

The dynamics of blood pressure in populations and hypertensive cohorts*

GIOVANNI B. AMBROSIO,¹ JOHN E. DOWD,² TOMA STRASSER,³ & JAAKKO TUOMILEHTO⁴

Two sets of data, derived from the WHO Cooperative Hypertension Community Control Project and concerned with spontaneous changes of blood pressure over a period of five years, are described. The first deals with the community as a whole, studied through the examination of two independent random samples of the same population made five years apart. The second pertains to cohorts of hypertensive subjects included in the hypertension registers from various centres participating in the WHO programme and followed up for four years.

The population blood pressure distribution showed a clear shift towards lower levels for both systolic and diastolic values. The mean changes, however, were smaller than 5 mmHg. In the subjects initially labelled as "hypertensive", the effects of "regression to the mean" were apparent both in the short-term evaluation (five months) and, more importantly, after four years of follow-up. In the latter case, the decreases were more remarkable in the first year but continued to show until the third year.

These findings suggest that a "controlled" design is necessary not only in prospective clinical trials but also in community projects where the effects of an intervention on blood pressure are to be evaluated.

In epidemiological studies and clinical investigations alike, spontaneous variations in an individual's blood pressure tend to confuse the assessment of the effects of hypotensive therapy, and therefore of community action for the control of hypertension. The term "spontaneous" in this context refers to blood pressure changes that cannot be ascribed to an intervention at the clinical or community level. Because of these spontaneous variations, as well as observer bias, there is a clear need

for *controlled* clinical investigations (trials) and *controlled* epidemiological (community) studies. More information about the spontaneous blood pressure variations should contribute to a better understanding of the induced (intentionally effectuated) blood pressure changes; thus, by comparing intervention populations with control (reference) populations or groups, the spontaneous changes observed in the reference group may be subtracted from the changes observed in the intervention group, and the difference may be assumed to be due to the intervention itself.

In this review, the spontaneous changes of blood pressure observed in the WHO Cooperative Hypertension Community Control Project will be discussed. Two separate issues will be analysed: (a) the changes observed in the reference communities (population blood pressure changes), and (b) the changes in hypertensive subjects that were unrelated to drug treatment, which occurred over a short time period and over years of observation.

* This article is based on data from the WHO Cooperative Hypertension Community Control Project. The members of this group are C. Dal Palu (Padua, Italy), F. de Padua (Lisbon, Portugal), N. Dondog (Ulan Bator, Mongolia), A. Froment (Lyon, France), I. Macias Castro (Havana, Cuba), H. Milon (Lyon, France), A. Nissinen (Kuopio, Finland), T. Omaa (Fukuoka City, Japan), J. M. Pereira Miguel (Lisbon, Portugal), J. O. M. Pobe (Accra, Ghana), P. Puskas (Helsinki, Finland), J. Richard (Paris, France), V. E. Smirnov (Moscow, USSR), and S. Zamboni (Padua, Italy), as well as the authors of this article. Requests for reprints should be sent to Cardiovascular Diseases, World Health Organization, 1211 Geneva 27, Switzerland.

¹ Clinica Medica I, University of Padua Medical School, Padua, Italy.

² Statistician, Epidemiology and Statistical Methodology, World Health Organization, Geneva, Switzerland.

³ Formerly Medical Officer, Cardiovascular Diseases, WHO, Geneva, Switzerland. Present address: Institute of Social and Preventive Medicine, Faculty of Medicine, University of Geneva, Geneva, Switzerland.

⁴ Chief, MONICA Data Centre, Department of Epidemiology, National Public Health Institute, Helsinki, Finland

POPULATIONS AND METHODS

In the design of the WHO programme on community control of hypertension, an assessment of

the baseline situation in the population that formed the two groups (the intervention community and the reference community) in each of the cooperating centres was included. This was done by examining a random sample of the resident population. The intervention carried out on the intervention community was based on educating the public, informing and educating the health professionals, and setting up a hypertension clinic and a hypertension register.

