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## Comparison of ambulatory blood pressure monitoring and conventional office measurement in the workers of a chemical company

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### Abstract

The aim of the present study was to define the different prevalence of hypertension when conventional office measurement and ambulatory monitoring are performed in a population of unselected workers. All the workers of a Florentine chemical company were invited to participate in the study. Enrolled subjects underwent blood pressure measurement using a conventional sphygmomanometer and ambulatory blood pressure monitoring. Of 191 workers, 145 agreed to participate in the study (76%). Six of the 145 were excluded from further analysis because they were undergoing antihypertensive therapy. Confidence limits for ambulatory monitoring were defined at 95% on normotensive workers. Thirty-five (25%) workers were found to be hypertensive according to World Health Organization parameters (diastolic pressure >90 mmHg) but only 14 of the 35 had higher 24-h diastolic ambulatory blood pressure than the 95% confidence limits of controls.

**Keywords:** Blood pressure; Ambulatory blood pressure monitoring; Epidemiology; Hypertension

### 1. Introduction

Blood pressure measurements performed in the office using a conventional sphygmomanometer may result in excessive diagnosis and treatment of hypertension [1]. Although careful observation of the rules for blood pressure measurement propos-

ed by the American Heart Association contributes to reducing the occasional increases in office blood pressure, ambulatory blood pressure monitoring appears to provide a better estimate of an individual's blood pressure. This is particularly relevant for job applicants as the finding of high blood pressure values at conventional sphygmomanometer often per se represents a criterion for exclusion.

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Most studies concerning ambulatory blood pressure have been mainly confined to hypertension research, and there are very few investigations comparing ambulatory blood pressure values at the worksite with those measured with a conventional sphygmomanometer in population studies [2,3]. In the present study, ambulatory monitoring during a usual working day was performed on the workers of a company, and the distribution of conventional and ambulatory pressure values were compared.

## 2. Methods

### 2.1. Subjects investigated and enrolment procedure

Subjects for the study were recruited among the civilian workers of the Istituto Chimico Farmaceutico Militare of Florence, where blood pressure values do not constitute a criterion for exclusion from job application.

All the workers were invited to participate in the epidemiological study. The enrollment procedure was started in November 1992 and was considered complete in June 1993. Enrolled subjects had to undergo conventional blood pressure measurement and ambulatory monitoring, after having filled in a questionnaire seeking details of clinical history, family history, weight, height, smoking habits, alcohol consumption and current drug treatment (including contraceptive drugs). All participating subjects gave informed consent.

### 2.2. Conventional blood pressure measurement

Blood pressure values were measured in the sitting position by a physician on two occasions, using a mercury sphygmomanometer according to the recommendations of the World Health Organization/International Society of Hypertension [4] and of the American Heart Association [5]. Briefly, subjects had avoided exertion, exposure to cold, eating or smoking for half an hour before the measurement. They were comfortably seated in a quiet room and did not undergo any postural change for at least five minutes before the measurement. The forearm was supported at the heart level and the arm was unobstructed by clothing or

other material. The diastolic blood pressure was measured at Korotkoff phase 5 and the systolic blood pressure at phase 1. The mean of the two office measurements was used in the analysis. Measurements were classified according to the fifth report of the Joint National Committee [6].

### 2.3. Blood pressure monitoring device

Blood pressure monitoring was performed with a portable automatic non-invasive device (ICR-90207, Spacelabs Inc, USA) [7] which measured and recorded blood pressure and heart rate at programmable time intervals. The ambulatory monitoring procedure has been previously described in detail [8]. Briefly, at least four calibration readings were taken in the seated position to ensure that the monitoring gave readings within 5 mmHg of a mercury sphygmomanometer measurement. The blood pressure recorder was then worn by the patient for a 24-h period on a normal working day. The monitoring procedure was started at 8:00 h and continued without interruption until completion of the 24-h period at 8:00 h on the following morning. During this period blood pressure measurements were pre-programmed at 15 min intervals. Each time the recorder took a reading, the subject was requested to keep his arm as motionless as possible to prevent artifactual readings. The following morning four additional calibration readings were obtained and the recorder removed.

During the monitoring period, all the subjects attended to their usual work or external activities. All subjects had lunch between 12:00 and 13:00 h in the Istituto Chimico Farmaceutico Militare.

