Assessment of casual blood pressure variations

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Summary

All residents in a suburban community in southern Sweden, 8 years of age and older, were invited to an ophthalmological examination. The examination included a blood pressure determination.

Of the 1917 persons invited 85.5% took part in the study. 3.5% of these were excluded because they were taking antihypertensive drugs. The investigations were conducted during 14 consecutive months and at different times of the day.

The systolic and diastolic blood pressure distribution curves exhibited a positive skewing. The blood pressures rose to a plateau with essentially unchanged pressures in the age groups 28-32 years up to 38-42 years. In these ages, the systolic blood pressure was significantly higher among the males than among the females. The relation was reversed in the age groups above 48 years. The diastolic blood pressure showed no significant sex differences in the various age groups.

A multiple linear regression analysis was used to determine whether there were diurnal and seasonal effects on the blood pressure independent of the age and sex. The systolic blood pressure during the winter months was 4.1 and 5.0 mmHg higher in the male and female subjects respectively, while the diastolic blood pressure during the winter months was 1.7 and 1.9 mmHg higher in the male and female subjects respectively. The time of day had no effect on the systolic blood pressure while the diastolic blood pressure increased by 0.24 and 0.27 mmHg/hr from 8 a.m. to 9 p.m. in the male and female subjects respectively.

It is concluded that the small genuine effects of the time of measurement of casual blood pressure lack practical importance in screening of hypertension.

Introduction

Many investigations conducted in representative samples of different populations have shown that

the systolic and diastolic blood pressures increase with age (Hamilton *et al.*, 1954; Bøe, Humerfelt and Wedervang, 1957; Comstock, 1957; Miall and Lovell, 1967). The elevation of blood pressure with age is greater in females than in males (Kagan *et al.*, 1958). The distributions of both systolic and diastolic blood pressures are considered to be unimodal but to manifest a skew to the right (Epstein, 1960).

The variation in blood pressure with the time of day has been studied in small groups of selected individuals. The blood pressure decreases appreciably during sleep but contradictory results have been obtained with respect to variations in blood pressure during the waking hours (Kain, Hinman and Sokolow, 1964; Richardson *et al.*, 1964; Athanassiadis *et al.*, 1969; Irving *et al.*, 1974).

With one exception (Sasaki *et al.*, 1969) studies of seasonal variations in blood pressure have also been conducted on selected groups of patients (Brown, 1930; Rose, 1961; Palmi, 1962; Paul *et al.*, 1963). The results suggest that the blood pressure is lowest during the warm season of the year.

Variations in blood pressure with season and time of day might be important both for patient care and for community-based studies of hypertension. The present study was undertaken to investigate these points further as a preliminary to a more comprehensive study of hypertension.

Material

The material was derived from a general ophthalmic population survey carried out at the Dalby Community Care Centre in southern Sweden from March 1969 to April 1970. Invitations with an appointment notification and a brief questionnaire were mailed in rotation, following a directory, to all persons, aged 8 years or more, who had been resident in the village, surrounding the Centre, since December 1968. The fact that a measurement of the blood pressure was part of the examination was not mentioned in the invitation. The questionnaire included a question as to what present medications

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were being used. Examinations were conducted from 8 a.m. to 9 p.m. In order to improve attendance, alterations of appointments were encouraged.

Of 1917 persons invited 1703 (89%) took part in the survey. Sixty-seven persons using drugs listed in a Swedish pharmacopoeia (*Farmaceutiska specialiteter i Sverige*, 1969) under the heading 'agents in hypertension' were excluded from the present study. The blood pressure measurement was omitted in sixty-six cases—usually because applanation tonometry was impossible or unreliable. Age and sex distributions are given in Table 1. Information about non-participants and persons not applanated has been given in an earlier report (Bengtsson, 1972).