All known and newly detected hypertensives (those with sustained blood pressure readings of ≥ 160 mmHg (≥ 21.3 kPa) and/or 95 mmHg (12.7 kPa) or already under treatment) in the intervention community were registered and followed up, and if considered necessary, were treated. In the reference community, any hypertensives detected during the baseline survey were referred to their general practitioners. Five years after the baseline survey a new random sample of the population was examined to assess the "terminal" situation in both communities. Since the initial and terminal random samples were drawn independently from one another and the participation rates were high (ranging from 80% to 96%), it is reasonable to assume that they are representative of the respective populations as they stood at the beginning and at the end of the programme.

In the reference community, hypertension care was provided by the existing health services without any intensified efforts; blood pressure changes observed in this community, which are analysed below in the first section of the results, may be called "spontaneous". The same label can be attached to the changes that occurred in subjects who were found to have initial blood pressure values in the hypertensive range, were subsequently followed up in the hyper-

tension clinics and through the hypertension register of the intervention community, and received no drug treatment throughout the observation period. Further details can be found in the protocol.^a

The blood pressures were measured by standard sphygmomanometers after a five minute rest, according to the WHO recommendations (1). "Casual" readings were used in this analysis, which includes data from three of the cooperating centres where a reference community was studied (Kuopio, Finland; Padua, Italy; Lyon, France) and from all of the centres participating in the WHO project where a hypertension register was set up.

RESULTS

Changes in the general population

The systolic blood pressure clearly decreased after five years only in the group of Finnish women; in Lyon it increased in both sexes, while the diastolic blood pressure did so only in the males. A clear decrease in diastolic blood pressure was also apparent in Kuopio and Padua (Tables 1 and 2). All the changes, however, were less than 5 mmHg. Fig. 1 shows the changes (pooled) in blood pressure distribution between baseline and terminal surveys. The range of systolic blood pressures became narrower after 5 years, since the proportion of subjects in the extreme classes (below 130 mmHg (17.3 kPa) and above 180 mmHg (24 kPa)) decreased. Diastolic pressures showed a more homogeneous pattern — all

^a *Community control of hypertension. Methodological considerations and protocol of a WHO project.* Unpublished WHO document CVD/74.3, II, 1973

Table 1. Changes in mean systolic blood pressure between baseline (B) and terminal (T) surveys

	Males			Females		
	Baseline	Terminal	T-B	Baseline	Terminal	T-B
Kuopio:						
Mean	146.0	145.7	-0.3	147.2	142.9	-4.3
S.D.	21.0	19.2		25.5	22.1	
No. of subjects	2520	2607		2621	2747	
Padua:						
Mean	142.9	142.6	-0.3	144.0	143.7	-0.3
S.D.	20.5	20.6		23.4	22.8	
No. of subjects	1803	2144		2220	2102	
Lyon:						
Mean	131.6	136.2	+4.6	127.5	131.2	+3.7
S.D.	14.4	16.2		14.2	17.4	
No. of subjects	744	5414		188	1567	

Table 2. Changes in mean diastolic blood pressure between baseline (B) and terminal (T) surveys

	Males			Females		
	Baseline	Terminal	T-B	Baseline	Terminal	T-B
Kuopio:						
Mean	93.3	92.6	-0.7	91.3	88.6	-2.7
S.D.	11.8	11.9		12.1	16.4	
No. of subjects	2520	2607		2620	2747	
Padua:						
Mean	89.2	84.4	-4.8	87.4	84.1	-3.3
S.D.	12.7	11.7		12.8	12.1	
No. of subjects	1803	2144		2220	2102	
Lyon:						
Mean	79.0	81.5	+2.5	78.1	78.7	+0.6
S.D.	11.2	11.1		9.7	10.5	
No. of subjects	744	5414		188	1564	

classes above 90 mmHg (12 kPa) became smaller, as if they had flowed into the lower ones, all of which increased in size; the shifts were larger among the women than the men.