### 2.4. Data analysis

For each subject the following parameters were obtained: (1) Blood pressure measurements recorded at the beginning of the monitoring period; (2) Daily mean values for systolic, diastolic and mean pressure; (3) Mean blood pressure during day-time (from 07:01 to 22:00 h) and during night-time (from 22:01 to 07:00 h).

Values are reported as mean  $\pm$  S.D. with range values reported in brackets. All tests were performed by SPSS (Microsoft Inc., USA).

Table 1

<b>Subjects investigated</b>	
Total workers	191
Refused to participate	46
Enrolled	145 (76%)
Family history of hypertension	40 (28%)
Aware of being hypertensive	15 (10%)
On antihypertensive therapy (excluded)	6 (4%)
Subjects investigated	139 (73%)
<b>Characteristics and anthropometric measurements</b>	
Age (years)	38.7 ± 9.8
Sex (M/F)	86/53
Smokers (M/F)	15/13
Weight (kg)	66 ± 11
Height (cm)	168 ± 9
<b>BMI</b>	
Male (M)	24 ± 2
Female (F)	22 ± 3

### 3. Results

#### 3.1. Characteristics of participants

One-hundred forty-five subjects (86 men, 53 women, aged 38.7 ± 9.8 years) out of the 191 total workers of the Istituto Chimico Farmaceutico Militare (76%) agreed to participate in the study.

Table 2  
Blood pressure values in all subjects investigated (n = 139)

	Mean ± S.D.	Median	Mode	Upper 95% C.I.
<b>Conventional sphygmomanometer</b>				
Systolic (mmHg)	129 ± 16	126	130	161
Diastolic (mmHg)	85 ± 11	83	79	105
<b>Ambulatory monitoring</b>				
24-h values				
Systolic (mmHg)	117 ± 11	115	116	137
Diastolic (mmHg)	71 ± 8	69	68	86
Day-time values				
Systolic (mmHg)	120 ± 11	118	107	140
Diastolic (mmHg)	75 ± 8	73	72	92
Night-time values				
Systolic (mmHg)	107 ± 12	106	112	131
Diastolic (mmHg)	63 ± 11	63	59	76

The age classes and office blood pressure distribution of subjects who refused to undergo ambulatory monitoring (n = 46) were similar to those of subjects who took part in the study, so that the sample investigated was considered to be representative of the whole group of workers. Ambulatory monitoring was repeated in four subjects because at the first 24-h measurement, more than one third of measurements were lacking. Twenty-eight subjects (15 men, 13 women) (19%) were smokers.

Forty subjects (28%) had a positive family history for hypertension. Fifteen subjects (10%) were aware of being hypertensive and six (4%) were undergoing treatment for hypertension. Those six subjects were excluded from further data analysis. Subject characteristics and anthropometric measurements are reported in Table 1.

#### 3.2. Comparison between conventional sphygmomanometer and ambulatory blood pressure measurements

**Whole population.** The mean blood pressure of subjects investigated (n = 139) was 129 ± 16 mmHg and 85 ± 11 mmHg for systolic and diastolic blood pressure, respectively (Table 2).

Ambulatory blood pressure values were lower than those measured by conventional

Table 3  
Blood pressure values in normotensives at conventional measurement ( $n = 104$ )

	Mean $\pm$ S.D.	Median	Mode	Upper 95% C.I.
<b>Conventional sphygmomanometer</b>				
Systolic (mmHg)	123 $\pm$ 11	122	130	141
Diastolic (mmHg)	80 $\pm$ 7	81	79	89
<b>Ambulatory monitoring</b>				
24-h values				
Systolic (mmHg)	113 $\pm$ 9	113	116	128
Diastolic (mmHg)	69 $\pm$ 5	68	68	80
Day-time values				
Systolic (mmHg)	117 $\pm$ 9	116	116	134
Diastolic (mmHg)	72 $\pm$ 6	72	72	84
Night-time values				
Systolic (mmHg)	104 $\pm$ 9	104	95	120
Diastolic (mmHg)	62 $\pm$ 5	62	57	71

sphygmomanometer. Mean 24-h pressure of all the subjects investigated ( $n = 139$ ) was  $117 \pm 11$  mmHg for systolic ( $P < 0.001$  vs. conventional sphygmomanometer) and  $71 \pm 8$  mmHg for diastolic pressure ( $P < 0.001$  vs. conventional sphygmomanometer). Ambulatory blood pressure values recorded both during the day-time and at night were also significantly lower than conventional sphygmomanometer values. The mean day-time pressure was  $120 \pm 11$  mmHg for systolic blood pressure ( $P < 0.001$  vs. conventional sphygmomanometer) and  $75 \pm 8$  mmHg for diastolic blood pressure ( $P < 0.001$  vs. conventional sphygmomanometer). The mean night-time pressure was  $107 \pm 12$  mmHg for systolic ( $P < 0.001$  vs conventional sphygmomanometer) and

$63 \pm 11$  mmHg for diastolic ( $P < 0.001$  vs. conventional sphygmomanometer).

