Determinants of masked hypertension in the general population: the Finn-Home study

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Introduction **Home blood pressure (BP) measurement has allowed the identification of individuals with normal office and elevated out-of-office BP (masked hypertension). It is, however, not feasible to measure home BP on all office normotensive individuals. The objective of the present study was to identify demographic, lifestyle, clinical and psychological characteristics suggestive of masked hypertension.**

Methods **Study population was drawn from the participants of a multidisciplinary epidemiological survey, the Health 2000 Study. The untreated nationwide population sample ($n = 1459$, age 45–74 years) underwent office (duplicate measurements on one visit) and home (duplicate measurements on 7 days) BP measurements and risk factor evaluation. Psychometric tests assessed psychological distress, hypochondriasis, depression and alexithymia. Masked hypertension was defined as normal office BP (<140/90 mmHg) with elevated home BP (≥135/85 mmHg).**

Results **The prevalence of masked hypertension was 8.1% in the untreated Finnish adult population. The cardiovascular risk profile of masked hypertensive patients resembled that of sustained hypertensive patients. High-normal systolic and diastolic office BP, older age, greater BMI, current smoking, excessive alcohol consumption, diabetes and electrocardiographic left-ventricular hypertrophy were independent determinants of masked hypertension in multivariate logistic regression analysis. Masked hypertension was also independently associated with hypochondria.**

Conclusion **Masked hypertension is a common phenomenon in an untreated adult population. Physicians should consider home BP measurement if a patient has high-normal office BP, diabetes, left-ventricular hypertrophy, or several other conventional cardiovascular risk factors.** *J Hypertens* **29:1880–1888 © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

Journal of Hypertension 2011, **29**:1880–1888

Keywords: home blood pressure measurement, left ventricular hypertrophy, masked hypertension, white-coat hypertension

Abbreviations: BDI, Beck Depression Inventory; BP, blood pressure; GHQ, General Health Questionnaire; LVH, left ventricular hypertrophy; TAS, Toronto Alexithymia Scale

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Received 26 August 2010 **Revised** 31 May 2011
Accepted 5 July 2011

Introduction

Blood pressure (BP) measurements taken in the office may not always correctly characterize a patient's typical BP level. The increasing use of out-of-office BP measurement has led to the identification of patients who have elevated ambulatory or home BP despite a normal office BP. This condition, called masked hypertension, is found in 7–17% of the general population and has been associated with increased cardiovascular risk [1]. A significant proportion of patients may therefore fail to receive needed treatment for hypertension when only office BP measurement is used. It is, however, not feasible to routinely measure out-of-office BP in all individuals with normal office BP values. Therefore, researchers have tried to identify characteristics that would be suggestive of masked hypertension.

Previous studies indicate that masked hypertension is frequently associated with other cardiovascular risk factors. Masked hypertensive patients lead an unfavourable lifestyle and have demographic and metabolic risk factors that are intermediate or similar to those of sustained hypertensive patients. Furthermore, masked hypertension has been related to a higher frequency of target organ damage than normotension [1]. Masked hypertension has also been associated with diseases such as sleep apnoea [2].

Psychological stressors have been suggested to influence masked hypertension but only a few studies have assessed psychological factors. All of these studies have been performed in selected patient populations. One study suggested that masked hypertension might differ from white-coat and sustained hypertension in terms of personality and mood pattern, whereas another study failed to find any significant differences [3,4].

Several previous studies have investigated determinants of masked hypertension using multivariate

0263-6352 © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins DOI:10.1097/HJH.0b013e32834a98ba

analysis. Two determinants, male sex [5–8] and high-normal systolic office BP [5,6,9,10], were proposed by most, but not all, of them. Other suggested determinants included older age [5,7,8], obesity [8,9], current smoking [6,7,11], habitual alcohol drinking [9], low physical activity [11], high-normal diastolic office BP [6] and the use of at least two antihypertensive drugs [9]. All of the previous studies, except for one [8], were performed in selected hypertensive patient populations.

The objective of the present study was to evaluate the prevalence and determinants of masked hypertension in an unselected Finnish adult population. We investigated a large nationwide population sample using home BP measurement to identify demographic, lifestyle, clinical and psychological characteristics of masked hypertensive patients. Only patients with no antihypertensive medication were included in the study to avoid any confounding effects.

