Twenty-four-hour ambulatory blood pressure in community-dwelling elderly men and women, aged 60–102 years

Cianán O'Sullivan[a,b], Joe Duggan[a,b], Neil Atkins[a] and Eoin O'Brien[a]

Objective **To investigate ambulatory blood pressure in elderly people, including 'old elderly' subjects, aged over 80 years.**

Design **Cross-sectional study of community-dwelling, elderly subjects.**

Methods **Subjects were healthy, self-caring, and living independently. Those who were taking medication affecting blood pressure were excluded. Conventional blood pressure was the mean of two measurements. Ambulatory blood pressure monitoring was performed using the SpaceLabs 90207 device. Daytime and night-time blood pressure were defined by fixed clock intervals.**

Results **Seventy-five 'young elderly', aged 60–79 years, (39 men, 36 women) and 81 'old elderly' aged 80 years and older (37 men, 44 women) underwent 24-h ambulatory blood pressure monitoring. Systolic blood pressure (SBP) was related to age, correlation coefficients between age and SBP were 0.31, 0.25 and 0.31, respectively, for conventional SBP, daytime SBP and night-time SBP ($P < 0.01$ for all). There was no correlation between age and diastolic blood pressure. Blood pressure levels were similar in men and women. Mean conventional blood pressure, daytime blood pressure and night-time blood pressure were found to be 149/81, 138/82 and 119/69 mmHg, respectively, in the 'young elderly' and 162/82, 147/83, and 133/71 mmHg, respectively, in the 'old elderly' ($P < 0.01$ for SBP). The night : day SBP ratio was significantly higher in the 'old' elderly compared with the 'young' elderly (0.90 versus 0.86, respectively; $P < 0.01$).**

Conclusions **Ambulatory blood pressure levels in healthy, community-dwelling 'old elderly' are higher than those reported for younger adults and reflect the prominent age-related rise in SBP associated with advanced old age. Advanced old age is associated with a diminished nocturnal dip in blood pressure. *J Hypertens* 21: 1641–1647 © 2003 Lippincott Williams & Wilkins.**

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[a]The Blood Pressure Unit, Beaumont Hospital, Dublin, Ireland and [b]Departments of Geriatric Medicine, Mater Hospital and St Mary's Hospital, Dublin, Ireland.

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Correspondence and requests for reprints to Dr Cianán O'Sullivan, Elderly Medicine Department, Homerton University Hospital, London E9 6SR, UK.
Tel: + 44 20 8510 7656; fax: + 44 20 8510 8777;
e-mail: cianan@osullivan.eu.com

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Introduction

Twenty-four-hour ambulatory blood pressure monitoring (ABPM) has advantages over conventional blood pressure (CBP) measurement [1]. It provides additional information on average blood pressure (BP) levels, nocturnal BP level and BP variability. Such information has clinical value, beyond that provided by CBP measurement, in assessing the extent of cardiovascular disease [2,3] and prognosis [4]. Age is an important factor in determining blood pressure. The application of ABPM to clinical practice in older people requires information on usual BP levels in this population. Several studies of ambulatory blood pressure (ABP) normality have been published, but have tended to focus on younger subjects [5–11]. More recently, studies have reported ABP levels in older subjects [12–16]. The older subjects included were predominantly 'young elderly' (i.e. 60–79 years); few if any 'old elderly' subjects (i.e. aged 80 years and older) were included. The 'old elderly' constitute an increasing proportion of the general population and of patients in clinical practice. There is also uncertainty about BP levels, and about the clinical correlates and prognostic significance of BP in people aged older than 80 years [17,18]. BP variability increases with age and ABPM may be a particularly useful technique in older subjects. Published reports of ambulatory BP levels of elderly subjects have reported variable results, mean daytime BP ranging from 128/77 mmHg in an Italian study [14] to 140/78 mmHg in a UK study [13]. Study setting, subject selection and age varied between studies, which may contribute to the variation in findings.

In particular, there is limited information on ABP levels in community-dwelling, healthy, 'old elderly' subjects.

