

Measurement with an automated oscillometric wrist device with position sensor leads to lower values than measurements obtained with an automated oscillometric arm device from the same manufacturer in elderly persons

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Objective Home blood pressure (BP) monitoring is recommended by several clinical guidelines and has been shown to be feasible in elderly persons. Wrist manometers have recently been proposed for such home BP measurement, but their accuracy has not been previously assessed in elderly patients.

Methods Forty-eight participants (33 women and 15 men, mean age 81.3±8.0 years) had their BP measured with a wrist device with position sensor and an arm device in random order in a sitting position.

Results Average BP measurements were consistently lower with the wrist than arm device for systolic BP (120.1±2.2 vs. 130.5±2.2 mmHg, $P<0.001$, means±SD) and diastolic BP (66.0±1.3 vs. 69.7±1.3 mmHg, $P<0.001$). Moreover, a 10 mmHg or greater difference between the arm and wrist device was observed in 54.2 and 18.8% of systolic and diastolic measures, respectively.

Introduction

The prevalence of hypertension increases with age to become a prominent health problem in elderly persons [1–3]. Randomized interventional trials performed in elderly hypertensive patients have demonstrated beneficial effects of blood pressure lowering on cardiovascular outcome, even in patients older than 80 years [4,5]. It is now recognized that out-of-office blood pressure, monitored either during 24 h everyday activities or at home, reflects better cardiovascular risk than blood pressure values determined in a clinical environment [6], and this is also true in elderly patients [7]. This accounts for the increasing use of self-measurement of blood pressure in diagnosing and treating hypertension [8,9]. A large number of validated automated blood pressure measuring devices are currently marketed (Dabl Educational Trust Limited, <http://www.dableducational.org>). Most of these have been developed for self-measurement at the upper arm, but several apparatuses with position sensor are also available for self-measurement of blood pressure at the wrist.

Self-measurement of blood pressure at home may be particularly useful in elderly patients with hypertension to adjust antihypertensive therapy and avoid overtreatment or

Conclusion Compared with the arm device, the wrist device with position sensor systematically underestimated systolic as well as diastolic BP. The magnitude of the difference is clinically significant and questions the use of the wrist device to monitor BP in elderly persons. This study points to the need to validate BP measuring devices in all age groups, including in elderly persons.

Keywords: arm device, elderly population, oscillometric blood pressure measuring device, position sensor, reliability, self-measurement of blood pressure, validated devices, wrist device

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undertreatment, as both conditions are potentially harmful for frail elderly persons [10,11]. In addition, blood pressure monitoring at home may serve to improve patients' adherence to treatment and, thereby, the blood pressure control rate [12,13]. The use of upper arm devices to monitor blood pressure at home is preferred to the use of wrist devices to monitor blood pressure at home [2,8]. Fitting a device at the wrist without external assistance may, however, be easier for an elderly person than fitting the cuff of an upper arm device. Another advantage of wrist devices in elderly individuals is minimal discomfort during the measurement, whereas cuff inflation at the arm may be harmful in some individuals and occasionally trigger a pressor response [14]. These considerations led us to compare blood pressure readings obtained in elderly persons living in our institutional care unit using two automated blood pressure devices of the same brand, one measuring blood pressure at the upper arm and the other one at the wrist.

Participants and methods

Study population

Participants were a convenience sample of elderly persons (≥ 65 years) admitted to the postcare unit of the Service

of Geriatrics and Geriatric Rehabilitation, University Hospital of Lausanne, Switzerland. All participants were previously living at home and within 1 week of being discharged back to their home at the time of measurements.

Participants with mid-arm circumference greater than 33 cm, with cognitive impairment (defined as a score <20 on Folstein's Mini Mental Status Exam [15]), unable to give informed consent for any reason (for instance, because of poor understanding of French), or experiencing a terminal health condition were excluded. Patients with atrial fibrillation, because of the potential inaccuracy of blood pressure readings obtained using oscillometric devices, were also excluded.

