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Comparative characteristics of individuals with high normal blood pressure according to the carotid intima-media values

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Abstract

Objective. Based on factor analysis, we identified the most clinically significant characteristics of subjects with high normal blood pressure (BP) depending on the values of carotid intima-media thickness (IMT). **Design and methods.** Altogether 88 patients (60 men and 28 women) with high-normal BP (Russian Society of Cardiology, 2010) were examined (mean age — 34.1 ± 2.7 years, duration of history of high-normal BP was 4.4 ± 1.3 years). They were divided into 2 groups: 1st included 45 individuals with IMT < 0.9 mm, the 2nd group consisted of 43 subjects with IMT ≥ 0.9 mm. All subjects underwent clinical examination, clinical and biochemical blood tests, electrocardiography (ECG), echocardiography, veloergometry, ambulatory blood pressure monitoring (ABPM) with central BP and arterial stiffness assessment, ECG monitoring, duplex scan of carotid IMT. Blood plasma levels of some hormones were also assessed. **Results.** Factor analysis showed that BP is not related to other traditional risk factors in the group 1, while it is the leading factor in the 2nd group. Cardio-renal relations are present even when IMT is within normal values. Group 2 is characterized by BP-associated vascular remodeling, and left ventricular remodeling. The structural and functional changes were independent from lipid levels. Vascular stiffness correlated with changes in BP circadian rhythm. Increased IMT is associated with «non-dipper» daily BP pattern. **Conclusions.** IMT increase in individuals with high normal BP may identify the risk of the transition from functional to organic vascular changes, followed by hypertension occurrence.

Key words: high-normal blood pressure, intima-media thickness, factor analysis, structural and functional state of the vascular bed

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Сравнительная характеристика лиц с высоким нормальным уровнем артериального давления в зависимости от размеров комплекса «интима-медиа» сонных артерий

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Резюме

Цель исследования — на основе метода факторного анализа выделить наиболее существенные клинические различия в группах лиц с высоким нормальным уровнем артериального давления (ВНАД) в зависимости от наличия у них неизмененного или увеличенного комплекса «интима-медиа» (КИМ) сонных артерий. **Материалы и методы.** Проанализировано 88 лиц с ВНАД, соответствующих критериям Всероссийского научного общества кардиологов 2010 года, из них 60 мужчин и 28 женщин, средний возраст — 34,1 ± 2,7 года, длительность анамнеза ВНАД составила 4,4 ± 1,3 года. Обследованные были распределены на 2 группы: в 1-ю вошли 45 лиц с КИМ сонных артерий менее 0,9 мм, 2-ю группу составили 43 пациента с КИМ сонных артерий равным или более 0,9 мм. Наряду с общеклиническим обследованием выполнялись клинические и биохимические анализы крови, электрокардиография, эхокардиография, велоэргометрия, суточное мониторирование артериального давления (АД) с измерением центрального АД и параметров артериальной жесткости**,** мониторирование электрокардиографии по Холтеру, дуплексное сканирование сонных артерий с определением толщины КИМ задней стенки общей сонной артерии. Также определялся уровень ряда гормонов в плазме крови. **Результаты.** Факторный анализ показал, что в 1-й группе уровень АД не является ведущим по отношению к другим традиционным факторам риска, напротив — во 2-й группе он, по факторной нагрузке, занимает одно из ведущих мест. Кардиоренальные взаимосвязи начинают проявляться еще тогда, когда КИМ сонных артерий остается в пределах нормальных величин. Для 2-й группы свойственны не только признаки ремоделирования сосудов, но и сопряженное с уровнем АД ремоделирование миокарда левого желудочка. При этом изменения структурно-функциональных показателей сосудистой стенки не зависели от уровня липидов сыворотки крови. Изменение ригидности сосудов взаимосвязано с изменением суточных ритмов АД. Лицам с увеличенным КИМ сонных артерий свойственен тип суточного ритма АД «non-dipper». **Заключение.** Увеличение размеров КИМ сонных артерий у лиц с ВНАД может свидетельствовать в пользу трансформации функ-

циональных изменений сосудов в органические, с последующим формированием артериальной гипертензии как самостоятельной нозологической формы.

