Ambulatory blood pressure of adults in Novosibirsk, Russia: interim report on a population study

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Objective To describe the distributions of the ambulatory blood pressure in a sample drawn from the Siberian population.

Methods In the European Project On Genes in Hypertension (EPOGH), a random population sample of 162 persons (72 men and 90 women) was investigated in Novosibirsk, Russia. Mean age ($\pm$ SD) was 40.6 $\pm$ 15.3 years. Validated oscillometric 90207 SpaceLabs monitors were programmed to obtain ambulatory blood pressure readings at intervals of 15 min from 0800 h to 2200 h and at 30 min intervals from 2200 h to 0800 h. Daytime and nighttime were defined using short fixed-clock time intervals, which ranged from 1000 h to 2000 h and from midnight to 0600 h, respectively.

Results In the 162 participants, of whom 54 were hypertensive, 24-h clocktime day and clocktime night blood pressures averaged 120/73, 126/79 and 110/60 mmHg, respectively. Compared with daytime values, blood pressures at the clinic were 5.7/1.1 mmHg lower in 108 normotensive people, but 17.0/13.1 mmHg higher in 54 hypertensive patients. In the normotensive subgroup, the 95th percentiles of the 24-h clocktime day and clocktime night blood pressures were 128/81, 136/86 and 118/72 mmHg, respectively.

Conclusion In comparison with other population surveys, the present interim report on the EPOGH study produced consistent results with respect to the distributions of the ambulatory measurements both in normotensive subjects and in the overall study population. *Blood Press Monit* 5:291–296 © 2000 Lippincott Williams & Wilkins.

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Introduction

The distribution of the ambulatory blood pressure must be better characterized in various conditions and populations and compared with conventional blood pressure measurements. Along these lines, several large-scale epidemiological studies in well-defined professional groups [1,2], in normotensive and hypertensive subjects [3–6] and in the population at large [7–15] have recently been completed. In an attempt to describe the distribution of the ambulatory blood pressure and to determine operational thresholds for ambulatory blood pressure monitoring, the 24-h blood pressure was recorded in a random sample drawn from the population of Novosibirsk, Russia.

Methods

Study population

In this population survey, the participants (minimum age 18 years) were randomly selected from the inhabitants of the Oktyabrsky district of Novosibirsk city. The sample comprised 200 subjects (response rate 66%). At the time of writing of this report, 165 of the participants had undergone ambulatory blood pressure measurement and were included in the analysis.

Auscultatory blood pressure readings

The subjects enrolled in this study were invited for technical examinations at a locally organized clinic. A self-administered questionnaire was employed to inquire into each participant's medical history, smoking habits, alcohol consumption and intake of medications. The participants were seated and asked to relax for 5 min. The observers measured the subjects' sitting blood pressure five times consecutively. In most subjects standard cuffs were used, which had an inflatable bladder with a length of 22 cm and a width of 12 cm. If arm circumference exceeded 31 cm, larger cuffs with 35 × 15 cm bladder were employed. The guidelines of the British Hypertension Society were followed [16]. Systolic and diastolic (phase V) pressures were determined to the nearest 2 mmHg. For analysis, the five readings of the clinic visit were averaged.

In agreement with current medical practice, normotension and hypertension were defined solely on the basis of traditional sphygmomanometry [17,18]. Normotension was defined as a conventional blood pressure not

higher than 139 mmHg systolic and 89 mmHg diastolic. Definite (moderate or severe) hypertension was present if the conventional blood pressure readings exceeded 160 mmHg systolic or 95 mmHg diastolic, or when the patients were on antihypertensive medication regardless of their actual blood pressure. Untreated subjects, whose conventional blood pressure ranged from 140 to 159 mmHg systolic or from 90 to 94 mmHg diastolic, were considered to have mild (borderline) hypertension.

The observers involved in this report ($n = 2$) were tested for the accuracy of their blood pressure measurements at 3-month intervals. Digit preference was checked at 6-month intervals.

Ambulatory blood pressure measurement

The ambulatory measurements were obtained with oscillometric SpaceLabs 90202 monitors (SpaceLabs Inc., Redmond, Washington, USA) [19,20]. The calibration of these devices was checked monthly against a mercury column. The recorders were programmed to obtain measurements with an interval of 15 min from 0800 h until 2200 h and every 30 min from 2200 h to 0800 h.

