Variations in the measurement of blood pressure between doctors and nurses

An observational study

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ALTHOUGH the accurate measurement of blood pressure is difficult using conventional instruments, life assurance statistics uniformly confirm the harmful significance of an elevated blood pressure (Society of Actuaries 1959, Metropolitan Life Insurance Company 1961).

The justification for another paper on variation in the measurement of blood pressure lies in the development of screening, when non-medically qualified personnel (normally nurses) may take and record the blood pressure.

This study presents our findings when the blood pressure readings of doctors and nurses on the same group of subjects are compared. There is every reason to expect that the results obtained may be subject to both systematic biases and random variation.

Subjects and methods

The subjects selected for study were those male patients who passed through the British United Provident Association (BUPA) screening line and also attended the Institute of Directors' Medical Centre in August and September 1970. The subjects came either as middle or senior executives from all types of firms dealing in commerce or trade such as finance, mining, transport, manufacturing or advertising or they come as individual members of the Institute of Directors. The full range of the examinations undertaken and some of our earlier findings have been published previously (Pincherle and Wright 1967 1970, Wright 1968, Richardson and Pincherle 1969 1971).

The blood pressure was first measured by one of 10 nurses on the BUPA screening line in one of three similar rooms. It was measured on the right arm, with the patient lying comfortably supine on a couch, after a standard 12-lead electrocardiogram, pulse and temperature had been taken. The blood pressure was estimated using standard Riva Rocci mercury sphygmomanometers with both systolic and diastolic (phase 5) pressures being recorded. The cuff pressure was reduced at approximately 2 mms. Hg. per second and the readings were made to the nearest mm. Hg. The same standard size 12 cuff (24 cms) was used on all occasions.

The subjects then proceeded to the floor above, and after a variable period of waiting of up to one hour, were seen and examined by one of the consulting doctors. The blood pressure was again measured on the right arm, with the patient supine. Standard equipment was used in the ten consulting rooms.

The initial measurement took place at an arbitrary time during the course of the screening process, but both nurses and doctors records were taken during the morning, or during the afternoon.

For this study, the following items were recorded for each patient: name and age of patient; name of attendant nurse and her record of systolic and diastolic blood pressure; name of doctor seen and his record of systolic and diastolic blood pressure. The results were then classified according to the doctor seen and also (separately) according to the nurse seen. Doctors who had seen less than 15 patients were omitted from the study, and the corresponding observations were rejected. This left a sample of 372 patients distributed between 15 doctors and 10 nurses.

Results

The frequency distributions of the systolic and diastolic blood pressure readings for doctors and nurses are shown in figures 1 and 2.