Ключевые слова: высокое нормальное артериальное давление, комплекс «интима-медиа» сонных артерий, факторный анализ, структурно-функциональное состояние сосудистого русла

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Introduction

Along with classical cardiovascular risk factors (RF), loss of elastic properties of the vascular wall, associated both with age and high blood pressure (BP), disorders of carbohydrate and lipid metabolism, is of particular significance. In their turn, changes in the vascular bed, caused by remodeling and thickening of the intima-media lead to stable increase in BP and development of arterial hypertension (HTN) [1].

According to the Framingham study, men with prehypertension (with "high normal" and "normal" BP) had the 2.5-fold 10-year cardiovascular risk compared to those with optimal BP (i.e. less than 120/80 mm Hg) [2]. At the same time, in the TROPHY study, HTN developed in ⅔ of patients with prehypertension who were monitored for four years in the absence of antihypertensive therapy [3, 4].

Intima-media complex (IMC) of carotid arteries is a known significant marker of poor cardiovascular prognosis, and its increase in young patients with unchanged lipid profile is considered an early sign of vascular damage, which confirms stabilization of prehypertension and development of HTN as a nosological form. A number of Russian and foreign studies showed a relation between the BP level and the IMC thickness [5–8]. In this respect, vascular remodeling in patients with high

Table 1

ХАРАКТЕРИСТИКА ОБСЛЕДОВАННЫХ БОЛЬНЫХ

Characteristics	Group 1, IMT < 0.9 mm (n = 45)	Group 2, IMT ≥ 0.9 mm (n = 43)
Age, year	33.8 ± 2.3	34.1 ± 3.2
Gender, M/F	28/12	32/16
Duration of high normal BP, year	4.5 ± 1.3	4.3 ± 1.2
SBP, mm Hg	133.9 ± 3.4	135.4 ± 4.5*
DBP, mm Hg	85.5 ± 4.2	86.6 ± 3.3*
BMI, kg/m^2	27.5 ± 4.2	29.6 ± 3.3*
Smoking, n (%)	9 (21.9%)	14 (32.2%)
Alcohol consumption > 20-30 g/24 h, n (%)	0	2 (5.7%)
Family history of premature HTN, n (%)	15 (31.4%)	10 (24.5%)
Low physical activity, n (%)	14 (30.8%)	10 (24.5%)
Fasting plasma glucose, mmol/L	4.77 ± 0.38	5.01 ± 0.59*
Total cholesterol, mmol/L	5.27 ± 0.88	4.97 ± 0.98*
HDL cholesterol, mmol/L	1.41 ± 0.39	1.11 ± 0.19*
LDL cholesterol, mmol/L	3.15 ± 0.73	2.57 ± 0.41*
VLDL cholesterol, mmol/L	0.72 ± 0.27	0.68 ± 0.30*
Triglycerides, mmol/L	1.84 ± 0.73	2.49 ± 0.96*

Note: IMT — intima-media thickness; BP — blood pressure; SBP — systolic blood pressure; DBP — diastolic blood pressure; BMI — body mass index; HTN — arterial hypertension; HDL cholesterol — high-density lipoprotein cholesterol; LDL cholesterol — low-density lipoprotein cholesterol; VLDL cholesterol — very low-density lipoprotein cholesterol; * — $p < 0.05$.

normal BP (HNBP) is of undoubtful research and clinical interest.

Objective of the study is to determine the most clinically significant differences in groups of subjects with HNBP depending on whether they have unchanged or increased IMC thickness of carotid arteries, on the basis of the factor analysis method.

Design and methods

We examined 88 persons with HNBP, including 60 men and 28 women. Diagnostic criteria of HNBP complied with recommendations of the Russian Society of Cardiology (2010) [9]. BP was measured on both arms initially (later — on the right arms) in accordance with the N. S. Korotkoff method with Welch Allyn sphygmomanometer (Speidel + Keller, Germany) according to the common standard common technique. When between-arm BP difference was equal or over 10 mm Hg, further measurements were performed on the arm with the higher BP level. Diagnosis was based upon the mean value of two BP measurements at three visits (at an interval of 3 weeks) after the primary finding of HNBP.