The aim of the present study was to investigate ABP in a healthy, community-dwelling older population, including 'old elderly' subjects aged older than 80 years.

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Methods

The study protocol was approved by Beaumont Hospital Research Ethics Committee. Subjects were assessed by a research nurse or a physician, at the study centre, the Blood Pressure Unit, Beaumont Hospital. Subjects were recruited from local active-retirement associations, the local community and a general practitioner's practice register. All were living independently in the community. Subjects were healthy as defined by being ambulant, self-caring, not limited by cardiovascular disease or taking vasoactive medication, and not limited by any other major illness. Additional health status details were obtained by questionnaire. A history of the following conditions (as diagnosed by a physician) was sought: hypertension, heart attack, angina, stroke, transient ischaemic attack, cardiac failure, or peripheral arterial disease. Current drug treatment was also recorded. A history of hypertension was permitted if the subject was not on treatment. Weight, height and mid upper-arm circumference were measured. Subjects taking medication affecting blood pressure were excluded. There were no blood pressure eligibility criteria, subjects found to be hypertensive were included if they were not taking medication affecting BP. BP was measured twice in the sitting position using a mercury sphygmomanometer, according to the recommendations of the British Hypertension Society [19]. The mean of these two measurements was used as the CBP. The SpaceLabs 90207 (SpaceLabs, Redmond, Washington, USA) ambulatory blood pressure monitor was then fitted to the non-dominant arm, using an appropriately sized cuff and programmed to record blood pressure every 30 min throughout the 24-h period, commencing between 0900 and 1200 h. This device has been previously validated [20]. Subjects were instructed to continue normal daily activities, but to rest their arm at the times of BP measurement. Diaries were supplied, and subjects were asked to record activities, including bedtime and meal times.

Data analysis

Twenty-four-hour ABP recordings were unedited. Daytime was defined as 0900–2100 h and night-time as 0100–0600 h, and mean daytime BP and night-time BP levels were calculated for each individual. Recordings with less than a minimum of 16 daytime, six night-time, or a total of 30 measurements were rejected. In calculating hourly means, each BP measurement is taken to represent the measurements at each minute from 15 min before to 15 min after the actual reading. The hourly mean is the average of all representative readings occurring from the start of an hour to 59 min past the hour. This calculation is well defined, as an alteration in time of a particular reading will at most have a marginal effect on the average of two representative hours. Data normality was checked using the Kolmogorov–Smirnov test. Normally distributed variables were compared using Students t test or analysis of variance. The chi-square test was used to analyse categorical data and Pearson's coefficient was used for correlation analysis. A value of $P < 0.05$ was considered significant for all tests. For analysis, the SPSS software package was used (SPSS Inc., Chicago, Illinois, USA).

Results

Subject characteristics

A total of 156 subjects had complete 24-h ABPM recordings, age range 60–102 years. There were 75 'young elderly' aged 60–79 years (39 men, 36 women) and 81 'old elderly' aged 80 years and older (37 men, 44 women). Subject characteristics are presented in Table 1. Ten subjects, five 'young elderly' and five 'old elderly', reported a history of cardiovascular disease. Age, subject characteristics and BP levels were similar in these 10 subjects compared with subjects without a history of cardiovascular disease (data not shown). Twenty-two subjects reported being told in the past that their BP was elevated, four of whom had a history of cardiovascular disease.

BP levels

There was a positive association between age and systolic blood pressure (SBP). Correlation coefficients between age and SBP were 0.31, 0.25 and 0.31, respectively, for conventional SBP, daytime SBP and night-time SBP ($P < 0.01$ for all). There was no correlation between age and diastolic blood pressure (DBP), neither CBP nor ambulatory DBP. CBP and ABP results are presented in Table 1. Gender did not influence BP levels. Mean CBP, daytime BP and night-time BP levels in the 'young elderly' were 149/81, 138/82 and 119/69 mmHg, respectively, and in the 'old elderly' BP levels were 162/82, 147/83, and 133/71 mmHg, respectively ($P < 0.001$, for SBP variables). There were no significant differences in conventional or ambulatory DBP between 'young' and 'old' elderly subjects. CBP and daytime BP were correlated, coefficients 0.69/0.51 for SBP/DBP, respectively ($P < 0.01$ for both).

