be an independent determinant of arterial stiffness (using both definitions) together with age, sex, and CRP concentration. In the smaller sample that excluded CVD and diabetes, fasting plasma glucose was not an independent factor determining PWV. This can be partly explained by the smaller sample size. On the other hand, metabolic syndrome remained as an independent factor even in this population free of CVD and diabetes. Similar results have been reported previously [18].

We did not find a significant difference between the NCEP and the IDF definitions in their ability to determine arterial stiffness. To our knowledge, this has not been studied previously. The main difference between these 2 definitions is that the latter makes central obesity mandatory for diagnosis. The IDF definition also has a lower waist circumference threshold. Because of this, the IDF definition produces a higher prevalence for metabolic syndrome than the NCEP definition. In our study population, the prevalence figures were 45.4% and 40.4%, respectively, which are relatively high when compared with most of the earlier studies. This is probably related to the age structure of our study population (older than 45 years). Nevertheless, this increases our understanding of the magnitude of metabolic syndrome as an important CVD risk factor.

C-reactive protein correlated significantly with PWV in the present study. The association of CRP and arterial stiffness has been reported previously [35-37]. Some [36,37] of the previous studies have suggested that CRP is associated with arterial stiffness independently of other CVD risk factors. In our population, however, CRP was not independently associated with arterial stiffness when all the other risk factors were taken into account. In the regression models with metabolic syndrome included instead of its components, CRP was an independent determinant. This is probably due to significant associations between CRP and all the components of metabolic syndrome.

Previously, PWV measurements have been done mostly by methods using Doppler ultrasound or mechanoelectrical pulse transducers [38,39]. PWV can also be measured by ICG_{WB}, which provides a handy and reliable tool for evaluating arterial stiffness on the basis of PWV simultaneously with cardiac output and related hemodynamic parameters. The ICG_{WB} method turned out to be applicable especially for large epidemiologic studies because it is not user dependent and does not require large personnel resources. The method is highly repeatable and reproducible [24].

In conclusion, our findings indicate that blood pressure, age, waist circumference, and fasting plasma glucose concentration are important independent factors for determining arterial stiffness in a middle-aged and elderly population. The NCEP and IDF definitions were both similarly associated with PWV, independently of other known cardiovascular risk factors. This suggests that both the NCEP and IDF definitions are able to identify subjects with increased arterial stiffness in a Finnish population. However, although metabolic syndrome is an important factor affecting cardiovascular health and its prevalence remarkably high in developed countries, its components have to be carefully evaluated as independent risk factors.

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