Patients were divided into 2 groups: the 1st group included 45 persons with IMC thickness of carotid arteries of less than 0.9 mm, the 2nd group included 43 patients with IMC thickness of carotid arteries equal or over 0.9 mm. Brief characteristics of the groups are listed in Table 1.

Clinical blood and urine tests, biochemistry was performed by EVOISE 900, P 800 device (Hitachi, Japan). Glomerular filtration rate (GFR) and tubular reabsorption were calculated with the Tareyev-Rehberg method. 24-hour albuminuria was measured using DCA Vantag automatic analyzer (Siemens, USA). Urine was collected during one day, and microalbuminuria (MAU) was detected with the help of the device cartridge. The MAU indicator was equivalent to 24-hour monitoring. The values from 10 to 300 mg/day were reference values. A 12-lead electrocardiography (ECG) was performed with BIOSET-8000 in the supine position. ECG were analyzed according to the common criteria. Echocardiography (EchoCG) was performed with Vivid 4 device (GE, USA). The examination included one-dimensional EchoCG and two-dimensional examination in the mode of sectoral scanning, Doppler real time EchoCG according to the standard procedure recommended of the American Society of Echocardiography. Ambulatory BP monitoring (ABPM) with measurement of central BP and parameters of arterial stiffness — pulse wave velocity in the aorta (PWVao), reflected wave transit time (RWTT), augmentation index (Aix), arterial stiffness index (ASI) — was conducted with the oscillometric method by MnSDP-2 device and BP Lab software in extended edition of Vasotens 24 (Petr Telegin LLC, Russia). ECG Holter monitoring was performed within 20–24 hours with Medilog Exell device (Oxford, UK) in accordance with the common technique. Duplex scanning of carotid arteries was performed byEsaote Biomedica My Lab 70 devices (Italy) with 9–11 MHz linear sensors with an embedded ECG unit and software for Qlab vascular studies; the IMC thickness of the posterior wall of the common carotid arteria (CCA) was assessed in the automatic mode at a distance of 1 cm lower than carotid bifurcation. The IMC thickness value was calculated as the average IMC thickness of the right and left CCA. People with atherosclerotic plaques in carotid arteries were excluded. Treadmill test was performed stepwise with increasing continuous load on X-Scrabe 2 cycle ergometer with Ergo-metris 800S (USA) in accordance with the commonly used criteria. The radioimmunoassay method was also used to determine the plasma levels of the following hormones: adrenocorticotropic hormone, angiotensin I, aldosterone, thyroid stimulating hormone, cortisol, triiodothyronine, and thyroxine with application of Beckman Coulter standard sets (Czech Republic).

Statistics

A formal protocol was used to register all the results either in absolute terms or as nominal values (encoded with a binary code, a certain ordinal number was assigned to each sign). Student's

t-test was used to assess the differences, which were considered statistically significant at p-level ≤ 0.05.

Factor analysis was performed after correlation matrix was obtained. As a result, clinical signs were grouped in accordance with the syndrome concept. The first factor (set of symptoms) bears the most information about the studied phenomenon, which is determined with the percentage of the dispersion used. Each following factor bears less information, but it is orthogonal to the previous information, i. e. the factors are not correlated. 85 signs were subject to factor analysis. Statistical analysis was performed with the use of Statistica 6.0 software [10].

Results

Based on statistical analysis, 5 factors in each comparison group were distinguished, they describe 51.2% and 74.4% of dispersion of a mathematical model of HNBP patients in the 1st and 2nd groups, respectively (Table 2).

In the 1st comparison group (IMC thickness < 0.9 mm), the first factor, which accounted for 14.6% of the system dispersion, included sixteen signs: eight of them characterized vessel elasticity