If the ambulatory recordings were longer than 24 h, only the first 24 h were used for analysis. Intra-individual means of the ambulatory measurements were weighted by the time interval between successive readings [21]. In keeping with current recommendations [22], daytime was defined as the interval from 1000 h to 2000 h and nighttime from midnight to 0600 h. These definitions have been used in previous publications [10,21] and eliminate the transition periods in the morning and the evening during which the blood pressure changes rapidly in most subjects.

Three subjects were removed from the analysis, because their ambulatory recording covered less than 20 h, or because less than 10 readings were available for the computation of the daytime blood pressure or less than 5 for the blood pressure at night.

Statistical analysis

Database management and statistical analyses were performed with SAS software, version 6.12 (SAS Institute Inc., Cary, North Carolina, USA). The central tendency and the spread of the data are reported as the mean ± SD. Departure from normality was evaluated by Shapiro–Wilk's statistic [23] and skewness by the computation of the coefficient of skewness, i.e. the third moment about the mean divided by the cube of the standard deviation [24]. The normal distribution was used to determine the significance of the coefficient of skewness [24].

The methods of analysis included Student's t-test, the

χ^2 statistic, and simple and multiple regression [25]. Multivariate analysis of variance was performed to test the null hypothesis of no differences between the parameters of regression equations [25,26]. The discrepancy between the daytime ambulatory measurements and the conventional blood pressure readings at the clinic was investigated by the methods proposed by Gould [27]. For each comparison, the mean discrepancy and the standard deviation of the individual differences were calculated.

Results

Characteristics of the population

The participants, 72 men and 90 women, were 40.6 ± 15 years old (mean ± SD; range 18–76 years). Body weight in the 72 men averaged 75.3 ± 12.8 kg, body mass index 24.5 ± 3.7 kg/m², and circumference of the upper arm 29.0 ± 2.6 cm (range 24.0–37.0 cm); in women these values were 69.2 ± 12.2 kg, 26.3 ± 5.7 kg/m², and 28.6 ± 4.2 cm (20.0–38.0 cm), respectively.

Of the 162 participants, 46 (28.4%, 36 men and 10 women) were smokers; 4 women (12.3% of those aged 55 years or younger) took the contraceptive pill.

Ambulatory measurements

In all subjects the distribution of the 24-h systolic blood pressure departed from normality ($P < 0.01$; Fig. 1) and was positively skewed ($P < 0.001$); the coefficient of skewness was 0.44. The distribution of the 24-h diastolic blood pressure was close to normality ($P = 0.1$; Fig. 1); the coefficient of skewness was 0.25.

Fig. 1
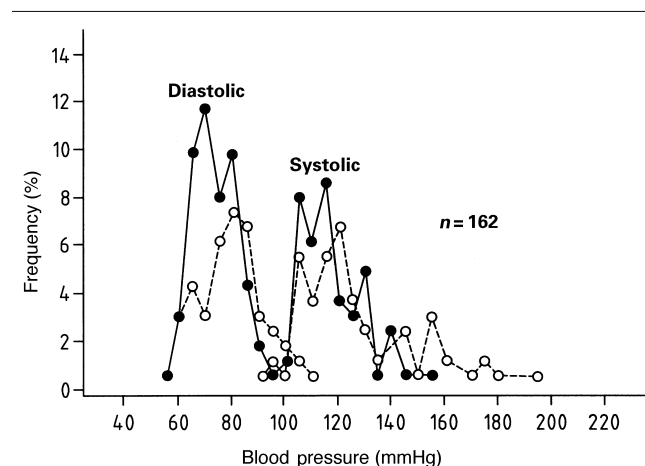
The distribution of the systolic and diastolic blood pressures in 162 individuals drawn at random from the general population. ●, 24-h ambulatory blood pressure; ○, conventional blood pressure measured at the clinic.

Fig. 2
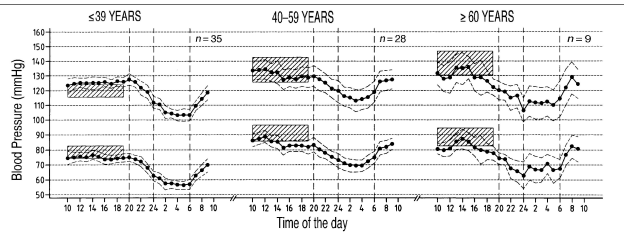
Ambulatory systolic (upper curves) and diastolic (lower curves) blood pressures in men in three age categories. The hourly means with 95% confidence interval are presented. The shaded bands indicate the 95% confidence interval for the clinic blood pressure measurements (five readings in the sitting position).