Changes in subjects with "hypertension"

Short-term changes. The spontaneous changes in blood pressure after two and five months were studied in a group of 685 subjects in one of the

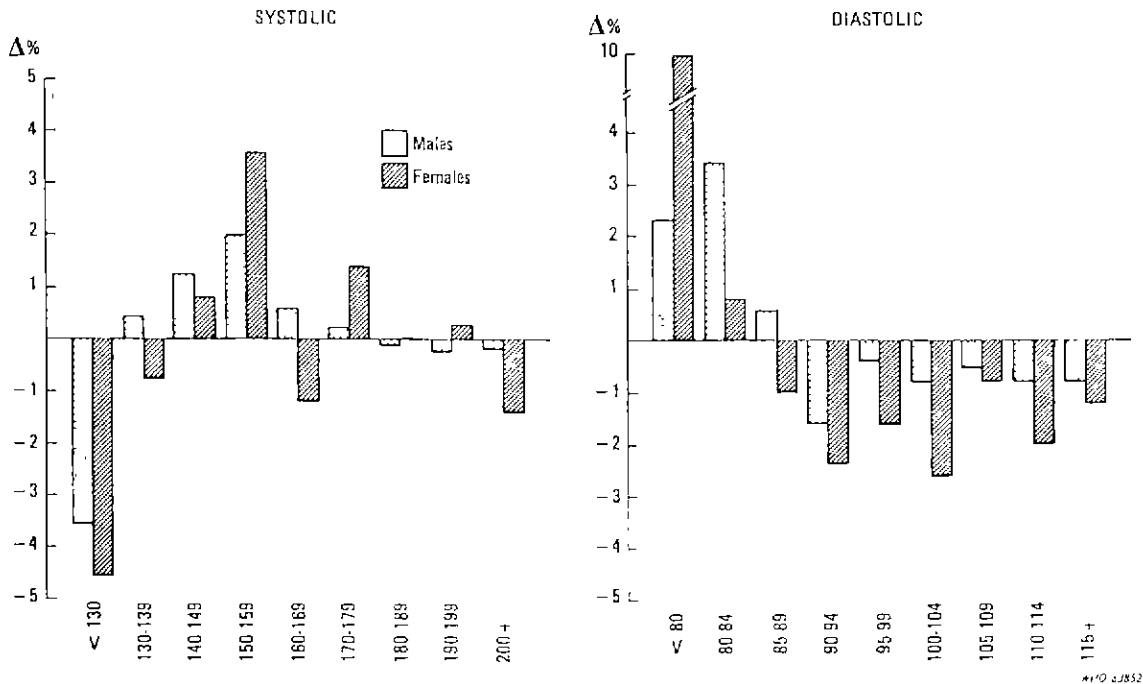


Fig. 1. Changes in blood pressure distribution between baseline and terminal surveys (pooled data from Kuopio, Padua and Lyon). The percentage change ($\Delta\%$ = terminal % minus baseline %) in the proportion of subjects belonging to each blood pressure class is shown for males and females.

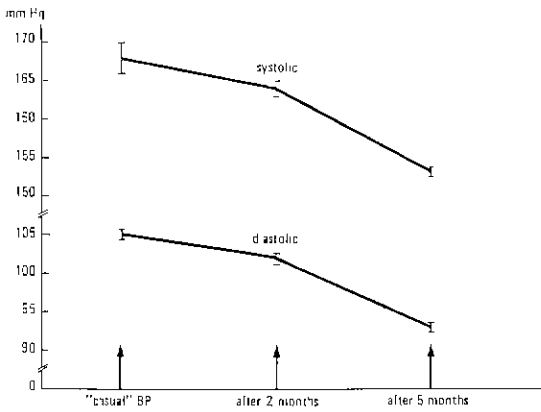


Fig. 2. Short-term changes in mean blood pressure in 685 untreated subjects with "casual" readings of ≥ 160 mmHg (systolic) and/or 95 mmHg (diastolic). "Casual" mean values were 168/105 and dropped to 164/104 mmHg after two months, and to 153/93 mmHg after five months (data from Padua).