Table 2

COMPARATIVE CHARACTERISTICS OF LEADING SETS OF SYMPTOMS

Factor	Group 1, IMT < 0.9 mm (n = 45)		Group 2, IMT ≥ 0.9 mm (n = 43)	
First	**"Vascular elasticity factor" (14.6 %)**		**"BP factor" (23.2 %)**	
	Age	–0.460	Duration of high normal BP	+0.468
	Hemoglobin	+0.568	Fibrinogen	+0.946
	ALAT	+0.592	USG	–0.593
	ASAT	+0.550	MAU	+0.775
	EDD LV	+0.498	Cortisol	–0.751
	ESD LV	+0.469	SBP, day	+0.966
	EDV LV	+0.481	DBP, day	+0.884
	ESV LV	+0.843	SBP, night	+0.883
	PP ao	–0.794	DBP, night	+0.903
	AIx ao, 24h	–0.738	SBP ao	+0.988
	AIx ao, day	–0.723	DBP ao	+0.935
	AIx ao, night	–0.860	SBP ao mean	+0.985
	ASI	+0.64	PP ao	+0.829
	Time of reflected pulse waves	+0.681	AIx ao, 24h	+0.849
	LVBF CCA	+0.61	SBP ao, day	+0.970
	F1 = 1/18.4 (–0.460X_1+…+0.610X_{16})		DBP ao, day	+0,900
			SBP ao, night	+0.985
			DBP ao, night	+0.957
			PP ao, day	+0.839
			PP ao, night	+0.805
			AIx ao, day	+0.844
			AIx ao, night	+0.866
			TI SBP, day	+0.966
			TI SBP, night	+0.856
			TI DBP, day	+0.793
			TI DBP, night	+0.733
			ND SBP	–0.456
			F1 = 1/35.1 (0.468X_1+...–0.456X_{27})	

Second	**"Cardiovascular risk factor" (11.2 %)**		**"Cardiovascular risk factor" (15.9 %)**	
	Age	+0.739	Family history of premature CVD	–0.482
	BMI	+0.898	BMI	+0.885
	Dyspnea with considerable physical activity	+0.508	Smoking	+0.700
	MAU	–0.490	Low physical activity	+0.820
	Triglycerides	+0.550	ASAT	+0.476
	Uric acid	+0.604	ALAT	+0.497
	LVMI	+0.543	Sodium	–0.694
	ISWT	+0.549	Potassium	+0.682
	PWT	+0.562	HDL cholesterol	–0.789
	LA	+0.777	LDL cholesterol	–0.758
	PWV ao	+0.526	VLDL cholesterol	+0.497
	Curl ICA	+0.690	TSH	–0.784
	GFR	+0.565	LVMI	+0.475
	F2 = 1/18.1 (+0.739X_1+…+0.565X_{13})		E/e	–0.553
			GFR	+0.736
			ESD LV	–0.593
			ESV LV	–0.517
			EF LV	+0.790
			ASI	+0.546
			SBP, day	+0.638
			DBP, day	+0.606
			SBP, night	+0.614
			DBP, night	+0.589
			LVBF CMA	+0.598
			LVBF BCA	+0.556
			F2 = 1/24.9 (–0.482X_1+…+0.556X_{25})	
Third	**"BP factor" (10.4 %)**		**"LV remodeling factor" (13.8 %)**	
	Platelets	+0.566	Age	+0.530
	Uric acid	+0.513	Duration of High normal BP	+0.546
	Tubular reabsorption	+0.570	Family history of premature CVD	–0.644
	GFR	+0.734	Hemoglobin	–0.520
	Thyroxine	+0.460	Creatinin	+0.533
	SBP, day	+0.782	Diuresis, day	–0.524
	DBP, day	+0.783	Diuresis, night	+0.637
	SBP, night	+0.544	USG	–0.614
	SBP ao	+0.684	LVMI	+0.799
	DBP ao	+0.727	E/e	–0.534
	SBP ao, day	+0.689	EDD LV	+0.834
	DBP ao, day	+0.663	ESD LV	+0.489
	SBP ao cp., day	+0.674	EDV LV	+0.828
	PWV ao	+0.658	ESV LV	+0.725
	TI SBP, day	+0.619	ISWT	+0.489
	TI DBP, day	+0.727	PWT	+0.520
	LVBF VA	–0.477	LA	–0.721
	F3 = 1/17,3 (+0,566X_1+…–0,477X_{17})		VE	–0.710
			AIx ao, night	+0.490
			ASI	–0.680
			PWV ao	+0.628
			LVBF IMT CCA	+0.787
			F3 = 1/23.2 (0.530X_1+…+0.787X_{23})	