Participants and methods

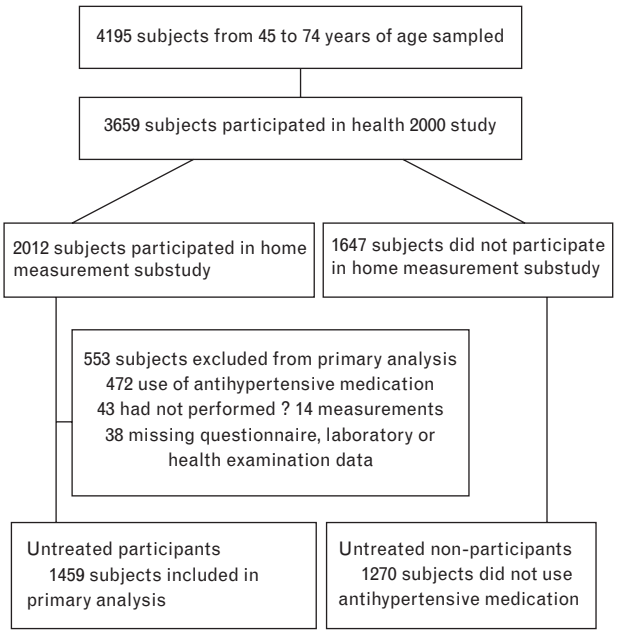
Participants

The study sample was drawn from the participants of a multidisciplinary epidemiological survey, the Health 2000 study, which was carried out in Finland from the fall of 2000 to the spring of 2001. A nationally representative sample of 8028 individuals aged 30 years or over was drawn from the population register using a two-stage stratified cluster sampling procedure. The stratification and sampling procedures have been previously described in detail [12].

Of the individuals aged 45–74 years ($n=4195$), 87% ($n=3659$) agreed to participate in the interview and attend the health examination (Fig. 1). Two thousand and twelve of these individuals were selected to participate in the home BP measurement substudy (Finn-Home study) on the basis of monitor availability (800 monitors) and willingness to participate. Patients who were using antihypertensive medication ($n=472$), had not performed at least 14 BP measurements at home ($n=43$) or had missing laboratory or health examination data ($n=38$) were excluded from the study. One thousand four hundred and fifty-nine individuals were thus eligible for the present analyses. As shown in Table 1, there were small but statistically significant differences between the participants and nonparticipants of the substudy. Participants were younger and had higher educational level and lower office SBP levels than nonparticipants. The prevalence of diabetes was lower among participants than among nonparticipants.

The study protocol of the Health 2000 survey was approved by the Epidemiology Ethics Committee of the Helsinki and Uusimaa Hospital region, and all participants gave signed informed consent.

Fig. 1



Flow of participant selection.

Flow of the study

An initial health interview was held at the patient's home. Centrally trained interviewers gathered information on basic background and socio-demographic factors, health and illnesses and the use of medication. After the interview, participants of the home measurement substudy received monitors for measuring home BP during the following week. A self-report questionnaire for the Beck Depression Inventory (BDI) and General Health Questionnaire (GHQ) was left for the study participants to fill in. A physical examination was performed 1–6 weeks later at a local health centre by centrally trained doctors and nurses. Each participant underwent height, weight and office BP measurement and determination of serum lipids and glucose levels. After the physical examination, participants received another self-report questionnaire for the Whiteley Index and the 20-item Toronto Alexithymia Scale (TAS) to be filled in at home and mailed to the National Public Health Institute. Details of the methodology of the project have been published elsewhere [12].

Blood pressure measurements

Office BP was measured by a trained nurse using a conventional calibrated mercury sphygmomanometer. Measurements were taken in the sitting position after a 10-min rest. The last 5 min were spent in the measuring room with the cuff around the right upper arm. A cuff with an appropriate bladder width was used. SBP and DBP were defined according to Korotkoff sounds I and V.

Table 1 Comparison of participants and nonparticipants of the study

Characteristics	Participants ($n=1459$)	Nonparticipants ($n=1270$)	P
Men (%)	47.0	48.7	0.4
Age (years)	55.8 (8.0)	56.5 (8.3)	0.03
Education level			0.03
Upper (%)	25.6	24.2	
Medium (%)	30.9	27.4	
Lower (%)	43.5	48.4	
Office SBP (mmHg)	135.2 (19.7)	137.7 (21.0)	0.001
Office DBP (mmHg)	83.0 (10.5)	83.7 (10.9)	0.09
BMI (kg/m^2)	26.9 (4.1)	27.2 (4.6)	0.1
Current smokers (%)	21.4	24.5	0.05
Excessive alcohol consumption (%)	7.0	7.7	0.4
Diabetes (%)	4.4	6.2	0.03
BDI (points)	7.1 (6.6)	7.2 (6.5)	0.7
TAS-20 (points)	46.2 (10.9)	46.1 (10.7)	0.9
Whiteley-7 (points)	13.6 (4.0)	13.7 (4.1)	0.4

Data are shown as mean (SD) or percentage for each subgroup. Diabetes was defined as fasting serum glucose level at least 7.0 mmol/l and/or a history of use of oral hypoglycaemic agents or insulin injection. Hypercholesterolaemia was classified according to fasting serum total cholesterol level ($\geq$7.0 mmol/l) and/or use of statins. Weekly alcohol intake of more than 24 units in men and 16 units in women was considered excessive consumption. BDI, Beck Depression Inventory; BP, blood pressure; TAS, Toronto Alexithymia Scale.