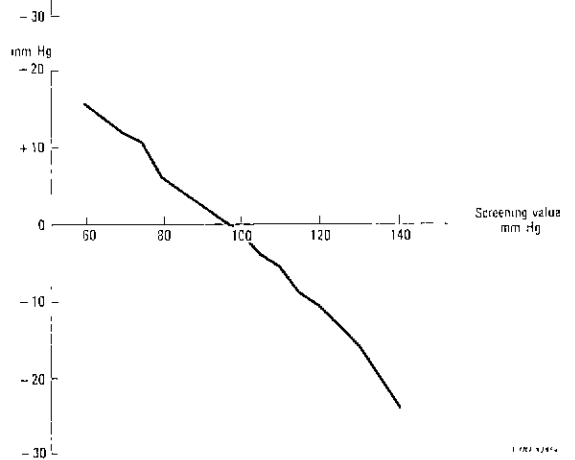
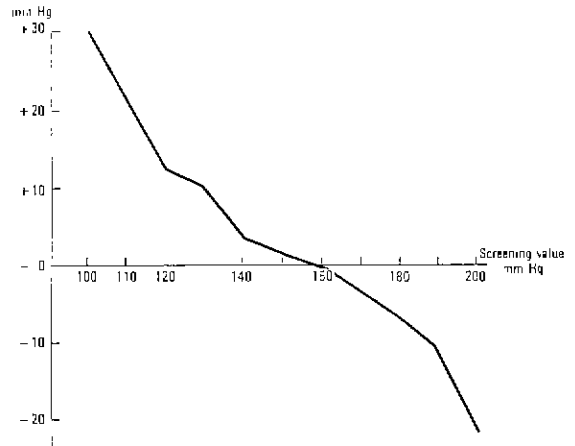


Fig. 4. Mean changes in systolic (top) and diastolic (bottom) blood pressures between screening and subsequent registration 5 months later. The farther the screening values lie from the centre of distribution (0 mmHg), the greater the subsequent change. Higher screening values display negative changes (i.e., a decrease), while lower screening values showed positive changes (pooled data from all participating centres).

cooperating centres in northern Italy, who were found to have readings at the initial examination (during the baseline survey) of ≥ 160 mmHg (≥ 21.3 kPa) and/or 95 mmHg (12.7 kPa). The mean value of casual blood pressures was 168/105 mmHg (22.4/14.0 kPa), falling to 166/104 (22.1/13.9 kPa) after ten minutes on the same

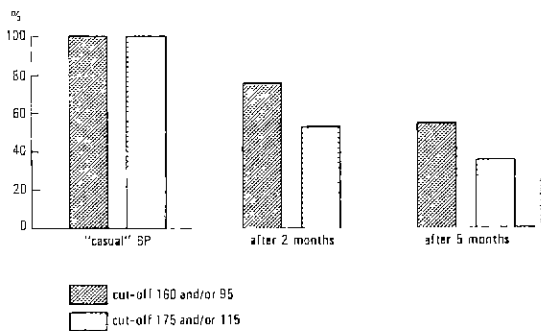


Fig. 3. Short-term changes in the prevalence of hypertension in untreated subjects according to the definition of hypertension. The prevalence fell by 24% after two months and by 45% after five months if a cut-off level of 160 and/or 95 mmHg was chosen for hypertension (hatched bars); with a higher cut-off level, such as 175 and/or 115 mmHg, the prevalence decreased by 47% and 64%, respectively (stippled bars) (data from Padua).

occasion, and to 164/104 (21.9/13.9 kPa) and 153/93 mmHg (20.4/12.4 kPa) after two and five months, respectively (Fig. 2). The prevalence of "hypertension" (160 or 95 mmHg (21.3 or 12 kPa)) after two and five months decreased by 24% and 45%. If a higher initial limit, such as 175 and/or 115 mmHg (23.4 and/or 15.4 kPa), is chosen to define hypertension, the decrease in the prevalence is even greater, reaching 47% and 64% respectively (Fig. 3). It is common practice in longitudinal studies