**Normotensives.** According to the World Health Organization criteria, 104 subjects (75%) were normotensive with office pressure values of  $123 \pm 11$  mmHg systolic and  $80 \pm 7$  mmHg diastolic blood pressure (Table 3).

In those subjects, the 24-h mean pressure at ambulatory monitoring was  $113 \pm 9$  mmHg for systolic and  $69 \pm 5$  mmHg for diastolic. The 95% upper confidence limit for the normotensive group was 128 mmHg for systolic and 80 mmHg for diastolic pressure. The mean day-time pressure at ambulatory monitoring was  $117 \pm 9$  mmHg for systolic and  $72 \pm 6$  mmHg for diastolic. The mean night-time pressure at ambulatory monitoring was  $104 \pm 9$  mmHg for systolic and  $62 \pm 5$  mmHg for diastolic (Table 3).

**Hypertensives.** According to manual conventional sphygmomanometer measurements, 35 subjects (25%) (22M/13F) were classified as hypertensive ( $146 \pm 14$  mmHg for systolic and  $100 \pm 7$  mmHg for diastolic). In these subjects, the 24-h mean pressure at ambulatory monitoring was  $126 \pm 11$  mmHg for systolic and  $79 \pm 9$  mmHg for diastolic. The mean day-time pressures were  $130 \pm 10$  mmHg for systolic and  $82 \pm 9$  mmHg

Table 4  
Classification of the 35 hypertensive subjects (conventional blood pressure measurement, diastolic  $> 90$  mmHg) by means of ambulatory blood pressure monitoring. Upper confidence limits at 95% for controls are considered as the upper normal limits for 24-h, day-time and night-time diastolic values

Hypertensive at ambulatory monitoring	$n$ (%)
24-h	14 (40%)
Day-time	16 (45%)
Night-time	14 (40%)

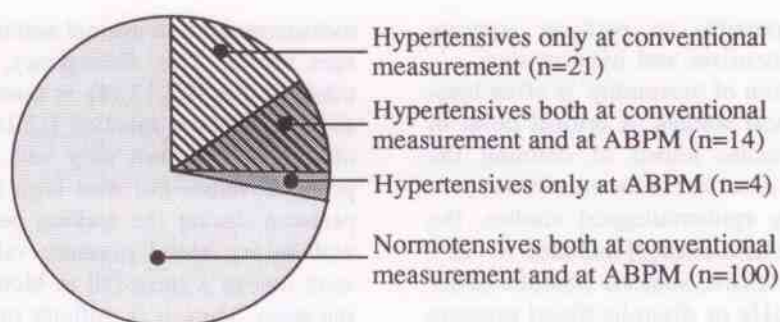


Fig. 1. Different prevalence of hypertension according to conventional and ambulatory blood pressure measurement on 139 workers.

for diastolic and the mean night-time pressures were  $116 \pm 14$  mmHg for systolic and  $70 \pm 11$  mmHg for diastolic.

### 3.3. Classification of hypertensive patients

According to the World Health Organization criteria, 35 workers out of 139 were defined as hypertensives (office diastolic pressure  $>90$  mmHg). Of these 35, there were subjects with diastolic blood pressure values at ambulatory monitoring within the 95% confidence limits of normotensives. When 24-h ambulatory blood pressure values at this confidence limit in normotensives were considered as upper limits for blood pressure normality, only 14 of the 35 hypertensives according to the World Health Organization had increased 24-h ambulatory blood pressure values (Table 4) whereas the remaining 21 were within the control range (Fig. 1). When the 95% confidence limit of day-time and night-time in normotensives was considered, 16 and 14 subjects, respectively of the 35 hypertensives had increased day-time and night-time diastolic pressure (Table 4).