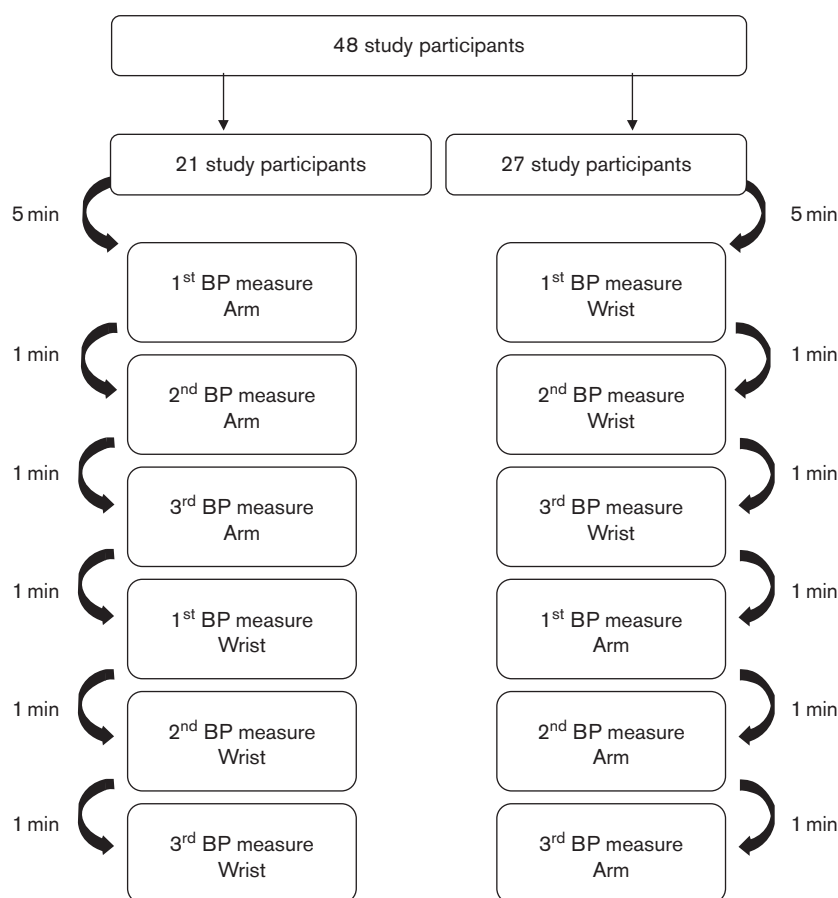
The study was approved by the Ethics Committee of the Canton of Vaud, Switzerland, and written consent was obtained from all participants.

Study procedures

Blood pressure measurements were performed at the upper arm using a validated automated oscillometric

device connected to a cuff of standard, 13 × 30 cm, size (Omron M6; Omron Medizintechnik, Mannheim, Germany). Notably, this device has been validated in a number of special populations, including in the elderly [16]. Wrist blood pressure readings were also taken using a validated automated device equipped with a position sensor (Omron R7; Omron Medizintechnik) [17]. These devices were used in accordance with the manufacturer's instructions. Blood pressure measurements were performed by an experienced member of the medical staff with the participant at rest and comfortably sitting in a chair for at least 5 min, in accordance with the 2013 ESH/ESC Guidelines for the management of hypertension [2]. Systolic and diastolic blood pressure readings were first taken at both arms using the upper arm device to rule out a difference exceeding 5 mmHg. The elbow of the arm that was measured was bent and supported on a chair arm to maintain the cuff at the heart level. In the presence of a difference exceeding 5 mmHg, all subsequent measures were taken at the arm exhibiting the highest blood pressure values. In all other participants, the left arm was

Fig. 1



Outline of the study protocol. The participants were randomized to have their blood pressure measured first either at the upper arm or at the wrist. BP, blood pressure.

Table 1 Characteristics of participants randomized to measurements of blood pressure at either upper arm or wrist first

Characteristics	Total population (n=48)	Arm first (n=21)	Wrist first (n=27)	P values*
Age (years)	81.3±8.0	80.4±8.3	82.0±7.7	0.493
Women	33 (69)	17 (81)	16 (59)	0.108
Treated with antihypertensive drugs	29 (40)	13 (62)	16 (59)	0.853
Systolic BP (upper arm)				
Left arm (mmHg)	131.3±16.5	132.1±14.3	130.8±18.2	0.800
Right arm (mmHg)	132.2±16.4	131.4±15.3	132.9±17.4	0.769
< 130 mmHg	33 (69)	14 (67)	19 (70)	–
130–160 mmHg	15 (31)	7 (33)	8 (30)	–
Diastolic BP (upper arm) (mmHg)				
Left arm (mmHg)	69.1±9.5	69.4±10.3	69.0±9.0	0.878
Right arm (mmHg)	69.8±10.5	71.0±11.9	68.9±9.5	0.487
< 80 mmHg	44 (92)	19 (90)	25 (93)	–
80–100 mmHg	4 (8)	2 (10)	2 (7)	–
Heart rate (beats/min)	79.5 [70; 85]	78 [70; 85]	80 [70; 85]	0.811
Basic ADLs	5 [4; 6]	5 [4; 6]	5 [4; 6]	0.760
Instrumental ADLs	6 [4; 8]	6 [5; 8]	6 [4; 8]	0.782
POMA score	22 [21; 23]	22 [22; 23]	22 [20; 23]	0.177
GDS score	2 [1; 4]	2 [1; 5.5]	2 [1; 4]	0.548
MMSE score	27 [26; 29]	27 [25; 28]	28 [26; 29]	0.208