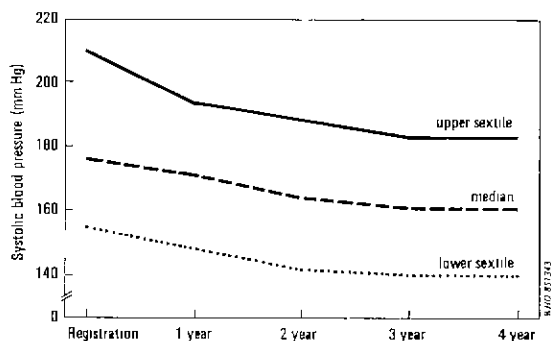


Fig. 5. Long-term systolic blood pressure changes in a cohort of 802 registered hypertensive subjects who received no drug treatment during the observation period. Downward changes are apparent in all parts of the initial distribution until the third year; higher initial values (upper sextile) show a bigger subsequent decrease.

to follow up only those subjects who, at the initial examination, fall into a given category or have certain given characteristics. Further selection may be carried out only on these, as was the case in the above example. Initial selection based on a given level of a variable that is subject to continuous biological oscillations and measurement errors, such as blood pressure, may be misleading not only because, as in the above example, it may overestimate a condition, but also because it may underestimate it. In fact, if on the same material the cut-off level chosen for a given population is 175 and/or 115 mmHg (23.4 and/or 15.4 kPa), but the subjects with readings below this level are also followed up, the prevalence of "hypertension" increases by 25% at two months but decreases by 47% at five months. This decrease is less than that observed when only those subjects at or above the cut-off level are studied. Moreover, it appears that "borderline" hypertensives on some occasions exceed the cut-off level and hence modify the proportion of subjects included in the definition of hypertension.

A further example of this can be seen in Fig. 4. These data are drawn from 27 730 subjects in the hypertension registers (all the data from the cooperating centres pooled). In the short time elapsing between the initial examination (screening) and the subsequent one ("registration"), notable changes occurred in both the systolic and the diastolic blood pressure. Initial values lying around the mean tended to remain stable, while values below the mean tended to increase and values above the mean to decrease. The magnitude of the changes was directly related to the initial blood pressure level.

Long-term changes. Over a longer time span, such as four years, the trend in spontaneous pressure changes in 802 untreated, registered hypertensive subjects was towards lower values in all parts of the distribution, although subjects in the upper sextile showed larger changes. The greatest decrease (i.e., 8 to 15 mmHg) was observed in the first year, with progressively smaller reductions until the third year. After this, no further change occurred (Fig. 5).

DISCUSSION

The increase in blood pressure observed in Lyon can be explained, at least partly, by the fact that the population was older at the terminal than at the initial survey. This was due to the fact that in Lyon the project covered a rather stable industrial population which itself was ageing during the five years of the project.

The downward changes that occurred in the reference communities in Kuopio and Padua are difficult to interpret, but some tentative explanations may be offered. The mean values of the body mass index remained very much the same in all the centres and thus cannot account for the changes in blood pressure levels. Observer bias such as an unconscious wish for a successful outcome of the study would have been more likely to give higher readings in the reference populations. Surveys of two independent population samples were performed in the USA in 1960-62 and in 1971-74 (2). In the second survey, the systolic blood pressure was significantly lower in men aged 35-44 and in both men and women aged 54-75 years; the diastolic blood pressure was significantly lower in the whole age range from 18 to 74 years. These changes have been ascribed partly to methodological differences between the two surveys. This might to some extent apply to our findings, although it is likely that the methodological bias was smaller in the WHO study, in which the same protocol was used by the same group of researchers in the two surveys.

Where the intervention and reference populations were in geographically adjacent areas (e.g., in Finland), there is a possibility that the effects of the intervention overflowed into the neighbouring communities ("halo" effect or "contamination"). Moreover, the screening carried out in the reference community may have influenced the blood pressure changes by creating a greater awareness of the need for hypertension control, both in the general public and among health workers. In fact, in the USA Grimm et al. also found that systematic blood pressure screening combined with immediate referral resulted in a significant improvement in hypertension control in the community (3). Finally, a "secular"

trend towards a lower blood pressure in the communities, owing to factors other than those mentioned above, cannot be excluded.