Fourth	**“Cardiorenal interconnections factor” (7.7 %)**		**“Hormonal and metabolic interconnections factor” (12.1 %)**	
	Hemoglobin	+0.462	Duration of high normal BP	+0.518
	Fibrinogen	+0.530	Low physical activity	+0.461
	MAU	+0.548	Fundoscopic abnormalities (salus1)	+0.670
	Creatinin	+0.642	ALAT	–0.576
	Potassium	+0.536	Total cholesterol	–0.863
	Daytime diuresis	+0.566	Triglycerides	–0.677
	USG	–0.475	VLDL cholesterol	–0.482
	Triiodothyronine	+0.532	Aldosterone	+0.539
	ESD LV	+0.460	ACTH	+0.834
	ESV LV	+0.462	Tubular reabsorption	–0.873
	LVMI	+0.754	GFR	+0.456
	ISWT	+0.612	Triiodothyronine	+0.776
	PWT	+0.592	ESD LV	–0.595
	DBP, night	+0.549	ESV LV	–0.596
	SBP ao, night	+0.600	EF LV	+0.538
	DBP ao, night	+0.684	PWT	+0.634
	SBP ao cp., night	+0.617	LA	+0.502
	TI SBP, night	+0.456	AIx ao, day	–0.488
	TI DBP, night	+0.559	LVBF VA	+0.480
	F4 = 1/16.0 (0.462X$_{1...+}$0.559X$_{19}$)		LVBF MCA	+0.500
			F4 = 1/21.6 (0.518X$_1$+…+0.500X$_{20}$)	
Fifth	**“Reduced exercise tolerance factor” (7.5 %)**		**“Factor of vascular stiffness” (9.9 %)**	
	Low physical activity	+0.489	Age	+0.676
	Dyspnea with considerable physical activity	–0.704	Fundoscopic abnormalities (salus 1)	+0.451
	Angiotensin 1	+0.484	Potassium	+0.576
	Aldosterone	+0.53	Triglycerides	+0.573
	DBP, night	+0.545	Uric acid	+0.716
	SBP, day	+0.664	Angiotensin 1	–0.557
	TI SBP, night	+0.541	LA	+0.493
	TI DBP, night	+0.492	ПЭ	–0.774
	ND DBP	–0.472	AIx ao, day	+0.970
	F5 = 1/12.3 (0.489X$_1$+…-0.472X$_9$)		PWV ao	–0.486
			Time of reflected pulse waves	+0.906
			SBP	+0.462
			DBP	+0.719
			BP	+0.832
			ND SBP	–0.643
			ND DBP	–0.837
			LVBF CCA	–0.531
			LVBF ICA	–0.775
			F5 = 1/20.5 (0.676X$_1$+…-0.775X$_{18}$)	
Total, %	**51.6**		**74.6**	

Note: BP — blood pressure; SBP — systolic blood pressure; DBP — diastolic blood pressure; ND — nocturnal decline; BMI — body mass index; CVD — cardiovascular disease; MAU — microalbuminuria; GFR — glomerular filtration rate; ao — aorta; ALAT — alanine aminotransferase; ASAT — aspartate aminotransferase; PP — pulse pressure; HDL cholesterol — high-density lipoprotein cholesterol; LDL cholesterol — low-density lipoprotein cholesterol; VLDL cholesterol — very low-density lipoprotein cholesterol; USG — urine specific gravity; LV — left ventricle; LVMI — left ventricular mass index; EF— ejection fraction; LA — left atrium; ESD LV — end systolic diameter of LV; EDD LV — end diastolic diameter of LV; ESV LV — end systolic volume of LV; EDV LV — end diastolic volume of LV; IVS — interventricular septum; ASI — arterial stiffness index; PWV — pulse wave velocity; TI — time index; LVBF — linear velocity of blood flow; CCA — common carotid artery; ICA — internal carotid artery; ISWT — interventricular septal wall thickness; PWT — posterior wall thickness of LV.