Methods

The systolic blood pressure and diastolic (phase five) blood pressures were measured on the right arm immediately after the subject had assumed the recumbent position. One mercury manometer and cuffs of three different sizes (9×28, 12×35 and 15×43 cm) were used. The readings were determined to the nearest 5 mmHg (1 mmHg≈0.133 kPa). All measurements were made by the same nurse. The room temperature was 21–23°C.

The time of day was noted in whole hours. In order to obtain an expression for season, a dummy variable was assigned the value 0 (zero) for persons attending during the months May–October—and the value 1 for others. This classification was adopted since the mean temperature at Dalby is highest for May–October and lowest for November–April (Statistisk årsbok, 1970; Lunds kommun: Statistisk årsbok, 1972).

All data were recorded immediately on special forms. Transfer to punch cards and further treatment were performed at the Computer Centre in Lund.

The multiple regression analysis was carried out with a standard computer program (BMD 02R) (Dixon, 1970). For polynomial approximation, in accordance with the least square criterion, a method of orthogonalization (Björck and Dahlkvist, 1974) was used.

The hypothesis that no differences existed between mean values of two groups was checked with Student's *t*-test.

All values are given as mean $\pm$ s.d. unless otherwise stated.

Results

1. Blood pressure and age

Table 2 shows the mean values for the systolic and diastolic blood pressures within the different male and female age groups. The systolic and the diastolic blood pressures increased with age (see also Fig. 1). The increase was most pronounced for the systolic blood pressure.

FIG. 1. Systolic and diastolic mean blood pressures and age. Males = — (n = 780), females = - - - (n = 790). Conversion from traditional units to SI units: 1 mmHg ≈ 0.133 kPa.

TABLE 1. Number of invited, attending, untreated and examined men and women in different age groups

Age (years)	Invited		In attendance		Untreated		Examined	
	Men	Women	Men	Women	Men	Women	Men	Women
8–9	48	45	46	43	46	43	44	38
10–19	160	147	141	134	141	134	133	128
20–29	158	166	127	154	127	154	125	149
30–39	179	172	160	163	160	163	155	158
40–49	141	132	120	117	120	112	116	105
50–59	107	102	93	94	90	85	90	82
60–69	95	97	86	86	76	75	75	73
70–79	48	74	40	62	34	48	33	46
80–	18	28	15	22	12	16	9	11
Total	954	963	828	875	806	830	780	790

In the male subjects the systolic blood pressure rose significantly ($P<0.001$) from one age group to the next in the interval 8 to 22 years. Thereafter, the systolic blood pressure remained essentially unchanged ($P>0.05$) up to the 38–42-year-old age group. Among subjects 43 years or older there was a significant positive correlation between blood pressure and age ($P<0.001$).

In the female subjects the systolic blood pressure rose significantly from the 8–12-year-old age group to the 13–17-year-old age group ($P<0.01$) and also from the 18–22-year-old age group to the 23–27-year-old age group ($P<0.05$). Thereafter, the systolic blood pressure remained essentially unchanged ($P>0.05$) up to the 38–42-year-old age group. In older females the blood pressure again had a significant positive correlation with age ($P<0.001$).

The diastolic blood pressure appeared to increase more steadily with age, even if there was a tendency for the curve to level out somewhat in the interval 28 to 42 years. The correlation between diastolic blood pressure and age was highly significant ($P<0.001$).

2. Blood pressure and sex

A comparison between the sexes with regard to the systolic blood pressure, revealed that it was essentially alike in the 8–12- and 13–17-year-old age groups ($P>0.05$). From the 18–22-year-old age group up to the 38–42-year-old age group, the systolic blood pressure was significantly higher in the male subjects. In the ages above the 48–52-year-old age group the mean value of the systolic blood pressure of the female subjects was significantly higher than the corresponding mean value of the male subjects.

The diastolic blood pressure showed no significant sex differences in the various age groups.

3. Distribution and dispersion of blood pressures

The distributions were skewed to the right. This was true for both systolic and diastolic pressures, for both sexes and all age groups. The age- and sex-specific distribution curves remained asymmetrical even after logarithmic transformation.