In all participants combined, the 24-h ambulatory blood pressures averaged 119.8 mmHg systolic and 73.2 mmHg diastolic [95% confidence intervals (CI) 118.0−121.6 and 72.0−74.5 mmHg]. The daytime blood pressures averaged 125.6 and 78.7 mmHg (CI 123.8−127.4 and 77.5−79.9 mmHg) and the nighttime pressures were 110.2 and 64.2 mmHg (CI 108.0−112.3 and 62.7−65.7 mmHg). The average blood pressures and corresponding 95% CI for any hour during the day are presented for men and women in three age groups (≤ 39, 40−59 and ≥ 60 years) in Figure 2 and Figure 3.

The hourly means with 95% confidence interval are presented. The shaded bands indicate the 95% confidence interval for the clinic blood pressure measurements (five readings in the sitting position).

A total of 54 (33.3%) participants were hypertensive, because their conventional blood pressure measured at the clinic exceeded the limits of 139 mmHg systolic or 89 mmHg diastolic (*n* = 34; 63.0%) or because they were on treatment with antihypertensive drugs (*n* = 20; 37.0%). Of these 54 patients, 10 were only borderline hypertensive and 44 had definite hypertension.

In the 108 normotensive people, the 24-h blood pressures averaged 114.5 mmHg systolic and 69.7 mmHg diastolic (CI 112.9−116.1 and 68.6−70.9 mmHg). The daytime blood pressures in the normotensive subjects were 120.8 and 75.7 mmHg (CI 119.0−122.6 and 74.5−77.0 mmHg) and the blood pressures at night were 104.4 and 60.1 mmHg (CI 102.7−106.1 and 58.8−61.4 mmHg). Additional statistics of the ambulatory blood pressures are presented for normotensive men and women and two age groups (≤ 39, ≥ 40 years) separately in Table 1.

Clinic versus ambulatory measurements

In the total study sample (*n* = 162), the blood pressures at the clinic averaged 127.4 mmHg systolic and

83.0 mmHg diastolic (CI 124.1−130.8 and 80.9−85.1 mmHg). The 95% CI of the average blood pressures obtained at the clinic visit in the six subgroups by sex and age are shown in Figure 2 and Figure 3 (hatched area).

In the total study sample (*n* = 162), systolic blood pressure at the clinic was 1.9 ± 16.2 mmHg higher (*P* < 0.001) than the daytime systolic blood pressure (CI 0.6−4.4 mmHg); for diastolic blood pressure the corresponding difference between the clinic and daytime pressures averaged 4.3 ± 10.4 mmHg (CI 2.7−5.9 mmHg; *P* < 0.001). The blood pressures at the clinic were considerably higher (*P* < 0.001) than the 24-h blood pressures, as the latter included both the daytime and the low nighttime values.

In the 108 normotensive subjects, the systolic and diastolic blood pressures at clinic averaged 115.1 mmHg (CI 113.3−116.9 mmHg) and 75.6 mmHg (CI 74.2−77.1 mmHg), respectively. In the normotensive subjects, systolic and diastolic blood pressures measured at the clinic were on average 5.7 ± 9.9 mmHg (CI 3.9−7.6 mmHg; *P* < 0.001) and 0.1 ± 8.0 mmHg (CI −1.4 to 1.6 mmHg) lower than the corresponding daytime blood pressures.

In contrast to the normotensive people, the 54 hypertensive patients had mean clinic blood pressures which were higher than daytime ambulatory measurements (*P* < 0.001). Compared with the latter values, the hypertensives' blood pressures at the clinic were systolic 17.1 mmHg (CI 12.8−21.3 mmHg) and diastolic 13.1 mmHg (CI 10.6−15.5 mmHg) more elevated.

Age as blood pressure determinant

There was a curvilinear association between the clinic and the 24-h blood pressures and age (Figure 4). A regression model, including age and age-squared, was therefore required to describe these relations in men and women. In men, age explained 19.2% of the variance of systolic pressure at the clinic and 17.2% of the variability of the corresponding diastolic pressure. In

Fig. 3
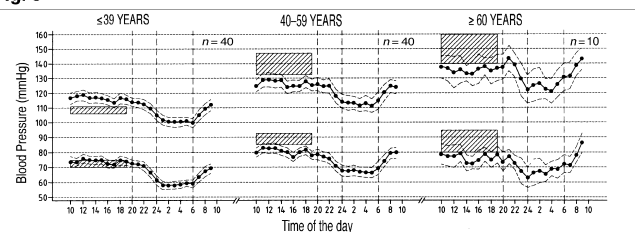
Ambulatory systolic (upper curves) and diastolic (lower curves) blood pressures in women in three age categories.