Office BP was determined as the mean of two measurements performed at a 2-min interval.

Home BP was self-measured with a validated, automatic oscillometric device (Omron model HEM-722C, Omron Corporation, Tokyo, Japan) according to the current guidelines [13,14]. After receiving written instructions and individual guidance, study participants took duplicate self-measurements every morning (between 0600 and 0900 h) and every evening (between 1800 and 2100 h) on 7 consecutive days. Measurements were taken in the sitting position at an approximately 2-min interval. Preparations for self-measurement of BP were the same as for office BP. Home BP was determined as the mean of 14 duplicate measurements (28 measurements). The mean number of performed measurements was 26.7 ± 3.7.

Classifications

Participants were divided into four subgroups according to their office and home BP values: normal office and home BP; normal office BP with elevated home BP, that is masked hypertension; elevated office BP with normal home BP, that is white-coat hypertension; and elevated office and home BP, that is sustained hypertension. The currently recommended cut-off levels of 140/90 and 135/85 mmHg [15], respectively, were used to define office and home hypertension.

Current smoking was defined as a daily use of tobacco products. Diabetes was defined as fasting serum glucose level at least 7.0 mmol/l and/or a history of use of oral hypoglycaemic agents or insulin injection. Hypercholesterolaemia was classified according to fasting serum total cholesterol level ($\geq$7.0 mmol/l) and/or use of statins. To determine heavy drinking we selected a definition that is commonly used in Finland [16]. Weekly alcohol intake of more than 24 units in men and 16 units in women was considered excessive consumption. One alcohol unit contains on average 12 g of 100% alcohol. Leisure-time physical activity was evaluated using a self-administered questionnaire. Participants were classified as having a sedentary lifestyle if, in their leisure time, they read, watched TV and did other activities in which they did not move much and which did not strain them physically. Nonsedentary lifestyle included individuals who, in their leisure time, walked, cycled and moved in other ways at least 4 h per week; exercised at least 3 h per week; or practised regularly several times per week for competition. Probable sleep apnoea was defined on the basis of self-reported snoring and other breathing symptoms as previously described [17].

Psychometric evaluation

Psychopathological symptoms were evaluated using several self-report questionnaires, which included the seven-item Whiteley index rated on a five-point Likert scale (Whiteley-7, range 7–35) [18], which measures worrying and convictions about illness and somatoform disorders; a minimally modified version of the 21-item BDI (range 0–63) [19], used for assessing the existence and severity of symptoms of depression; the 12-item GHQ-12 (range 0–12) [20], used to detect the presence of nonpsychotic psychiatric morbidity, especially depression and anxiety; and the 20-item Toronto Alexithymia Scale (TAS-20, range 20–100) for measuring alexithymia, a personality trait encompassing difficulties in emotional regulation [21]. A higher score in all previous psychometric tests indicates a greater risk of the respective psychological symptoms or traits.

Electrocardiographic measurements

Standard resting 12-lead electrocardiograms (ECG) were digitally recorded by using a Marquette MAC 5000 device and stored as digital data on a Marquette MUSE CV 5B system (Marquette Hellige, Milwaukee, Wisconsin, USA). All ECGs were over-read, and the computerized diagnoses and measurements corrected if

needed, by a single physician experienced with electrocardiography before being stored into the database.

QRS duration was measured to the nearest 4 ms and the QRS amplitudes to the nearest 0.5 mm. Electrocardiographic left-ventricular hypertrophy (ECG-LVH) was assessed with two commonly used ECG criteria: the Sokolow–Lyon voltage ($S_{V1} + R_{V5/6}$) [22] and the Cornell product which was calculated as RaVL + SV3 (with 6 mm added in women) times QRS duration [23]. Threshold values of 35 and 2440 mm × ms were used to identify LVH using the Sokolow–Lyon and Cornell product criteria, respectively.