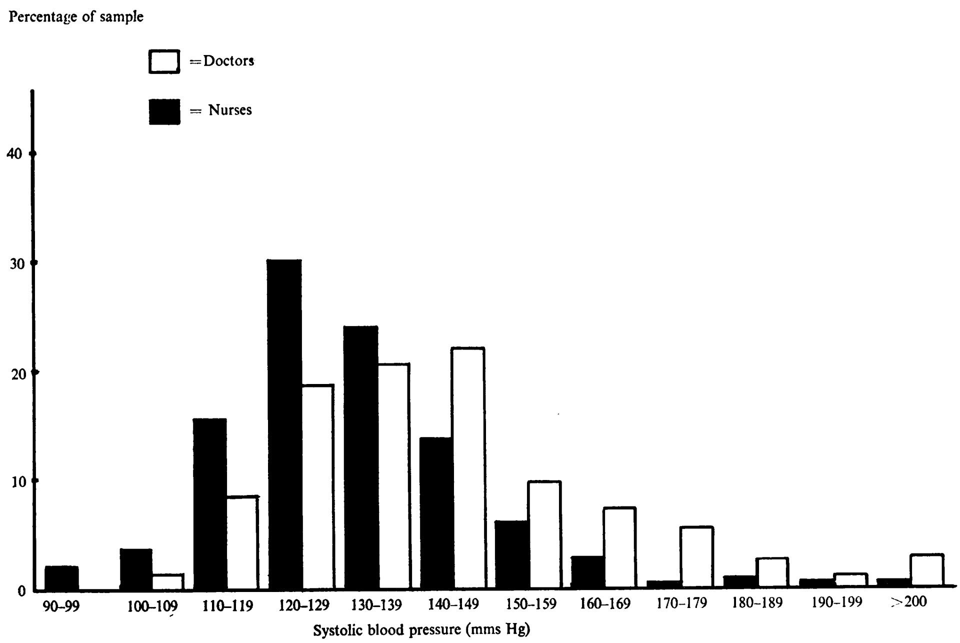

Figure 1
Frequency distribution of systolic blood pressure

In order to compare variation between doctors and between patients within doctors, analyses of variance were performed, for both systolic and diastolic blood pressures. The calculations were carried out on a restricted sample with 15 observations in each class, in order to facilitate the analyses. If a particular doctor had seen only 15 patients all those were included in the analyses, but where a doctor had seen more than 15 patients, 15 were chosen at random, using tables of random digits.

The results for the doctors (table I) provide strong evidence that the mean blood pressure readings (both systolic and diastolic) differ from doctor to doctor, ie, there is a significant doctor effect. Analysis suggests that age is not a significant factor in the variation obtained and that there is a true doctor effect.

A similar analysis of variance was carried out on the nurses' results (table II). Although there is a significant difference between nurses in the measurement of diastolic blood pressure, there is no significant difference between nurses in the measurement of systolic blood pressure.

Using the whole sample of 372 patients, a paired comparison was performed to establish whether or not the nurses' readings differed significantly from those of the doctors. Details of the method are given in the appendix.

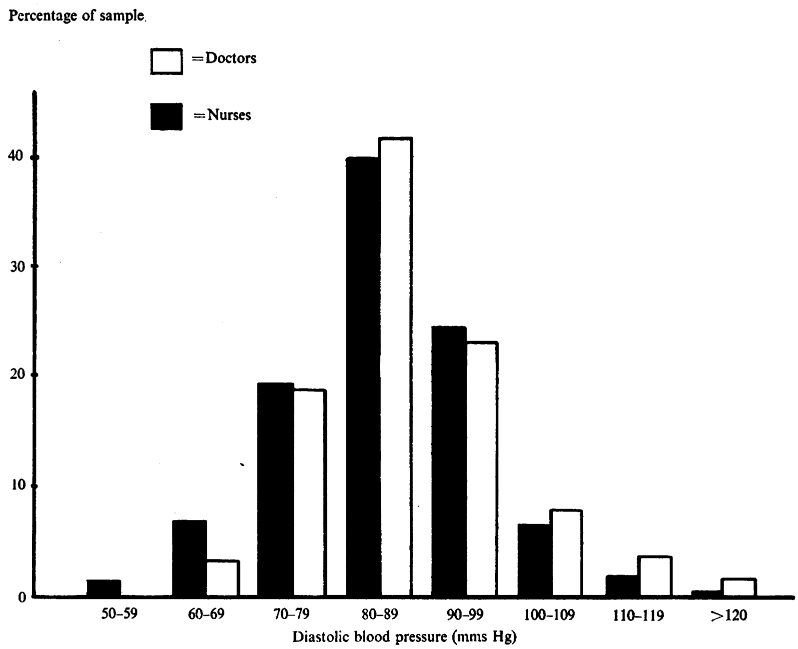

Figure 2
Frequency distribution of diastolic blood pressure

The results are shown in table III and demonstrate that the doctors' readings are on average significantly higher than those of the nurses for both systolic and diastolic blood pressures.

As it had been suggested that the nurses might be failing to record the high blood pressures, reduced samples were formed for both systolic and diastolic blood pressure readings. This was done by omitting from the original sample those patients for whom

TABLE I
DOCTORS' BLOOD PRESSURES—ANALYSIS OF VARIANCE

	Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*
Systolic	Between doctors	14	19,553·31	1,396·67
F (14,210)=3·11, P<0·001	Between patients Within doctors	210	94,446·67	449·75
	TOTAL	224	113,999·98	—
Diastolic	Between doctors	14	7,664·86	547·49
F (14,210)=4·87, P<0·001	Between patients Within doctors	210	23,586·13	112·31
	TOTAL	224	31,250·99	—

the doctor had recorded a blood pressure higher than the overall doctors' mean for the particular blood pressure under consideration.