Twenty-two subjects (14%) reported a history of hypertension but were not taking treatment. These 22 subjects were of similar age to the 134 subjects who did not report a history of hypertension, but had significantly higher BP levels, both CBP and ABP (Table 2). Age-related differences in SBP between 'young elderly' and 'old elderly' subjects persisted, and remained significant, when subjects with a history of hypertension were excluded.

Twenty-four-hour BP profile

Twenty-four-hour BP and heart rate profiles are shown in Figures 1 and 2. In addition to the nocturnal dip in BP, a mid-afternoon dip in blood pressure with a nadir

Table 1 Subject characteristics and blood pressure levels

	'Young' elderly (60–79 years)		'Old' elderly (80+ years)		All subjects	
	Men	Women	Men	Women	'Young' elderly	'Old' elderly
n	39	36	37	44	75	81
CV history	3	2	1	4	5	5
History of high blood pressure	5	5	3	9	10	12
Age (years)	70 ± 5	69 ± 3	86 ± 5	86 ± 5	70 ± 4	86 ± 5
Weight (kg)	80 ± 9	65 ± 9	68 ± 10	58 ± 10	73 ± 12	62 + 11***
Height (cm)	177 ± 7	161 ± 5	169 ± 7	155 ± 8	169 ± 10	161 ± 10***
Body mass index (kg/m^2)	26 ± 4	25 ± 3	24 ± 3	24 ± 4	26 ± 3	24 ± 3**
Conventional SBP	148 ± 20	150 ± 18	158 ± 23	164 ± 26	149 ± 19	162 ± 24***
Conventional DBP	80 ± 11	82 ± 9	81 ± 9	83 ± 11	81 ± 10	82 ± 10
Daytime SBP	139 ± 16	136 ± 14	146 ± 18	148 ± 19	138 ± 15	147 ± 19**
Daytime DBP	84 ± 12	80 ± 10	85 ± 9	82 ± 10	82 ± 1	83 ± 9
Night-time SBP	121 ± 17	117 ± 14	131 ± 19	133 ± 23	119 ± 15	133 ± 22***
Night-time DBP	72 ± 12	66 ± 9	72 ± 9	70 ± 12	69 ± 11	71 ± 10
SBP difference	9 ± 17	14 ± 16	12 ± 14	17 ± 18	11 ± 17	15 ± 16
DBP difference	−3 ± 11	1 ± 10	−4 ± 8	0.8 ± 11	−1 ± 11	−1 ± 9
Night : day SBP†	0.87 ± 0.09	0.86 ± 0.07	0.90 ± 0.09	0.90 ± 0.1	0.86 ± 0.08	0.90 ± 0.09**
Night : day DBP†	0.86 ± 0.1	0.82 ± 0.08	0.85 ± 0.08	0.85 ± 0.1	0.84 ± 0.09	0.85 ± 0.09
Day − night SBP	19 ± 13	20 ± 10	14 ± 13	14 ± 14	19 ± 12	14 ± 14*
Day − night DBP	12 ± 10	15 ± 7	13 ± 7	12 ± 9	13 ± 9	13 ± 8

Data presented as mean ± standard deviation (mmHg) (rounded to nearest mmHg). †Data presented as ratio. SBP, systolic blood pressure; DBP, diastolic blood pressure; CV, cardiovascular; difference, conventional − daytime blood pressure difference; day − night BP, day − night blood pressure difference. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, compared with the 'young' elderly.