Statistical analysis

Results are reported as mean ± standard deviation or percentage. A chi-squared test and *t*-test were used to compare the participants and nonparticipants. The statistical significance of between-group differences was tested by analysis of variance (ANOVA) with post-hoc pair-wise comparisons (Tukey test) with age and sex as covariates. The Bonferroni method was applied to maintain the overall significance of pair-wise comparisons of the categorical variables. A Wilcoxon or Kruskal–Wallis nonparametric test was used to analyse the variables with skewed distribution (BDI, GHQ-12). Univariate logistic regression was used to identify the factors that were significantly associated with masked hypertension. All significant variables except home BP were entered in the multivariate logistic regression model. A *P* value less than 0.05 was considered statistically significant. Classification trees using chi-squared Automatic Interaction detector (CHAID) method [24] were developed to study the relationship between masked hypertension and categorized independent factors within office normotensive individuals. In this interactive process each split of the subgroup (node) of the classification tree is based on chi-squared maximization. We assessed the predictive value of diabetes by developing classification trees with varying minimum number of cases in the nodes of the tree to be split. With large minimum numbers the split of a node cannot be based on predictors with relatively small number of prevalent cases. With smaller minimum numbers the splits are based on all predictors in order of their significance. All statistical analyses were conducted with SAS version 9.1 (SAS Institute Inc., Cary, North Carolina, USA) and PASW Statistics 18 (SPSS Inc., New York, USA).

Results

The prevalence of masked hypertension was 8.1% in the study population. Among untreated office normotensive individuals, the prevalence of masked hypertension was 14.2%.

Demographic and lifestyle characteristics

The characteristics of patients with normotension, white-coat hypertension, masked hypertension and sustained hypertension are presented in Table 2. The proportion of men was higher in the masked, white-coat and sustained hypertensive groups than in the normotensive one. Masked, white-coat and sustained hypertensive patients were also older than normotensive individuals. The educational level did not differ between masked hypertension and the three other groups.

Masked and sustained hypertensive individuals had a greater BMI and waist-to-hip ratio than normotensive and white-coat hypertensive individuals. Masked hypertensive patients were more often current smokers than the other individuals. Heavy drinking was more common in masked and sustained hypertensive patients than in normotensive individuals. Sustained hypertensive patients were more sedentary than normotensive individuals (Table 2).

Clinical characteristics

Diabetes was more common in white-coat, masked and sustained hypertension than in normotension. Moreover, the proportion of patients with diabetes was highest in the masked hypertensive group. The sustained hypertensive group included a higher proportion of hypercholesterolaemic patients than the normotensive one. The prevalence of probable sleep apnoea was significantly different between all the four groups, but the pair-wise differences did not reach statistical significance (Table 2).

Blood pressure was significantly lower in the normotensive group than in white-coat, masked or sustained hypertension groups. Masked and white-coat hypertensive patients had intermediate office and home BP values. Office heart rate was higher in the white-coat and sustained hypertensive groups than in the normotensive one. Masked and sustained hypertensive patients had higher home heart rate than normotensive individuals and white-coat hypertensive patients. Mean difference between office and home BP (i.e. white-coat effect) was negative only in masked hypertension (Table 2).

Target organ damage

Table 2 presents the prevalence of electrocardiographically determined LVH in each subgroup. Normotensive individuals had significantly lower prevalence of ECG-LVH than the other individuals. The prevalence of LVH increased from normotension over white-coat and masked hypertension to sustained hypertension.

Psychological characteristics

Masked hypertensive patients had higher Whiteley-7 scores than normotensive individuals or sustained hypertensive patients. Sustained hypertensive patients had higher BDI scores than normotensive individuals. Sustained hypertensive patients also received higher scores on TAS-20 than white-coat hypertensive patients. GHQ-12 scores did not differ significantly between the groups.