The dispersion of the systolic and diastolic blood pressures increased with age in both the male and female subjects. From Table 2 it is evident that the dispersions are, above all, increased in the ages above the 38–42-year-old age group.

In the male subjects the coefficients of variation for systolic blood pressure ranged from 7.8% in the 28–32-year-old age group to 15.8% in the 68–72-year-old age group. The diastolic blood pressure showed the lowest and the highest coefficients of variation, 7.1 and 15.0% respectively, in the same age groups.

In the female subjects the coefficients of variation for systolic blood pressure ranged from 6.3% in the 18–22-year-old age group to 18.3% in the 53–57-year-old age group. The diastolic blood pressure showed the lowest and the highest coefficients of variation, 7.3 and 12.2% respectively, in the same age groups.

4. Blood pressure and time of measurement

Older persons attended, to a greater degree, during the morning hours and in winter months, whereas wage earners and school children more often were in attendance early in the morning, after work or school and during the summer. In order to separate

TABLE 2. Systolic and diastolic blood pressures, mean $\pm$ s.d. (mmHg) for male and female subjects within different age groups

Age group (years)	Systolic blood pressure				Diastolic blood pressure			
	Males (No.)	Males (Mean $\pm$ s.d.)	Females (No.)	Females (Mean $\pm$ s.d.)	Males (No.)	Males (Mean $\pm$ s.d.)	Females (No.)	Females (Mean $\pm$ s.d.)
8–12	96	113.1 $\pm$ 9.5	79	114.2 $\pm$ 7.3	96	74.8 $\pm$ 8.0	79	75.4 $\pm$ 6.0
13–17	66	121.1 $\pm$ 12.2	67	117.9 $\pm$ 7.9	66	77.0 $\pm$ 7.3	67	78.1 $\pm$ 6.5
18–22	42	127.3 $\pm$ 14.1	53	118.2 $\pm$ 7.4	42	80.0 $\pm$ 7.0	53	77.8 $\pm$ 5.7
23–27	67	126.9 $\pm$ 10.1	75	121.3 $\pm$ 10.9	67	81.9 $\pm$ 7.9	75	80.3 $\pm$ 7.4
28–32	76	124.1 $\pm$ 9.7	101	120.5 $\pm$ 9.1	76	80.1 $\pm$ 5.7	101	78.8 $\pm$ 7.0
33–37	84	126.4 $\pm$ 12.2	69	121.4 $\pm$ 10.6	84	82.6 $\pm$ 7.8	69	80.9 $\pm$ 7.7
38–42	68	126.0 $\pm$ 11.8	72	121.7 $\pm$ 12.0	68	83.3 $\pm$ 8.3	72	81.3 $\pm$ 7.7
43–47	60	130.6 $\pm$ 13.7	50	129.0 $\pm$ 15.9	60	86.0 $\pm$ 9.0	50	85.3 $\pm$ 8.4
48–52	39	134.2 $\pm$ 16.4	39	137.1 $\pm$ 20.4	39	88.3 $\pm$ 9.6	39	88.3 $\pm$ 10.8
53–57	41	137.4 $\pm$ 16.8	32	144.2 $\pm$ 26.4	41	89.8 $\pm$ 11.1	32	88.3 $\pm$ 10.8
58–62	50	141.7 $\pm$ 19.3	43	152.9 $\pm$ 25.6	50	89.5 $\pm$ 9.3	43	92.8 $\pm$ 10.1
63–67	38	148.0 $\pm$ 20.1	39	155.5 $\pm$ 23.7	38	92.2 $\pm$ 9.9	39	92.2 $\pm$ 10.2
68–72	27	156.7 $\pm$ 24.7	36	158.8 $\pm$ 23.8	27	94.1 $\pm$ 14.1	36	91.8 $\pm$ 11.0
73–	26	155.0 $\pm$ 23.2	35	170.0 $\pm$ 22.8	26	92.9 $\pm$ 11.1	35	98.0 $\pm$ 10.2

Conversion from traditional units to SI units: 1 mmHg $\approx$ 0.133 kPa.

the effects of the time of measurement from those of age and sex a multiple regression analysis was performed.