When the whole group of subjects investigated ( $n = 139$ ) was considered, 18 (13%), 20 (14%) and 20 (14%) subjects had respectively, 24-h, day-time and night-time diastolic ambulatory pressure values exceeding the 95th percentile of controls (Fig. 1). Furthermore 19 (14%), 17 (12%) and 17 (12%) subjects had, respectively, 24-h, day-time

and night-time systolic ambulatory pressure values exceeding the 95th percentile of controls.

When the whole population was considered ( $n = 139$ ), a statistically significant positive correlation between ambulatory blood pressure monitoring values and age was found. The best correlation was observed for diastolic 24-h ( $r = 0.29$ ,  $P < 0.005$ ), day-time ( $r = 0.30$ ,  $P < 0.005$ ) and night-time ( $r = 0.39$ ,  $P < 0.0001$ ) values. Systolic pressure was significantly related to age only for 24-h ( $r = 0.18$ ,  $P < 0.05$ ) and night-time ( $r = 0.21$ ,  $P < 0.05$ ) but not for day-time ( $r = 0.15$ , n.s.) values.

### 4. Discussion

Subjects investigated in the present study can be considered as a representative group of normal subjects of working age. As a consequence, the results of this study can usefully define normal blood pressure values in a working population. In our investigation, all the workers of the company were invited to take part in the study, encouraged by a promotional campaign against hypertension performed among people working inside the company. The high percentage of subjects participating in the study and the similarity of their occupations and timing of meals within the monitoring day guaranteed an homogenous sample representative of the whole group of workers. The preliminary classification of their blood pressure values according to the World Health Organi-

zation made it possible to perform separate analyses on normotensives and hypertensives.

A proper definition of 'normality' is often biased in epidemiological studies. A critical point in epidemiological studies aimed at defining the range of normality often lies in the enrollment procedure. Two large epidemiological studies, the Belgian [3] and the Irish ones [2] included 10–12% of untreated hypertensive subjects (systolic blood pressure >140 mmHg or diastolic blood pressure >90 mmHg) and the mean pressure values reported in these studies were also calculated on data from these hypertensive patients. These two studies are also enclosed in a meta-analysis [9] aimed at determining the mean and range of normal ambulatory blood pressure.

In other epidemiological studies [9,10], normotensive subjects were enrolled among those with normal blood pressure values at an examination performed during a medical examination in a hypertension unit. Those subjects cannot however be fully regarded as controls, since they had often been referred to the medical unit by their family physician, due to previous findings of high blood pressure values.

Unlike the above-mentioned studies [2,3,9], we performed separate analysis for normotensives so that a range of normality could be defined. Ambulatory pressure values recorded in our subjects were similar to those reported in a recent large study performed only on normotensive subjects [11] that re-assessed ambulatory pressure of the 4577 normotensives enrolled in different previous studies.

In the present study, ambulatory pressure values were found to be lower than values measured with a conventional sphygmomanometer, as also previously noted in several other reports [2,3,9,11]. Thus the real pressure values are probably lower than those estimated using the sphygmomanometer. In our study about 25% of subjects investigated (35 out of 139) were found to be hypertensive according to World Health Organization criteria (diastolic pressure >90 mmHg). Similar percentages have also been reported by others [2,3,11–13]. It should be noted however that 60% ( $n = 14$ ) of our subjects classified as hypertensives at conventional sphygmomanometer

measurements had normal ambulatory blood pressure values. This discrepancy, also reported in other studies [2,3,12,14], is usually attributed to a short-term alarm reaction [12,14]. However, most of our subjects not only had high office blood pressure values but also high ambulatory blood pressure during the waking period. The normal ambulatory blood pressure values for the 24 h were due to a steep fall in blood pressure during the sleep. Thus, it is difficult to sustain the hypothesis of an alarm reaction. This group of subjects are instead probably hypertensives during the waking and normotensives during sleep, thus producing normal 24-h blood pressure values. The present findings demonstrate that ambulatory monitoring is able to screen not only those subjects who present a short-term alarm reaction, but also those with a hypertensive status lasting throughout the day which is counterbalanced by a steep blood pressure fall at night. So not only the whole 24-h period but also the separate day-time period have to be considered in order to define hypertensives.

In conclusion conventional and ambulatory blood pressure measurements seem to give a discordant classification of hypertension by selecting two different populations of hypertensives, not completely overlapping each other. Although ambulatory blood pressure cannot be performed for screening population, it appears to be a useful tool for proper classification of the patient's hypertensive status.

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