Table 1 **Systolic-diastolic blood pressures (mm Hg) in 108 subjects who were randomly selected from the population and who were normotensive at the clinic visit**

	Men			Women			Both sexes
	< 40 years	≥ 40 years	All men	< 40 years	≥ 40 years	All women	
Number	32	18	50	39	19	58	108
Clinic blood pressure[a]							
Mean	118/76	119/80	118/78	109/72	120/78	112/74	115/76
SD	9/8	7/5	9/7	8/8	8/5	10/8	10/8
P5	103/61	103/69	103/66	94/61	108/69	95/61	99/62
P50	117/77	120/81	118/79	108/72	119/79	125/84	128/85
P90	131/86	126/85	129/86	120/84	133/86	125/84	128/85
P95	135/87	127/87	131/87	124/87	138/88	129/87	131/87
Daytime blood pressure							
Mean	125/75	123/80	124/76	116/75	120/77	118/75	121/76
SD	8/7	14/7	10/7	8/6	6/6	8/6	9/7
P5	112/61	107/68	109/65	102/64	110/64	104/64	108/65
P50	125/73	118/79	124/76	116/74	119/77	119/75	120/75
P90	135/83	145/89	137/85	129/83	132/84	129/83	133/84
P95	136/84	150/90	140/87	132/86	133/85	132/85	136/86
Night-time blood pressure							
Mean	107/58	106/65	106/60	102/59	105/62	103/60	104/60
SD	9/7	11/5	9/7	8/6	9/9	8/7	9/7
P5	94/48	91/58	94/50	93/50	84/45	93/50	93/50
P50	109/57	104/64	107/60	99/58	106/63	101/59	103/59
P90	117/68	120/73	117/71	115/68	117/72	115/70	117/71
P95	120/72	128/75	120/72	115/71	122/77	117/72	118/72
Whole day blood pressure							
Mean	118/68	117/75	118/70	111/68	115/71	112/69	115/70
SD	7/6	12/6	9/6	7/6	7/7	7/6	9/6
P5	107/57	102/67	106/60	100/59	98/58	100/59	102/59
P50	118/68	114/74	116/70	110/68	116/73	112/69	114/69
P90	126/82	139/82	129/79	121/76	126/81	121/79	126/79
P95	131/85	140/85	132/81	125/81	128/81	126/81	128/81

Normotension was defined as a systolic pressure < 140 mmHg and a diastolic pressure < 90 mmHg on conventional blood pressure measurement at the clinic (average of five readings in the sitting position). Daytime ranges from 1000 h to 2000 h and night-time from midnight to 0600h. [a]Blood pressure readings obtained by conventional sphygmomanometry.

women, these percentages were 48.3% and 33.9%, respectively ($P < 0.001$ for all). For the 24-h systolic and diastolic blood pressures, the variance attributable to age amounted, respectively, to 7.9% ($P = 0.02$) and 30.8% ($P < 0.001$) in men and to 36.6% ($P < 0.001$) and 15.3% ($P < 0.001$) in women. Thus, with the exception of diastolic blood pressure in men, the relations with age were weaker for the 24-h than for the clinic blood pressures (Fig. 4).

Discussion
In the present study a random population sample was examined. The response rate was 66%. The ambulatory blood pressure in all participants aged 18–76 years averaged 120/73 mmHg over the whole day, 126/79 mmHg during daytime and 110/60 mmHg at night.

In previous studies which recruited mainly healthy subjects or patients referred to specialized clinics to exclude the diagnosis of hypertension (for review, see [3]) the average systolic blood pressures over the whole day ranged from 111 to 124 mmHg, the daytime systolic pressure averages ranged from 115 to 128 mmHg and the nighttime systolic means from 99 to 111 mmHg; the corresponding ranges for the diastolic blood pressure

means embraced 59 and 79 mmHg, 63 and 85 mmHg and 51 and 70 mmHg, respectively [3]. Furthermore, the means of the ambulatory measurements in the present study were almost identical to those noticed for the 24-h, daytime and nighttime blood pressures in a recent Belgian population study (119/71, 125/77 and 108/62 mmHg, respectively) [10].