As for the changes in the subjects selected because of a high initial measurement, interpretation seems easier and more in keeping with the experience of other researchers (4, 5). Alderman & Yano re-examined subjects with screening measurements equal to or exceeding 160 or 95 mmHg (21.3 or 12.7 kPa) (6) and found a decrease of 29% and 53.6% in the proportion of subjects in that blood pressure range after one and three weeks, respectively. This fall in the prevalence of hypertension is similar to that observed in the WHO study in northern Italy, although the time interval between measurements was shorter. Hartley et al. in fact found that the number of visits (i.e., the effect of "getting familiar" with the procedure) rather than their timing was an important contributor to the fall in blood pressure over several months (7). Although the above and other factors, such as the "reassurance effect" (8) or the "extinction of a defence reflex" (9) have been proposed, the phenomenon of regression to the mean could explain most if not all of the decreases observed in repeat measurements of values that were initially far from the centre of the distribution (10).

Whatever the role played by the underlying factors or their various possible combinations, the above findings have important practical implications in the initial phase of an intervention programme, concerning when the subjects to be followed up (e.g.,

entered in the hypertension register) are selected, when the decision to start drug treatment is taken and, in general, when the relation with the community and health workers is established. The use of "casual" measurements and a cut-off level of 160 and/or 95 mmHg. (21.3 and/or 12.7 kPa) may overestimate the prevalence of hypertension by 17%, with 5% "false negatives" and 35% "false positives" (11). "False positives" may constitute a particular problem since it has been shown that an incorrect labelling as hypertensive may have harmful psychological consequences (12). A much higher specificity can be obtained by using a cut-off level for "casual" measurements which is higher than that adopted to define the hypertensives (13), or by repeating the measurements. The latter procedure also enhances the sensitivity (11). How many of these measurements must be made, on how many separate encounters, and with what frequency are but a few of the questions that require further clarification, although, for practical purposes, some suggestions (7) and even a set of guidelines (14) have been proposed. The matter is further complicated by the important finding that in untreated subjects, with initially high blood pressure readings, a downward trend may continue for up to three years. A similar long-lasting trend has been observed only in the Australian mild hypertension trial, where 48% of the subjects with initial readings in the mild hypertension range (diastolic 95-109 mmHg or 12.7-14.6 kPa) fell below the limit of 95 mmHg after three years of placebo treatment (15).

RÉSUMÉ

LA DYNAMIQUE DE LA PRESSION SANGUINE DANS DES POPULATIONS TÉMOINS ET CHEZ DES COHORTES D'HYPERTENDUS

Ce document fait état des découvertes du projet collectif OMS de lutte contre l'hypertension au niveau de la communauté, en ce qui concerne les modifications spontanées de la pression sanguine sur une longue période de temps. Le programme de l'OMS comprenait l'examen d'un échantillon aléatoire de sujets âgés de 20 à 64 ans, vivant dans une communauté définie ("enquête initiale"). Leurs pression sanguine, poids et taille ont été mesurés et on a noté s'ils suivaient ou non un traitement préventif ou curatif de l'hypertension. Une intervention systématique, au niveau de la communauté, a ensuite été menée au cours d'une période de 5 ans, et consistait en la détection, l'enregistrement et le suivi régulier des sujets hypertendus. Une "enquête terminale", effectuée sur un échantillon aléatoire indépendant de cette "communauté d'intervention", a conclu le projet.

Les enquêtes initiale et terminale ont également été effectuées dans une autre communauté ("communauté témoin")

de taille et de caractéristiques démographiques, sociales et économiques semblables. Celle-ci n'a fait l'objet d'aucune intervention.

Deux groupes de données sont décrits. Le premier traite des modifications de la pression sanguine survenues entre les enquêtes initiale et terminale dans les populations des communautés témoins à Padoue (Italie), Kuopio (Finlande) et Lyon (France). Le second groupe de données se rapporte aux cohortes de sujets que l'on a trouvés hypertendus au début de l'étude, inscrits sur les registres d'hypertension des communautés d'intervention, et suivis pendant 4 ans, mais qui n'ont pas pris de traitement antihypertenseur (Accra, Fukuoka, La Havane, Lisbonne, Paris, Oulan-Bator, Moscou).