Mean±SD or median [25%; 75%] for continuous variables.

Number (%) for categorical variables.

ADLs, activities of daily living; score range from 0 to 6 (higher score indicate better function) [18]; BP, blood pressure; GDS, Geriatric Depression Scale: score range from 0 to 15 (higher score indicate more depressive symptoms) [19]; MMSE, Mini Mental Status Exam, score range from 0 to 30 (higher scores indicate better cognition) [15]; POMA, Performance Oriented Mobility Assessment, score range from 0 to 28 (higher score indicate better gait and balance performance) [20].

*P values from Student's *t*-test or Wilcoxon rank-sum test for continuous variables and Pearson's χ^2 or Fisher's exact test for categorical variables.

used for blood pressure determination. Three consecutive blood pressure readings were obtained at a 1-min interval both at the upper arm and the wrist (Fig. 1). The sequence of measurements (upper arm or wrist first) was randomized. The second and third readings of each set of measurements were averaged for subsequent analysis. Blood pressure was measured at the wrist with the arm positioned appropriately as required by the sensor. All measures were carried out during the daytime, at least 1 h after the last meal. Only a single wrist blood pressure measurement failed with the persistence of an error message on three successive attempts.

Statistical analysis

The sample size was determined to provide an 80% statistical power, at an α level of 0.05, to detect a 2.0 ± 2.0 mmHg difference between blood pressure values obtained with the upper arm device and the wrist device.

Characteristics of individuals randomized to start blood pressure measurements at the upper arm versus wrist were compared using χ^2 or Fisher's exact test (according to distribution) for categorical variables, and Student's *t*-test or Wilcoxon rank-sum test (according to distribution) for continuous variables. Agreement between blood pressure measures at arm and wrist levels was evaluated using Bland–Altman scatter plots, and differences were assessed using Student's *t*-test. Data were expressed as means±SD, and statistical significance was set at *P* less than 0.05. All statistical analyses were performed using STATA 12.0 (Stat Corp., College Station, Texas, USA).

Table 2 Distribution of differences in systolic and diastolic blood pressures between values measured at upper arm or at wrist

Absolute difference in BP values (mmHg)	N (%)	
	Systolic BP	Diastolic BP
0–4.9	8 (17)	27 (56)
5.0–9.9	14 (29)	12 (25)
10.0–14.9	17 (35)	7 (15)
≥ 15.0	9 (19)	2 (4)

BP, blood pressure.