The present study confirmed that daytime ambulatory blood pressure was on average lower than the conventional blood pressure in hypertensive patients, whereas the opposite was observed in individuals who were normotensive on regular sphygmomanometry. In our study the conventional blood pressure compared with the daytime blood pressure was 5.7/0.1 mmHg lower in 108 normotensive people, but 17.1/13.1 mmHg higher in 54 hypertensive patients. A similar trend was also observed in the International Database of Ambulatory Blood Pressure Monitoring [5]. Observer bias and the white-coat effect [28–30] may explain why in hypertensive patients the blood pressure at the clinic was usually higher than the daytime ambulatory blood pressure. On the other hand, in the normotensive participants, the daytime ambulatory blood pressure was recorded during regular activities, when the blood pressure may rise slightly due to physical or psychological stress. Moreover, in normotensive people, the conven-

Fig. 4
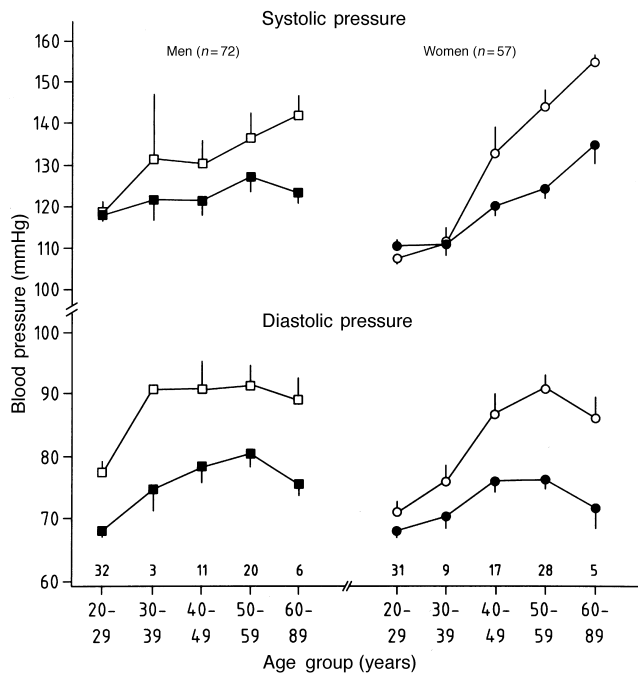
The conventionally measured blood pressure and the 24-h ambulatory blood pressure by age in men (squares) and women (circles). Values are means ± SEM. Conventionally measured blood pressure (average of five readings at the clinic; ○, □); 24-h ambulatory blood pressure (● or ■).

tional pressure may decrease by a few mmHg, when measured in relaxed conditions after a few minutes rest in the sitting position.

In proposing operational thresholds for use in clinical practice, the present study should not be considered in isolation. In the normotensive participants enrolled in this study, the 95th percentiles were considered as the upper limits of normality for the 24-h, clocktime day and clocktime night blood pressures. These values were 128/81, 136/86 and 118/72 mmHg, respectively (Table 1). In previous analyses [10], averaging the 95th percentiles in normotensives and rounding the resulting boundaries downwards or upwards to the nearest value ending in 0 or 5, produced working definitions of normality for ambulatory blood pressure monitoring, which can be easily remembered. Following the same procedure, the upper limits of normotension in the Novosibirsk population, would be values less than 130/80 mmHg for the 24-h pressures and 135/85 and 120/70 mmHg for the daytime and nighttime pressures. These preliminary threshold values for the population of Novosibirsk do not account for sex and age. However, in agreement with previous reports [7,9], the present data (Fig. 4) also confirmed that age is a much

stronger correlate of the conventional than of the ambulatory blood pressure.

The present study has some limitations because it involved only 162 participants, of whom 33.3% were borderline or definitely hypertensive. Nevertheless, this first interim report, based on the Novosibirsk arm of the EPOGH study, attempted to describe the distribution of the ambulatory blood pressure measurements and to determine a preliminary threshold for ambulatory blood pressure monitoring in a random sample drawn from the population of Novosibirsk, Russia. In comparison with several large studies on ambulatory blood pressure monitoring [2,5,10,15], the present interim report produced consistent results with respect to the distributions of the ambulatory measurements in the general population.

Acknowledgements

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