En 5 ans, la distribution des mesures de la pression sanguine dans les population témoins s'est, dans l'ensemble, nettement déplacée vers des valeurs plus faibles, les pressions diastoliques en particulier. Les modifications

moyennes étaient néanmoins inférieures à 5 mmHg.

En ce qui concerne les modifications survenues chez les sujets inscrits sur le registre d'hypertension, considérés au départ comme hypertendus, les effets de "régression vers la moyenne" étaient apparents tant lors de l'évaluation à court terme que lors du suivi de 4 ans, ce qui est plus important. Ainsi, dans un des centres (Padoue), la pression sanguine est tombée en 5 mois de valeurs moyennes de 168/105 mmHg à 153/93 mmHg, avec, parallèlement, une baisse de 45% de la prévalence de l'hypertension (définie comme une pression

sanguine supérieure ou égale à 160 ou 95 mmHg). Regroupées, les données de tous les centres ont montré une réduction des valeurs de la pression sanguine jusqu'à la 3ème année d'observation, la plus forte baisse (15 mmHg) se produisant lors de la première année.

Ces découvertes suggèrent que l'emploi de populations témoins est nécessaire, non seulement pour les essais cliniques, mais aussi pour les projets communautaires dans lesquels les effets d'une intervention sur la pression sanguine doivent être évalués.

REFERENCES

1. WHO Technical Report Series No. 231, 1962 (*Arterial hypertension and ischaemic heart disease: preventive aspects: report of an Expert Committee*).
2. NATIONAL CENTER FOR HEALTH STATISTICS. *Blood pressure levels of persons 6-74 years. US, 1971-1974.* (Series 11, No. 204, DHEW Publication No 78-1648.) Washington, DC, Health Resources Administration, 1977.
3. GRIMM, R. H. JR. ET AL. Long-term effects of a blood pressure survey on patient treatment in a community. *Circulation*, **65**: 946-950 (1982).
4. MEDICAL RESEARCH COUNCIL WORKING PARTY ON MILD TO MODERATE HYPERTENSION. Randomized controlled trial of treatment of mild hypertension: design and pilot trial. *British medical journal*, **1**: 1437-1440 (1977).
5. GLASUNOV, I. S. ET AL. Repetitive health examinations as an intervention measure. *Bulletin of the World Health Organization*, **49**: 423-442 (1973).
6. ALDERMAN, M. H. & YANO, K. How prevalence of hypertension varies as diagnostic criteria change. *American journal of the medical sciences*, **271**: 343-349 (1976).
7. HARTLEY, R. M. ET AL. Confirming the diagnosis of mild hypertension. *British medical journal*, **286**: 287-289 (1982).
8. GOLDRING, W. & CHASIS, H. Antihypertensive drug therapy: an appraisal. In: Ingelfinger, F. J. et al., ed., *Controversy in internal medicine*. Philadelphia, Saunders, 1976, pp. 83-91.
9. PICKERING, G. Hypertension: definition, natural history and consequences. In: Laragh, J. H., ed., *Hypertension manual*. New York, Yorke Medical Books, 1974, pp. 3-30.
10. DAVIS, C. E. The effect of regression to the mean in epidemiologic and clinical studies. *American journal of epidemiology*, **104**: 493-498 (1976).
11. ARMITAGE, P. ET AL. The variability of measurements of casual blood pressure. II. Survey experience. *Clinical science*, **30**: 337-344. (1976).
12. BLOOM, J. R. & MONTEROSSA, S. Hypertension labeling and sense of well-being. *American journal of public health*, **71**: 1229-1232 (1981).
13. WILHELMSEN, L. Treatment of hypertension in a Swedish community. The problem of borderline hypertension. *Acta medica scandinavica (suppl.)*, No. 576: 99-108 (1975).
14. Guidelines for the treatment of mild hypertension: Memorandum from a WHO/ISH Meeting. *Bulletin of the World Health Organization*, **61**: 53-56 (1983); also in *Lancet*, **1**: 457-458 (1983).
15. Australian Therapeutic Trial in Mild Hypertension. Untreated mild hypertension. *Lancet*, **1**: 185-191 (1982).