Table 2 Blood pressure levels in subjects with and without a history of hypertension

	'Young' elderly (60–79 years)		'Old' elderly (80+ years)	
	History of hypertension	No history of hypertension	History of hypertension	No history of hypertension
n	10	65	12	69
Age (years)	69 ± 5	70 ± 4	84 ± 3	86 ± 5
Conventional SBP	163 ± 15**	147 ± 19	187 ± 15***	157 ± 23
Conventional DBP	90 ± 7**	79 ± 10	91 ± 7***	80 ± 10
Daytime SBP	153 ± 16***	135 ± 13	167 ± 19***	143 ± 16
Daytime DBP	92 ± 13**	81 ± 10	88 ± 7	82 ± 10
Night-time SBP	135 ± 15**	116 ± 14	157 ± 27***	128 ± 18
Night-time DBP	77 ± 8*	68 ± 11	78 ± 11*	69 ± 10

Data presented as mean ± standard deviation (mmHg) (rounded to nearest mmHg). †Data presented as ratio. SBP, systolic blood pressure; DBP, diastolic blood pressure. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, history of hypertension versus no history of hypertension.

at 1400 h was evident, especially in the old elderly subjects. Unlike the nocturnal dip in BP, the mid-afternoon dip in BP was not accompanied by a decline in heart rate. Subjects who recorded meal times in their diaries indicated that most subjects had their main meal between 1200 and 1330 h and a lighter meal in the evening. The change in hourly mean BP between 1200 h (readings occurring between 1200 and 1259 h) and 1400 h (readings between 1400 and 1459 h) averaged 4.1/3.7 and 16.9/8.5 in the 'young' and 'old' elderly, respectively ($P < 0.001/0.05$ for SBP/DBP). In contrast, over the same period, heart rate changed little and non-significantly, with average increases of 3 and 1 beats/min in the 'young' and 'old' subjects, respectively.

The night-time dip in SBP was less prominent in the older subjects, both in absolute terms ($P < 0.05$) and, relatively, the night : day ratio ($P < 0.01$) (Table 1).