TABLE II
NURSES' BLOOD PRESSURES—ANALYSIS OF VARIANCE

	Source of variation	*Degree of freedom*	*Sum of squares*	*Mean square*
Systolic	Between nurses	9	980·51	108·95
F (9,140)=0·35 N.S.	Between patients Within nurses	140	43,760·93	312·58
	TOTAL	149	44,741·44	—
Diastolic	Between nurses	9	3,072·24	341·36
F (9,140)=3·02 P<0·01	Between patients Within nurses	140	15,798·80	112·85
	TOTAL	149	18,871·04	—

TABLE III
PAIRED COMPARISONS FOR THE WHOLE SAMPLE—372 SUBJECTS

	Systolic BP	*Diastolic BP*
Doctors' overall mean blood pressure (mms/Hg.)	140·14	85·02
Nurses' overall mean blood pressure (mms/Hg.)	128·55	82·16
Estimate of variance of population of difference (S_D^2)	324·46	152·07
Estimate of variance of difference of population means (S_D^2) ..	0·87	0·41
't' test	12·41	4·47

't' test is significant in both cases (p<0·001)

A paired comparison was again performed, and the results show (table IV) that even with the omission of the high blood pressures as recorded by the doctors, the nurses on average produce significantly lower systolic readings than the doctors. However, there is no significant difference in diastolic blood pressure readings between doctors and

TABLE IV
PAIRED COMPARISONS FOR THE REDUCED SAMPLES

	Systolic BP	*Diastolic BP*
Doctors' overall mean blood pressure (mms/Hg.)	128·17 (253)	77·64 (229)
Nurses' overall mean blood pressure (mms/Hg.)	123·09 (253)	78·35 (229)
Estimate of variance of population of differences (S_D^2)	150·55	127·59
Estimate of variance of difference of population means (S_D^2) ..	0·60	0·56
't' test	6·58	0·95

Numbers of subjects in brackets
't' test is significant for systolic BP (P<0·001) but N.S. for diastolic BP

nurses. Hence, by eliminating the high (diastolic) blood pressure readings, we have removed the discrepancy between the doctors' and nurses' results for diastolic blood pressure.

As a further test of the suggestion that the nurses tend to produce lower readings than the doctors, particularly for the higher blood pressures, the ratio of the nurse's to the doctor's readings for both the systolic and diastolic records was computed for each patient. The mean and standard deviation were calculated and expressed as percentages for the whole and the reduced sample (table V).

TABLE V
MEAN AND S.D. OF $R_I = N_I/D_I$

	Systolic		*Diastolic*	
	Mean Per cent	*S.D. Per cent*	*Mean Per cent*	*S.D. Per cent*
Whole sample ..	*92·8*	*11·26*	*97·3*	*15·03*
Reduced samples	*96·4*	*9·57*	*100·9*	*17·12*

All the mean values of the ratios obtained differ significantly from 100 per cent with the exception of that obtained for the diastolic blood pressure in the reduced sample, which confirms our earlier findings.

Discussion

Vascular disease is a leading cause of mortality and morbidity in middle age and later life in both sexes, whether through cardiovascular disease, cerebrovascular accidents or renal failure. A raised arterial pressure is a causative factor in most forms of vascular disease, although in the case of coronary thromboses, other factors such as age, sex, serum cholesterol, cigarette smoking and exercise are also implicated. Increasing numbers of subjects are having their blood pressures measured in epidemiological surveys, whether cross-sectional or longitudinal, or through attendance at public health screening clinics. In addition, the development of effective screening of antenatal patients, the wider use of pre-employment and life insurance examinations and of industrial and executive health schemes adds greatly to this number. Consequently, it is necessary for the significance of variation in the measurement of blood pressure to be understood, and the importance of any single reading whether normal or high must not be overrated.

The blood pressure of an individual varies widely throughout the day, and it is apparent that, even under carefully standardized conditions of measurement, the within-subject standard deviation is about half of the real between-subject standard deviation (Armitage and Rose 1966). When the conditions of measurement more closely resemble normal life, greater variation ensues.

Differences between observers have been reported as high as 15 mms Hg on average (Eilertson and Humerfelt 1968) and the effects of the circumstances of the measurement, and especially the emotional state of the subject at that time, are most important.