Table 2 Characteristics of the study population

	Normotension	White-coat hypertension	Masked hypertension	Sustained hypertension	P^a
n (%)	715 (49.0)	221 (15.2)	118 (8.1)	405 (27.8)	
Men (%)	39.0	51.6*	62.7***	53.8***	<0.001
Age (years)	53.9 (7.2)	56.2 (8.1)***	56.9 (8.1)***	58.6 (8.5)***,††	<0.001
Education level					<0.001
Upper (%)	31.6	21.3	18.6	19.3*	
Medium (%)	31.3	35.8	34.8	26.4*	
Lower (%)	37.1	43.0	46.6	54.3*	
Office SBP (mmHg)[b]	121.0 (10.6)	146.0 (10.0)	129.6 (7.9)	156.0 (16.2)	<0.001
Office DBP (mmHg)[b]	76.7 (7.2)	88.2 (7.8)	80.6 (7.0)	92.0 (9.7)	<0.001
Office heart rate (per min)	65.7 (9.9)	67.9 (10.5)**	67.5 (9.8)	70.0 (11.5)***	<0.001
Home SBP (mmHg)[b]	114.3 (9.8)	124.0 (7.3)	139.8 (10.1)	148.2 (13.4)	<0.001
Home DBP (mmHg)[b]	73.3 (5.8)	77.6 (5.0)	85.2 (6.1)	88.8 (7.3)	<0.001
Home heart rate (per min)	67.5 (8.2)	68.2 (9.3)	70.8 (10.0)***,†	70.5 (9.2)***,††	<0.001
Office–home SBP difference (mmHg)	6.8 (10.4)	22.0 (10.4)***	−10.2 (11.2)***,†††	7.8 (15.3)†††,§§§	<0.001
Office–home DBP difference (mmHg)	3.5 (6.7)	10.5 (6.5)***	−4.5 (8.4)***,†††	3.3 (8.0)†††,§§§	<0.001
BMI (kg/m^2)	25.7 (3.7)	26.5 (4.0)*	28.4 (4.3)***,†††	28.8 (4.1)***,†††	<0.001
Waist-to-hip ratio	0.89 (0.08)	0.91 (0.09)	0.95 (0.08)***,††	0.94 (0.08)***,†††	<0.001
Sedentary lifestyle (%)	19.6	21.7	27.1	27.7**	0.01
Current smokers (%)	21.4	15.4	34.8**,†††	20.7§	<0.001
Excessive alcohol consumption (%)	4.2	7.7	11.0*	10.1***	<0.001
Diabetes (%)	1.3	4.5*	11.9***	7.7***	<0.001
Hypercholesterolaemia (%)	22.2	28.1	28.0	35.3**	<0.001
Probable sleep apnoea (%)	7.4	8.0	12.0	12.6	0.03
ECG-LVH (%)[c]	11.0	18.6**	22.0**	29.8***,††	<0.001
BDI (points)	6.6 (6.4)	6.5 (6.0)	8.2 (7.8)	7.8 (7.0)*	0.03
GHQ-12 (points)	1.7 (2.9)	1.4 (2.6)	2.1 (3.2)	1.9 (2.8)	0.2
Whiteley-7 (points)	13.4 (3.8)	13.6 (3.7)	14.7 (4.5)*	13.6 (4.1)§	0.02
TAS-20 (points)	45.0 (10.8)	45.3 (10.6)	47.8 (11.2)	48.4 (10.7)†	0.04

Data are shown as mean (SD) or percentage for each subgroup. Analyses were adjusted for age and sex. BDI, Beck Depression Inventory; BP, blood pressure; ECG-LVH, electrocardiographically determined left ventricular hypertrophy; GHQ, General Health Questionnaire; TAS, Toronto Alexithymia Scale. [a] Comparison between all four groups. [b] All pair-wise group comparisons $P<0.001$. [c] Cornell product $\geq$2440 mm × ms or Sokolow–Lyon $\geq$35 mm. * $P<0.05$ vs. normotension. ** $P<0.01$ vs. normotension. *** $P<0.001$ vs. normotension. † $P<0.05$ vs. white-coat hypertension. †† $P<0.01$ vs. white-coat hypertension. ††† $P<0.001$ vs. white-coat hypertension. § $P<0.05$ vs. masked hypertension. §§§ $P<0.001$ vs. masked hypertension.

Determinants of masked hypertension

We further examined factors that distinguished masked hypertensive patients from the other groups. At first we performed univariate logistic regression analysis (Table 3). We separately analysed office normotensive individuals. Of the demographic and lifestyle characteristics, older age, male sex, higher BMI, greater waist-to-hip ratio, current smoking and excessive alcohol consumption were significantly associated with masked hypertension. Among the clinical characteristics, diabetes, ECG-LVH, high-normal systolic and diastolic office BP and faster office heart rate were related to masked hypertension. Of the psychological characteristics, higher points on BDI and Whiteley-7 were associated with masked hypertension. The same variables, except for age, office heart rate, alcohol consumption and ECG-LVH, were found to be associated with masked hypertension among all study participants.

To identify factors that were independently associated with masked hypertension, we performed two multivariate logistic regression analyses. The first model included the whole study population. All of the significant variables in univariate analysis except BP were entered in the multivariate regression model. As shown in Table 4, male sex, higher BMI, current smoking, diabetes and higher points on Whiteley-7 were independent determinants of masked hypertension.

We further examined factors that distinguished masked hypertensive individuals from normotensive ones. The second regression model in Table 4 included only office normotensive individuals. Older age, high-normal systolic and diastolic office BP, higher BMI, current smoking, excessive alcohol consumption, diabetes, ECG-LVH and higher points on Whiteley-7 were independently associated with masked hypertension. Male sex was no longer a significant determinant of masked hypertension after ECG-LVH was added in the multivariate model. Among office normotensive individuals, the prevalence of masked hypertension increased with office BP levels (Fig. 2).

Finally, a decision tree was constructed to identify individuals who were most likely to be masked hypertensive (Fig. 3). The first division was based on office SBP threshold of 130 mmHg. Thirty percent of patients who had office SBP above the threshold were identified as masked hypertensive. The model classified correctly 87% of patients.