At this stage the facts that the relation between systolic blood pressure and age was not linear and that the distribution curves showed a positive skew (see above) had to be taken into account. Therefore, an attempt was made to fit the data also to second and third degree polynomials before and after logarithmic transformation of the blood pressure values (Table 3).

Table 3 shows that neither polynomial approximation nor logarithmic transformation resulted in an essential improvement of the correlation between the observed and expected blood pressures. A linear regression analysis was therefore considered adequate—and logarithms unwarranted—for the present purpose.

The goal of the regression analysis was to derive an equation: $y = a + b_1x_1 + b_2x_2 + b_3x_3 + e$ expressing blood pressure (y or the 'dependent variable') as a mathematical function of age, season and time of day (x_1 , x_2 and x_3 or the 'independent variables'), a constant (a , or the 'y-intercept') and an error term (e , 'the residual' or the difference between observed blood pressures and blood pressures expected from the independent variables in the equation).

To this end a sequence of regression equations was computed in a stepwise manner. At each step the independent variable which had the highest partial correlation with the dependent variable (i.e. the highest correlation with the residuals) was added to the regression equation. The course of events can be followed in Table 4.

In both sexes the correlations between blood pressure and age were by far the greatest and age was the independent variable entered first in all cases.

The total correlations between season and blood pressure were quite substantial (0.20 to 0.26) but, as soon as age had been added to the regression equation, the partial correlations between season and blood pressure were markedly reduced, even though they remained highly significant ($P < 0.001$).

The total correlation between time of day and blood pressure was 0.11 for the diastolic pressure in males but very small (-0.01 to 0.05) for systolic pressures and in females. When the correlations with age had been taken into account the partial correlations between time of day and systolic blood pressure remained insignificant while the partial correlation between time of day and diastolic blood pressure was increased to 0.13 in females and remained unaltered in males. This meant that the partial correlations between time of day and diastolic blood pressure were highly statistically significant ($P < 0.001$) and in fact greater than those of season in both sexes.

Plots (scattergrams) of the residuals versus the independent variables, provided by the standard computer program, did not disclose any non-linear 'effects' of season or time of day on the blood pressure. Major interactions between time of day and (systolic or diastolic) blood pressures were considered to be ruled out by the fact that the dispersion of the residuals was independent of the time of day.

Thus the multiple regression analysis resulted in the following four equations describing the observed variations of blood pressure with time of measurement in the present material.

Systolic blood pressure in males = $108.0 + 0.53 \times \text{age} + 4.1 \times \text{season}$.

Systolic blood pressure in females = $98.8 + 0.76 \times \text{age} + 5.0 \times \text{season}$.

Diastolic blood pressure in males = $68.7 + 0.28 \times \text{age} + 1.7 \times \text{season} + 0.24 \times \text{time of day}$.

Diastolic blood pressure in females = $67.0 + 0.31 \times \text{age} + 1.9 \times \text{season} + 0.27 \times \text{time of day}$.

In other words: when the effect of age on blood pressure was eliminated the systolic blood pressure was found to be 4.1 (5.0)—and the diastolic 1.7 (1.9), mmHg higher in men (women) during the winter-half of the year. The time of day had no influence on the systolic pressure but the diastolic pressure increased during the waking hours by 0.24 and 0.27 mmHg/hr in male and female subjects respectively.