The extent of the variation between consecutive casual recordings of arterial pressure are well known (Ayman and Goldshine 1940, Hamilton, Pickering, Roberts, Sowry 1954, Glock, Vought, Clark, Schweitzer 1956, Veale, Hamilton, Irvine, Smirk 1956, Ostfeld and Lebovits 1960). Within short periods, repeated measurements tend to show a fall in arterial pressure, presumably a result of extinction of the orienting reflex (Pickering 1968). This was well demonstrated in patients referred to a hypertensive clinic by Dunne

(1969). Over a longer period, 9 to 24 months, there is a regression towards the mean (Humerfelt 1963), and after three or more years, there is an increase with age in the developed countries (McKeown, Record and Whitfield 1963, Miall 1967).

Random variation in the measurement of blood pressure cannot be avoided, and in epidemiological studies is relatively unimportant. However, some systematic differences are important both for the individual, in case he is misclassified, and in epidemiological work.

Our results show a systematic difference between doctors and nurses. Although poor measurement technique may contribute to this result, there are two likely sources of variation, viz, the stress of interview and examination by a doctor, and the lower ambient temperature at the time of the doctors' measurement of arterial pressure.

The subjects studied were all middle-aged men, as were the doctors, while all the nurses were young and comely. It is likely that the initial readings, taken in all cases by the nurses, were more basal than those taken by the doctors.

There is evidence from our results that the level of arterial pressure rose more in some subjects than in others, although again this might be due to measurement variability. Similarly, wide variation was found by Wolf and Wolff (1951) in their studies of cardiovascular responses to psychological stimuli in conversation. Nestel (1969) studied the effects of mild mental stress on blood pressure and found that the rise was significantly greater in both systolic and diastolic blood pressures in the mild hypertensive patients. It seems likely therefore that some of the between-doctor variation is due to patient-doctor interaction.

Another important source of variation may have been a lower ambient temperature in the doctors' consulting rooms only, which all face north, while the screening rooms face south. There is evidence that arterial pressure is considerably affected by the air temperature at the time when it is measured (Takahashi, Sasaki, Takeda, Ito 1957), being higher at low temperatures than at high temperatures. McKeown, Record and Whitfield (1963) invoked this explanation for an anomalous finding in a follow-up study of blood pressure.

As this is only an observational study, it is impossible to apportion the effects that stress, cold and measurement variation may have had on our findings. If, as seems likely, the combination of stress of interview and a relatively cold consulting room has caused undue elevation of some subjects' blood pressures, then it is reasonable to classify these subjects as having a labile arterial pressure.

The significance of a labile blood pressure is not known, although the factor of lability has been correlated with personality traits (Ostfeld and Lebovits 1960). There is evidence that labile hypertension should not necessarily be regarded as a benign disease (Hamer, Fleming and Shinebourne 1967). It seems probable that a casual blood pressure reading may give a better guide to prognosis than more basal readings because, although life insurance readings are unlikely to be basal, yet they are good predictors of future mortality.

To maintain our standards, not only is there continuous monitoring of all our results, but training of both doctors and nurses by the use of tape-recordings of Korotkov sounds is planned (Rose 1965). When this is complete, a further investigation is envisaged to confirm and enlarge our findings on subjects with labile arterial pressures.

Summary

The blood pressure of each member of a sample of 372 men was taken and recorded by one of 15 doctors and also by one of 10 nurses. There was greater variation between doctors than between nurses in the measurement of both systolic and diastolic blood pressures; and in both groups there was less variation in the measurement of systolic

than in the measurement of diastolic blood pressure. The doctors' readings for both blood pressures were found on average to be significantly higher than those of the nurses. Possible reasons for this finding include the stress of interview and examination by a doctor, and a lower ambient temperature in the doctors' consulting rooms.

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APPENDIX

Let D_i, N_i be the readings of (say) systolic blood pressure made on patient i by the doctor and the nurse respectively (i=1, 2, ... , n). Let $\bar{x}_1$ be the doctors' overall mean systolic, and let $\bar{x}_2$ be the corresponding quantity for the nurses. Then an estimate of the variance of the population of differences (D_i—N_i) is given by:

$$S_D{}^2 = \frac{\sum (D_i - N_i)^2 - \left[\sum (D_i - N_i) \right]^2/n,}{(n-1)}$$

where n is the total number of pairs (D_i, N_i). The estimate of the variance of the difference of the population means is then given by

$$S_{\bar{D}}{}^2 = S_D{}^2/n$$

The test statistic used to test the null hypothesis $\bar{x}_1 = \bar{x}_2$ is then:

$$t_{n-1} = \frac{| \bar{x}_1 - \bar{x}_2 |}{S_{\bar{D}}}$$