Discussion

The present study showed that masked hypertension, detected with home BP measurement, is a common phenomenon in the Finnish adult population. As the cardiovascular risk profile of masked hypertensive patients resembles that of sustained hypertensive

Table 3 Age-adjusted and sex-adjusted odds ratios for masked hypertension in univariate logistic regression analysis

	Office normotensive individuals ($n=833$)		All participants ($n=1459$)	
Variable	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)	*P*
Male sex	2.63 (1.76–3.93)	<0.001	2.01 (1.36–2.96)	<0.001
Age (years)	1.05 (1.03–1.08)	<0.001	1.02 (1.00-1.04)	0.1
Education		0.1		0.4
Lower vs. upper	1.60 (0.92–2.78)		1.35 (0.79–2.29)	
Medium vs. upper	1.72 (0.99–3.01)		1.48 (0.86–2.54)	
Office SBP (mmHg)[a]		<0.001		
120–129 vs. <120 mmHg	2.37 (1.22–4.58)			
>130 vs. <120 mmHg	7.79 (4.23–14.35)			
Office DBP (mmHg)[a]		<0.001		
80–84 vs. <80 mmHg	2.02 (1.22–3.35)			
>85 vs. <80 mmHg	4.56 (2.73–7.62)			
Office heart rate (per min)	1.03 (1.01–1.05)	0.01	1.00 (0.99–1.02)	0.7
BMI (kg/m^2)	1.18 (1.12–1.24)	<0.001	1.09 (1.05–1.14)	<0.001
Waist-to-hip ratio[b]	2.33 (1.64–3.31)	<0.001	1.63 (1.18–2.26)	0.003
Sedentary lifestyle (yes/no)	1.50 (0.95–2.38)	0.08	1.30 (0.85–1.99)	0.2
Current smoking (yes/no)	2.11 (1.36–3.26)	<0.001	2.14 (1.42–3.24)	<0.001
Excessive alcohol consumption (yes/no)	2.94 (1.45–5.99)	0.003	1.55 (0.82–2.91)	0.2
Diabetes (yes/no)	8.10 (3.32–19.77)	<0.001	2.90 (1.53–5.49)	0.001
Hypercholesterolaemia (yes/no)	1.17 (0.74–1.84)	0.5	1.01 (0.66–1.54)	1.0
Probable sleep apnoea (yes/no)	1.11 (0.56–2.18)	0.8	1.03 (0.55–1.94)	0.9
ECG-LVH (yes/no)[c]	1.96 (1.18–3.26)	0.009	1.14 (0.72–1.82)	0.6
BDI (points)	1.04 (1.01–1.07)	0.008	1.03 (1.01–1.06)	0.02
GHQ-12 (points)	1.05 (0.99–1.12)	0.1	1.05 (0.98–1.11)	0.15
Whiteley-7 (points)[d]	1.07 (1.02–1.13)	0.005	1.07 (1.02–1.12)	0.003
TAS-20 (points)	1.01 (0.99–1.03)	0.3	1.01 (0.99–1.03)	0.5

BDI, Beck Depression Inventory; BP, blood pressure; CI, confidence interval; ECG-LVH, electrocardiographically determined left-ventricular hypertrophy; GHQ, General Health Questionnaire; TAS, Toronto Alexithymia Scale. [a] Odds ratios of office BP were calculated only for office normotensive individuals. [b] Odds ratio represents the increase of risk by 0.1 units (10%) increase in waist-to-hip ratio. [c] ECG-LVH was defined as Cornell product ≥2440 mm × ms or Sokolow–Lyon ≥35 mm. [d] Participants who had not completed Whiteley-7 questionnaire ($n=112$) were included in the univariate analyses.

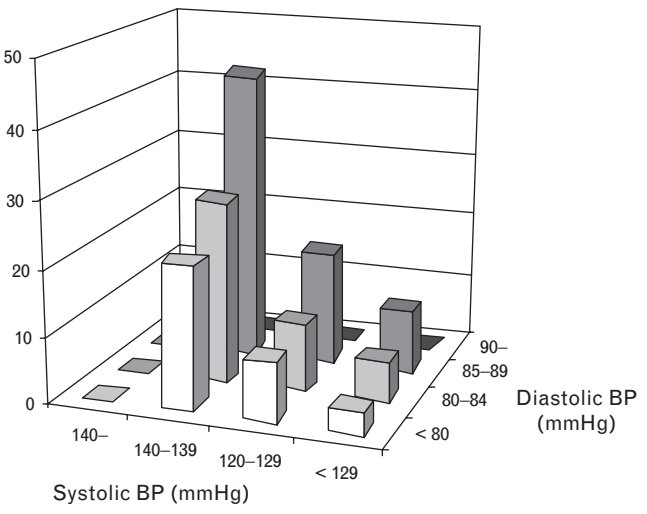
patients, identification of this form of hypertension is necessary for more precise evaluation and management of hypertension. Even though home BP measurement is less expensive, widely available and better accepted than ambulatory BP measurement, it cannot be performed on all office normotensive individuals. We investigated an untreated nationwide population sample to identify characteristics of patients who would most benefit from home BP measurement. Older age, high-normal systolic and diastolic office BP, greater BMI, current smoking, excessive alcohol consumption, diabetes, ECG-LVH and higher score on Whiteley-7 were found to be