TABLE 3. Correlation between observed values and blood pressures expected from age after polynomial approximation

	Degree of polynomial	Systolic blood pressure		Diastolic blood pressure	
		not transf.	log transf.	not transf.	log transf.
Males	1	0.582	0.591	0.539	0.543
	2	0.589	0.594	0.540	0.545
	3	0.592	0.598	0.540	0.545
Females	1	0.686	0.699	0.589	0.584
	2	0.719	0.726	0.593	0.587
	3	0.720	0.727	0.597	0.590

TABLE 4. Multiple regressions of arterial blood pressure on age, season and time of day

A. Coefficients of total and partial correlations between SYSTOLIC blood pressure and independent variables in MALES

Independent variable	Independent variables added to the regression equation		
	None	Age	Age and season
Age	0.58	—	—
Season	0.23	0.14	—
Time of day	0.05	0.04	0.03

B. Coefficients of total and partial correlations between SYSTOLIC blood pressure and independent variables in FEMALES

Independent variable	Independent variables added to the regression equation		
	None	Age	Age and season
Age	0.69	—	—
Season	0.26	0.15	—
Time of day	-0.01	0.08	0.06

C. Coefficients of total and partial correlations between DIASTOLIC blood pressure and independent variables in MALES

Independent variable	Independent variables added to the regression equation		
	None	Age	Age and time of day
Age	0.54	—	—
Time of day	0.11	0.11	—
Season	0.20	0.11	0.10

D. Coefficients of total and partial correlations between DIASTOLIC blood pressure and independent variables in FEMALES

Independent variable	Independent variables added to the regression equation		
	None	Age	Age and time of day
Age	0.59	—	—
Time of day	0.05	0.13	—
Season	0.23	0.12	0.11

Discussion

The Dalby population was invited to attend an ophthalmological examination. It was not mentioned that it was intended to measure the blood pressure. It was felt that this omission would lessen the risk of the subjects refusing participation because they were afraid to have their blood pressures measured.

Among those attending, 7% were subsequently excluded, half of these because they were taking diuretics or other antihypertensive drugs, the other half for other reasons unrelated to the blood pressure. Therefore the results are based on 82% of the invited population. In the different groups under 70 years of age, the participation varied between 75 and 92%. It was appreciably lower in the oldest age groups. In other population studies of the blood pressure, it cannot be excluded that a certain portion of the loss in participants might be caused by the fact that the invitation had specified that the blood pressure was going to be measured (Berglund, 1974).

The blood pressure values in the present study agreed with corresponding values in other population studies (Hamilton *et al.*, 1954; Comstock, 1957; Eilertsen and Humelfelt, 1968). The increase in systolic blood pressure with age was not linear. The blood pressures rose to a plateau with essentially unchanged pressures in the interval 28 to 42 years. In these ages, the systolic blood pressure was significantly higher in the male subjects. In older subjects, the increase in systolic blood pressure was most pronounced in the females. There were no sex differences in the diastolic blood pressure.

The systolic and diastolic blood pressures in the various age groups were not normally distributed. Even after logarithmic transformation, the distribution curves were skewed. Despite the fact that the total material included 1570 individuals, the number of individuals in the different age groups was too small to ascertain if the positive skewing of the curves was conditioned by the occurrence of more than one population or by other factors.

Previous reports have emphasized the importance of variations in blood pressure with the time of measurement (National Health Survey, 1964; Berglund, 1974; Hardy, Cutter and Hawkins, 1976). Such variations were encountered also in the present study. However, the variations could be shown to be largely dependent on the fact that the invited subjects were allowed to choose freely the time for the examination. The preferred time for examination was strongly dependent on age and sex and since the blood pressure varied with age the variations with the time of measurement were partly caused (or counteracted) by variations with age and sex. Such effects do not seem to have been analysed previously. They may explain some apparent discrepancies between earlier reports.

When the effect of age on the blood pressure had been eliminated the genuine effects of the time of measurement were found to be rather small. The authors feel that these lack practical importance even if they are highly significant from a statistical point of view.

In screening hypertension, it can thus be accepted that the individuals in a population are going to come at different times of the day for the examination. It is not necessary to counteract this selection effect.

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