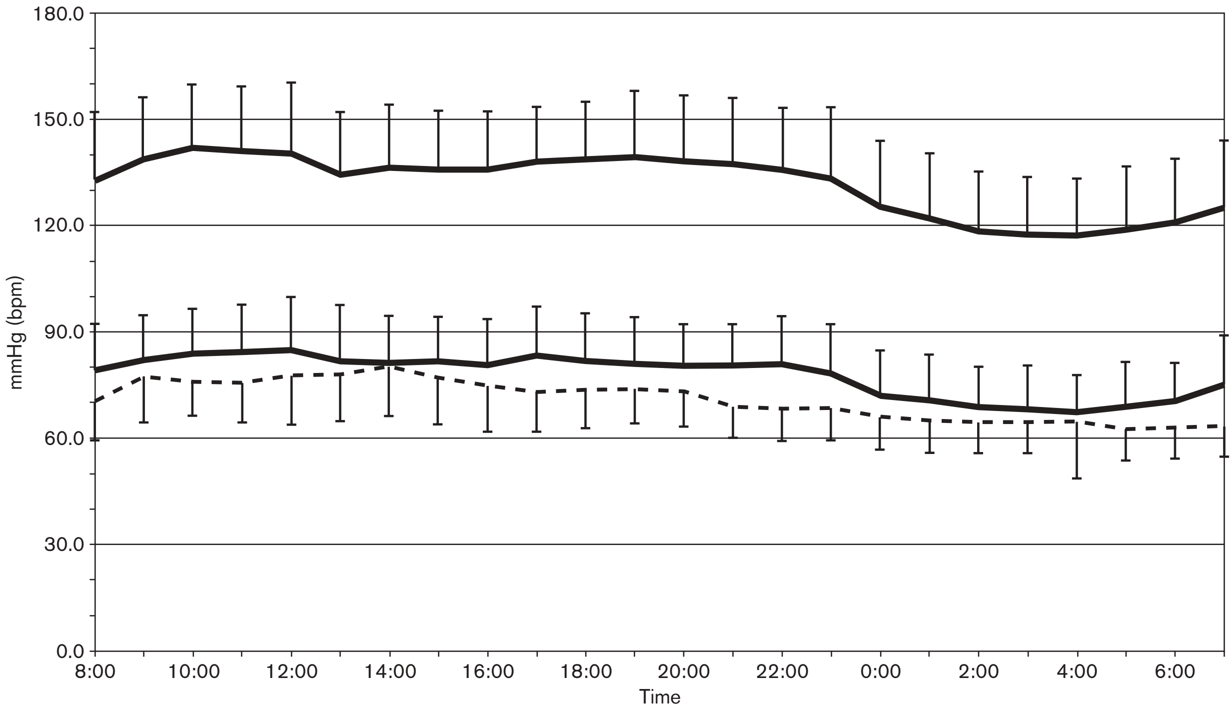
Distribution of ABP

The distribution of ABP, the 5th and 95th percentiles, in 'young' and 'old' elderly subjects, when the subjects with a history of hypertension were excluded, is presented in Table 3. There was considerable variability in BP levels, especially in the 'old elderly' and hence a broad range of BP levels.

Discussion

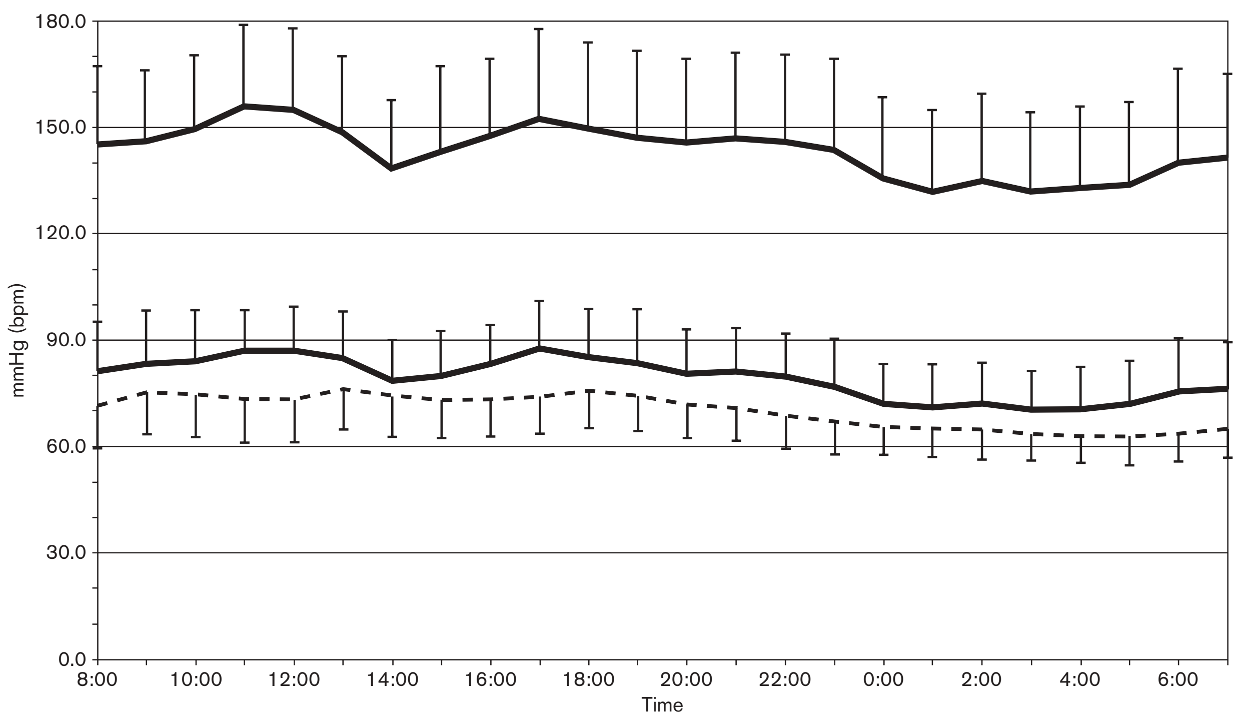
The present study is a community-based investigation of ABP levels in elderly subjects, and included 81 subjects aged 80 years or older, the 'old elderly', who were not taking medication affecting BP. This is the largest number of old elderly subjects included in any

Fig. 1



Hourly mean blood pressure (mmHg, + 1 standard deviation) and heart rate (beats/min, − 1 standard deviation) in 'young elderly' subjects. Solid line represents blood pressure, broken line represents heart rate.