Table 4 Factors independently associated with masked hypertension in multivariate analysis

Variable	Odds ratio	95% CI	*P*
Model A: all participants			
R-square = 4.1% ($n=1347$)[a]			
Male sex	1.84	1.21–2.79	0.004
BMI (kg/m^2)	1.09	1.04–1.15	<0.001
Current smoking (yes/no)	2.21	1.43–3.42	<0.001
Diabetes (yes/no)	3.02	1.53–5.94	0.001
Whiteley-7 (points)	1.06	1.02–1.11	0.009
Model B: Office normotensive individuals			
R-square = 19.5% ($n=778$)[a]			
Age (years)	1.05	1.01–1.08	0.009
Office SBP (mmHg)			<0.001
120–129 vs. <120 mmHg	2.19	1.04–4.61	
130–139 vs. <120 mmHg	5.86	2.87–11.94	
Office DBP (mmHg)			0.002
80–84 vs. <80 mmHg	1.32	0.71–2.43	
85–89 vs. <80 mmHg	2.99	1.62–5.49	
BMI (kg/m^2)	1.17	1.10–1.24	<0.001
Current smoking (yes/no)	2.57	1.50–4.42	<0.001
Excessive alcohol consumption (yes/no)	2.99	1.27–7.02	0.01
Diabetes (yes/no)	8.69	2.95–25.61	<0.001
ECG-LVH (yes/no)	2.51	1.37–4.59	0.003
Whiteley-7 (points)	1.08	1.02–1.14	0.01

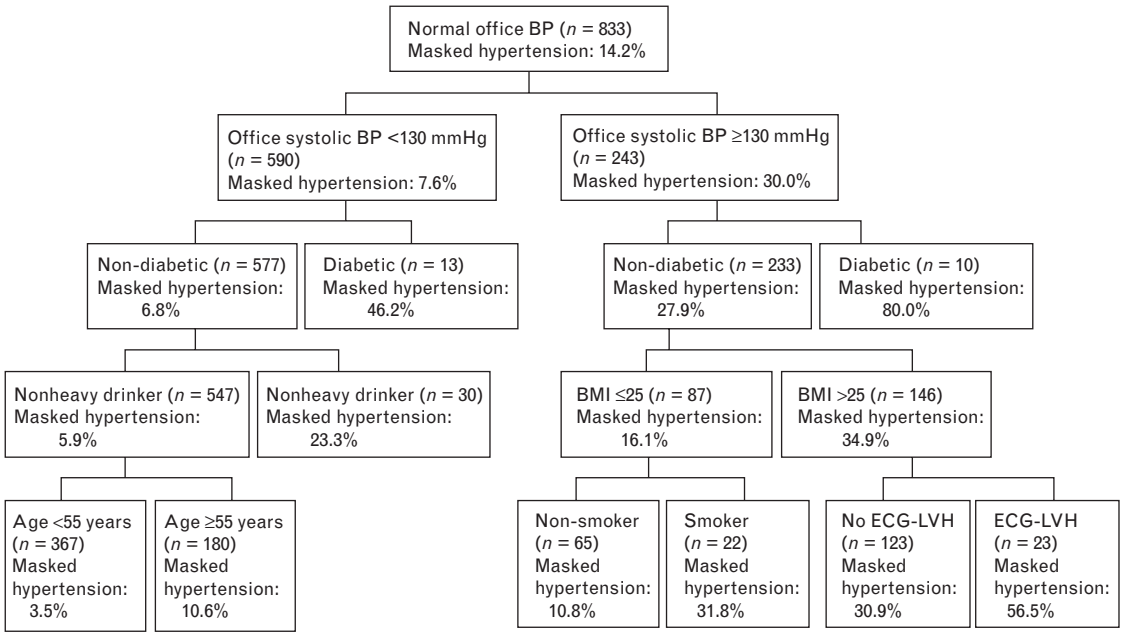
BP, blood pressure; CI, confidence interval; ECG-LVH, electrocardiographically determined left-ventricular hypertrophy. [a] Participants who had not completed Whiteley-7 questionnaire ($n=112$) were excluded from the multivariate analyses.