(so the 1st set of symptoms was called a "vascular elasticity factor"), four of them characterized the size and volume of the left ventricle in both systole and diastole; and the rest four were not directly related to the state of the cardiovascular system (CVS). It is no coincidence that most of signs of the first factor characterize the CVS state, as pulse pressure is known to represent elastic properties of trunk vessels and the pumping function of the left ventricle [11]. Analysis of signs included in this factor confirms that changes in elastic vessels lead to changes in geometry of the left ventricle. A direct relationship between the pulse pressure value in the aorta and geometry of the left ventricle and a reverse correlation with the age within one factor are consistent. Thus, changes in elastic properties of vessels and left ventricular geometry in HNBP patients appear prior to occurrence of detectable vascular remodeling and are to some extent associated with the age of patients.

The second set of symptoms (factor) of the 1st comparison group, that accounts for 11.2% of the system dispersion, included the signs traditionally considered as cardiovascular risk factors, as well as the signs representing the left ventricular myocardial state. They were distributed as follows regarding the factor load: "body mass index" (BMI) (0.898), "age" (0.739), "uric acid" (0.604), "GFR" (0.565), "triglycerides" (0.550), "MAU" (-0.490). Therefore, it was called a "cardiovascular risk factor". Based on the analysis, the signs conditioning the CVD risk positively correlate with the signs characterizing the state of the left ventricle — myocardial mass, and wall thickness. It is important that the second factor does not include the BP-related signs. Thus, cardiovascular risk factors in patients with the IMC thickness < 0.9 mm (1st comparison group) were shown to be BP-independent predictors of cardiovascular remodeling as early as at the HNBP stage. The MAU negative value does not correspond to the proposed association. At the same time, high rate of GFR factor load, which positively correlates with the other parameters, suggests potential intraglomerular hyperfiltration that, in addition to MAU, is considered to be an unfavorable sign with regard to cardiovascular complications. To some extent, it confirms the analysis of the third and fourth factors of the analyzed mathematical model, which will be described later.

As opposed to the "risk factors of cardiovascular diseases", the third set of symptoms (10.4% of the system dispersion) included the signs (thirteen out of nineteen cases) related to both systolic (SBP) and diastolic (DBP) blood pressure. Thus, it was called the "BP factor". The vast majority of signs are positively interconnected, and mean daily SBP (+0.783) and DBP (+0.782) have the highest factor load. The average daily and average daytime SBP and DBP measured in the aorta have slightly weaker correlations. Within both the second and third factors the GFR demonstrates high positive factor load (+0.734), which indicates the connection between the GFR and SBP/DBP in 1st study group. The same is found for the "tubular reabsorption" (+0.570). Thus, the third set of symptoms demonstrates close connection between ABPM data and renal functions.

The fourth factor specifies this connection. Based on the analysis the signs included into the fourth factor might be grouped into the signs of "red blood" and hemocoagulation indicators; signs of renal functions; parameters of the left ventricular dimensions; and, finally, BP parameters. Irrespectively of the group, all signs have positive correlations within the factor (the "urine relative density" is the only exception). The fourth group of interrelated signs, including the parameters of renal and cardiovascular functions was called the "factor of cardiorenal interconnections" and composed 7.7% of the system dispersion. MAU was included into this set of symptoms and demonstrates high positive correlation with almost all other parameters confirming the recognized association between cardiovascular risk and urinary albumin excretion [12]. It is impostant that MAU is found as early as at the stage of HNBP, prior to the abnormal carotid IMC thickness.

The last, fifth factor is to some extent connected with the second factor — the "cardiovascular risk factor". The sign "shortness of breathing at significant physical load" (-0.704) is the most weighty. Moreover, except for the sign "nighttime

DBP reduction", it is negatively associated with the other parameters, i. e. shortness of breathing is associated with sedentary lifestyle and the tendency to blood pressure increase, which indicates lack of training. In addition, the nighttime DBP reduction also decreases. Therefore, the fifth factor was called "the factor of the decrease of physical load tolerability".

Thus, the mathematical model of a patient with IMC thickness < 0.9 mm and HNBP is a combination of sets of symptoms that represent vascular elasticity, cardiovascular risk, BP level, cardiorenal relations, and reduction of physical load tolerability.