Fig. 2



Hourly mean blood pressure (mmHg, + 1 standard deviation) and heart rate (beats/min, − 1 standard deviation) in 'old elderly' subjects. Solid line represents blood pressure, broken line represents heart rate.

Table 3 Distribution of ambulatory blood pressure

	'Young' elderly (60–79 years)			'Old' elderly (80+ years)		
	Mean	5th percentile	95th percentile	Mean	5th percentile	95th percentile
Daytime SBP	135	118	162	143	119	173
Daytime DBP	81	66	105	82	68	101
Night-time SBP	116	94	141	128	98	158
Night-time DBP	68	53	88	69	54	87

Data refers to 134 subjects without a history of hypertension. SBP, systolic blood pressure; DBP, diastolic blood pressure.

such study to date. Two previous studies of ABP levels including subjects aged 80 years and older have been published [13,16]. Sample sizes were smaller ($n = 52$ and $n = 36$, respectively) [13,16] than in the present study. The mean levels of ABP in the 'young elderly' in the present study are similar to [11,15] or slightly higher than [6–9,12–14] in similarly aged subjects in other studies. In the 'old elderly', mean BP levels in the present study are consistently higher than in other studies of elderly subjects [12–16].

There are a number of possible explanations for the differences in BP levels between the present study and some previous reports of ABP in older people. A contributing factor to the higher levels in the present study is the inclusion of subjects with a history of hypertension. Previous cross-sectional studies of ABP in the elderly excluded subjects with a history of hypertension, even if no longer receiving treatment, but did include subjects found to be hypertensive on entry [12,13]. It could be argued that such a design applies BP eligibility criteria inconsistently and makes the study sample less representative of the population under investigation. The present study did not exclude anyone on the basis of past or current BP level. We sought to measure ABP in elderly people who were not subject to the two main confounding influences on BP in old age: antihypertensive (or other vasoactive) medication, and ill-health. When subjects with a history of hypertension were excluded from the present study, ABP levels in the 'young elderly' were similar to levels reported in previous studies, and although BP levels in the 'old elderly' were reduced they remained higher than in previous reports [12–16]. Only two of these studies included subjects aged older than 80 years and there were differences in subject selection and methods to the present study. The study by Fotherby and Potter [13] was of a similar northern European (British) population, although 45% of subjects were recruited from a hospital setting, either in-patients or from an out-patient clinic, whereas the present study was community based. In the latter study, which excluded subjects with a history of hypertension, there were 52 subjects aged older than 80 years, and mean CBP and daytime BP levels in 'old elderly' subjects were lower than in the present study but night-time BP levels were similar. In the study by Bertinieri *et al.*, of a southern European (Italian) population, the comparable subjects (20 octogenarians) were selected to be normotensive, and BP levels were therefore lower than in the present study [16].

Our findings can be explained by a significant age-related change in BP in old elderly people. Age-related changes in BP, such as the rise in SBP, were evident on comparing the 'young elderly' with the 'old elderly' in the present study. Stiffening of large arteries and decreased arterial compliance is a feature of ageing and causes a rise in SBP [21]. This age-related process would be expected to be most prominent in healthy old elderly people who are not subject to the confounding influence of co-morbid illness on BP, such as the subjects in our study.