Fig. 2



Frequency of masked hypertension according to office SBP and DBP.

Fig. 3



Classification tree (CHAID method). BP, blood pressure; ECG-LVH, electrocardiographically determined left-ventricular hypertrophy.

independent determinants of masked hypertension among office normotensive individuals.

The prevalence of masked hypertension has ranged from 7 to 10% in general population-based studies using home BP measurement [25–29]. Similar prevalence (8% in the untreated Finnish population and 14% in the office normotensive group) was observed in the present study.

Lifestyle and metabolic risk factors have been frequently associated with masked hypertension in previous studies [8,25,26,29–31]. The demographic, lifestyle and metabolic characteristics of masked hypertensive patients in the present study resembled those of sustained hypertensive patients, whereas white-coat hypertensive patients had somewhat healthier lifestyle habits. Smoking and diabetes were most common in the masked hypertensive group. In line with previous studies, masked hypertensive individuals also had high-normal office BP and higher home heart rate than normotensive individuals and white-coat hypertensive patients [26,31,32].

Several previous studies have shown that masked hypertensive patients are more likely to have echocardiographic LVH than normotensive individuals [1,27,29]. In clinical practice, ECG is commonly used to detect LVH due to its wide availability and low cost. LVH diagnosed by the Sokolow–Lyon index or the Cornell voltage-duration product has been shown to be an independent predictor of cardiovascular events [33]. In the present study, the prevalence of ECG-LVH in masked and white-coat hypertension was intermediate between that of normotension and that of sustained hypertension. This finding is in line with previous population studies which investigated the association between masked hypertension and echocardiographically determined LVH using home BP measurement [27,29].

Psychological distress has been proposed as a possible explanation for masked hypertension. Only two previous studies have investigated psychological factors in masked hypertension. One of them suggested that masked hypertensive patients have lower score for type-A personality and are less depressive than white-coat or sustained hypertensive outpatients, whereas the other failed to find any significant differences [3,4]. The present study is the first to evaluate the psychological characteristics of masked hypertension in a general population. Masked hypertensive patients received a significantly higher score on Whiteley-7 and were thus more hypochondriac than normotensive individuals and sustained hypertensive patients. Masked hypertensive patients also tended to have higher points on BDI and to be more depressive than normotensive and white-coat hypertensive individuals. Alexithymia has been previously associated with untreated essential hypertension [34], but difficulties in emotional regulation, as measured with the TAS-20, were not associated with masked hypertension.

One previous population study has investigated the independent determinants of masked hypertension. This

study was performed on 694 Chinese and reported that the risk of masked hypertension increased with age and BMI. Masked hypertension was associated with male sex but not with smoking, drinking or energy expenditure. [8] In the present study, older age, high-normal systolic and diastolic office BP, greater BMI, current smoking, excessive alcohol consumption, diabetes, ECG-LVH and higher score on Whiteley-7 were found to be independent determinants of masked hypertension among office normotensive individuals.

One previous study has investigated the determinants of masked hypertension using classification tree procedure. This study was performed on 1150 elderly treated hypertensive patients with controlled office BP. In line with our results, the first division in the tree was based on office SBP threshold of 130 mmHg. Among patients with office SBP under 130 mmHg, two variables, male sex and age (with a threshold of 70 years), were chosen in the model [5]. High-normal systolic office BP is one of the most often suggested risk factors for masked hypertension [5,6,9,10].

The present study has both its strengths and limitations. It was performed on a large nationwide population sample and home BP was measured over a period of 1 week using currently recommended measurement protocol. However, only two office BP measurements were taken at only one visit. This may have affected the reliability of the subgroup classification and lead to an underestimation of the prevalence of masked hypertension. Study participants were slightly younger, had lower systolic office BP levels and were less often diabetic than nonparticipants, which may have attenuated between-group differences. Some groups in the decision tree model (e.g. diabetes) were based on small numbers of patients, which may have affected the proportions of masked hypertension. The present study was a cross-sectional study so no causal inferences can be drawn from the relationships between variables.

In conclusion, we found a substantial prevalence of masked hypertension in the Finnish adult population using home BP measurement. The cardiovascular risk profile of masked hypertensive patients resembled that of sustained hypertensive patients. The proportions of current smokers and diabetic patients were highest in masked hypertensive patients. High-normal office BP, older age, greater BMI, smoking, excessive alcohol consumption, diabetes and ECG-LVH were found to be independent determinants of masked hypertension among office normotensive individuals. Our findings suggest that masked hypertension may also be related to hypochondriasis and depression. To identify masked hypertension, physicians should consider home BP measurement in patients who have high-normal office BP, diabetes, ECG-LVH, or several other conventional cardiovascular risk factors.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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