Factor analysis performed in the 2nd comparison group (combination of HNBP and IMC thickness > 0.9 mm) demonstrated different results. The first factor appeared to be the most significant (23.2 % of the system dispersion). It appeared to be similar to the third factor of the 1st comparison group, so it was named the "BP factor". At the same time, it was the most weighty among all other sets of symptoms, and included the highest number of the parameters. All of these parameters are strongly and positively interrelated. Eighteen of twenty-seven signs are related to various ABPM parameters. The "nighttime SBP reduction" is negatively related to all other signs that is a specific feature of the daily BP profile in the analyzed comparison group ("non-dipper"), differentiating it from the 1st group. The specific feature is the inclusion of MAU associated with BP. Thus, there are direct connections between the BP level and the albuminuria degree. As in the 1st comparison group, cardiovascular risk factors composed the set of symptoms with the highest system dispersion rate (15.9 %). Thus, the "BMI" coefficient was +0.885, "smoking" — +0.700, "low exercise level" — +0.820, "very-low-density lipoproteins" — +0.497, and BP: "SBP" — +0.638, DBP — +0.606. So the second factor was named the "factor of cardiovascular risks".

The third factor is mostly composed by the parameters the left ventricular myocardium: dimensions, wall thickness, contractility. These parameters are directly interconnected and associated with the age, duration of the HNBP, some parameters of arterial elasticity, such as "arterial stiffness" (+0.490). Therefore, this factor is called the "left ventricle remodeling factor".

The fourth factor united 12.1 % of the system dispersion. It is mostly composed by the parameters of lipid metabolism and hormonal status (adrenocorticotropic hormone, triiodothyronine, aldosterone). In addition, lipids and hormones have reverse associations. Based on these data, the fourth factor was called the "factor of hormonal and metabolic interconnections".

Finally, the fifth factor takes 9.9 % of the system dispersion and includes a range of signs, which mostly characterize vascular wall stiffness and various ABPM parameters. It was called the "vessel stiffness factor". Interestingly, the coefficients of vascular elasticity are negatively related to nighttime BP reduction, i. e. the higher vessel stiffness the lower the degree of nighttime SBP and DBP reduction. In addition, vascular stiffness is directly related to such signs as "age" (+0.676), frequency of "changes in eye fundus vessels (salus 1)" (+0.451), some blood parameters (triglycerides, uric acid, potassium).

Conclusions

The factor analysis showed the following differences. Firstly, though each group included five factors, the dispersion of each factor in subjects with IMC thickness > 0.9 mm (2nd group) is higher than among those with its normal value (1st group), indicating a higher stability of the changes.

Secondly, while in the 1st group the factor of "the vascular elasticity" was the most significant, in the 2nd group the "BP" set of symptoms associated with the duration of HNBP and with MAU is the most important factor. BP factor only holds the third place in the 1st group regarding in the entire mathematical model of patients with HNBP.

Thirdly, the factor of "cardiovascular risks" has almost the same value in both comparison groups, though there are certain differences regarding the set of parameters. While BP level is not a leading factor regarding other traditional RFs in the group with the IMC thickness < 0.9 mm (1st group), its weight is rather high in the group with the IMC thickness > 0.9 mm (2nd group). The fifth factor of the 1st comparison group shows the correlation

between tolerability to physical load and BP levels, which specifies the value of risk factors in the mathematical model of HNBP.

Fourthly, factor analysis demonstrated that cardiorenal interconnections began revealing quite early, when IMC thickness of carotid arteries was still within normal range, though the dispersion percentage of the fourth factor was low. At the same time, in the group of persons with IMC thickness > 0.9 mm (2nd group), the signs that represent renal dysfunctions are included into almost all sets of symptoms with high enough degree of positive interconnection.

Fifthly, both vascular and BP-associated left ventricular remodeling are typical for the group with increased carotid IMC thickness (2nd group). Moreover, changes in structural and functional parameters of vessel walls did not depend on the serum lipid level, i. e. they seem to have non-atherogenic nature. Thus, carotid IMC thickness in this age group is not only a marker of atherosclerotic lesions.

Sixthly, the type of BP circadian rhythms affects vascular stiffness: "non-dipper" type is typical for persons with increased carotid IMC thickness proven by the fifth factor.

Thus, the increase in carotid IMC thickness in people with HNBP may indicate transformation of functional vascular changes into structural ones leading subsequently to the HTN development.

Conflict of interest
The authors declare no conflict of interest.

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