The contention that the levels of ABP in the 'old elderly' subjects in the present study are a reflection of a prominent age-related rise in SBP in this age group is supported by epidemiological studies that have consistently reported high BP levels in elderly populations in different countries, [15,22–24]. A recent Belgian population study found that almost one-half of a sample of 818 people aged 75–89 years either had a measured conventional SBP in excess of 160 mmHg or were taking antihypertensive treatment [24]. A Swedish population-based study involving 1800 elderly subjects, whose mean age was 83 years, which included those taking medication affecting BP, found that 44% of subjects had a conventional SBP in excess of 160 mmHg [25]. CBP in 603 elderly people, whose mean age was 76 years, reporting no health problems and taking no medication, was found to be 160/86 mmHg in a British study [26]. Furthermore when subjects in the latter study were followed up, those who remained disease and medication free experienced a continued rise in SBP over the succeeding 7 years [27].

On the other hand, the present study did not include all potentially eligible elderly and 'old elderly' subjects in the population. Less healthy, frail or non-community-dwelling older people tend to have lower BP levels and such subjects were not included in the present study. The subjects included were healthy and living independently, and there were no BP selection criteria. The results are therefore applicable to this population (i.e. healthy, free-living elderly people).

Some authors have reported gender differences in BP behaviour. In the Allied Irish Bank study, BP in men was consistently higher than in women, both CBP and ABP, although male–female differences did diminish with increasing age [6]. Although SBP in men tends to be higher than SBP in women from youth to middle age, in the elderly the situation reverses, with women having higher SBP than men. Imai *et al*. reported that the age-associated rise in ABP was significantly higher for women than men and that nocturnal dip declined with age in men but not women [8]. In the present study mean BP levels did not differ in men and women. The old elderly women did tend to have higher SBP than old elderly men, differences were small, and not statistically significant.

A change in the circadian BP pattern with age has been postulated. An age-related lessening of the nocturnal dip has been reported in elderly men [8]. An absent nocturnal BP has been reported in very elderly women [13] and in centenarians [16]. In the present study mean night-time BP levels (both SBP and DBP) were consistently lower than mean daytime BP levels, although to a significantly lesser extent in the 'old elderly' compared with the 'young elderly'. Our findings are consistent with an alteration in the circadian BP profile with a lessening of nocturnal dip with age.

A fall in BP that is unaccompanied by a fall in heart rate is characteristic of postprandial hypotension. The elderly may be more susceptible to post-prandial hypotension [28]. In the present study, the 'old elderly' subjects demonstrated a prominent mid-afternoon dip in BP, the timing of which and associated heart rate changes were characteristic of postprandial hypotension. The greater magnitude of this afternoon BP change in the old elderly is consistent with an age-related susceptibility to postprandial hypotension. Thus, old age appears to be associated with two separate, and somewhat contradictory, changes in short-term BP regulation: an attenuated nocturnal BP reduction, and an exaggerated post-prandial BP reduction. Our results are in agreement with a recent study of extreme old age (centenarians) that found a consistent post-prandial BP reduction despite an absent nocturnal BP reduction [16]

Our study does have some limitations. Although subjects were generally healthy and nearly all were free of clinical cardiovascular disease (and other significant illness), they were not formally screened to exclude disease. It is possible that if screening had been undertaken, occult or undiagnosed disease may have been present. Considering the BP levels of the sample, it is possible that undiagnosed hypertensive target-organ damage was present in some subjects. The study subjects were drawn from a white, northern European (Irish), population and therefore the results may not be applicable to other elderly populations. We have attributed the drop in mid-afternoon BP, which was especially prominent in the 'old elderly', to post-prandial hypotension. Although the timing, diary card information and heart-rate changes suggest this was the case, the study was not specifically designed to investigate meal-induced changes in BP, and further studies would be required to confirm our results. The inclusion of subjects with a history of hypertension influenced results as discussed earlier.

In conclusion, ABP levels in 'old elderly' subjects, aged 80 years and older, are higher than those reported for younger adults and reflect the prominent age-related rise in SBP associated with advanced old age. Advanced old age is associated with alterations in the circadian BP profile, a lessening of the nocturnal dip in BP, and appears to be associated with an increased post-prandial fall in BP.

Further studies are required to investigate the relationship between ABP and cardiovascular abnormalities in the elderly, in particular to establish the clinical correlates of ABP in people aged older than 80 years.

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