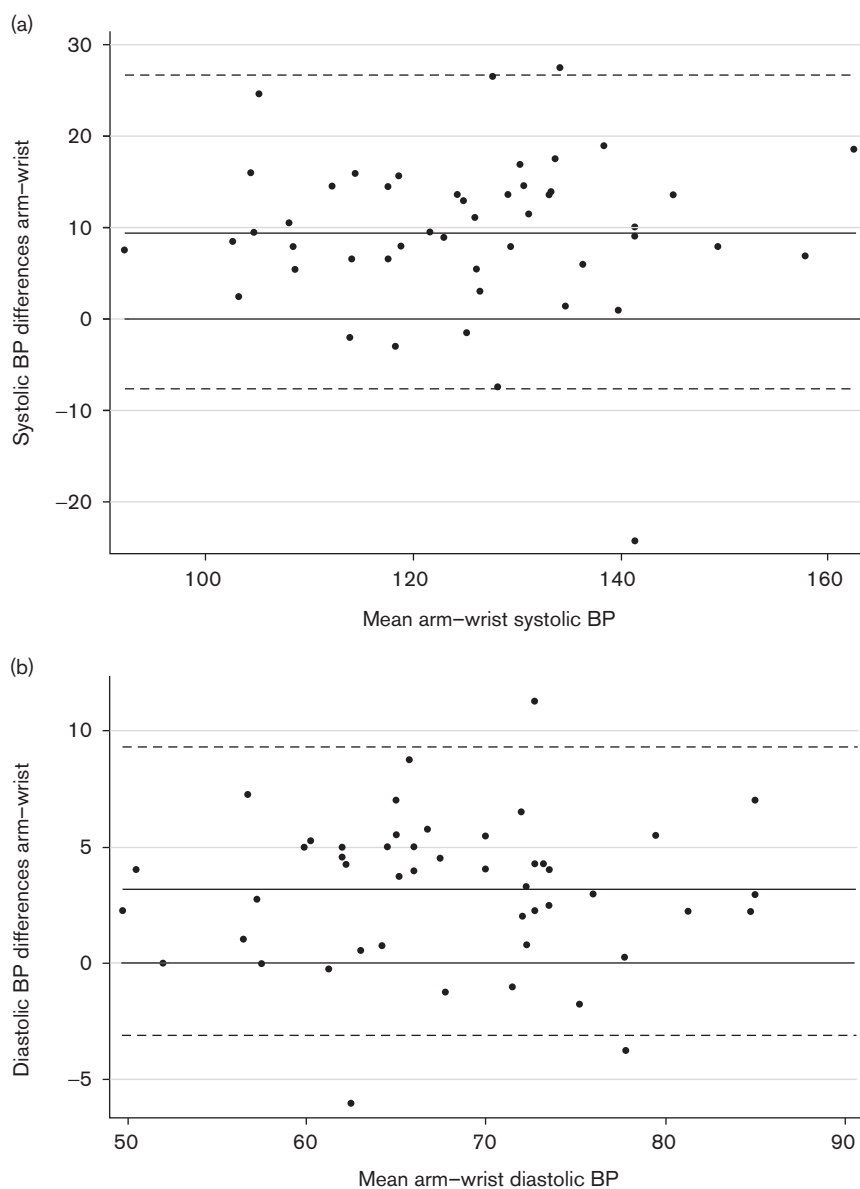
Results

The characteristics of the enrolled participants, taken all together ($n = 48$) or divided into two groups according to the site (upper arm or wrist) used for the first set of blood pressure measurements, are given in Table 1. There was no significant difference in all studied parameters between the two randomized groups.

Systolic blood pressure measured at the wrist was significantly ($P < 0.001$) lower than that measured at the upper arm ($120.1\pm 2.2/66.0\pm 1.3$ vs. $130.5\pm 2.2/69.7\pm 1.3$ mmHg, respectively). Table 2 depicts the magnitude of the difference between the upper arm and wrist blood pressures. This difference was greater than 10 mmHg for systolic blood pressure in 54.2% of participants. The corresponding value for diastolic blood pressure was 18.8%.

Figure 2 depicts the Bland–Altman scatter plot relating the difference in systolic (Fig. 2a) and diastolic (Fig. 2b) blood pressures measured at the upper arm and at the wrist (on the ordinate) and the mean of blood pressures measured at the two sites (abscissa). The magnitude of the difference between the two sets of values was not

Fig. 2



Bland-Altman scatter plot relating the difference in systolic (a) and diastolic (b) blood pressures (BP) measured at the upper arm and at the wrist (on the ordinate) and the mean of blood pressures measured at the two sites (abscissa).

influenced by the level of blood pressure *per se*. This was true for both systolic and diastolic blood pressure.

Discussion

This study performed in elderly patients was aimed to compare blood pressure values measured at the upper arm and wrist using two validated automated oscillometric devices (Dabl Educational Trust Limited, <http://www.dableducational.org>). Notably, the upper arm device has been validated in various populations, in particular in the elderly [16]. It was hoped that the wrist device

equipped with a position sensor would also provide reliable measurements in this population. Such a device would be especially convenient for self-measurement of blood pressure in elderly patients for whom it may be particularly difficult to fit themselves with an arm cuff at the upper arm.

In fact, major differences were observed between upper arm and wrist blood pressure values, the latter being consistently lower than the former when considering the mean values, although in a very variable way when considering the individual values, as illustrated in the

Bland–Altman scatter plots of both systolic and diastolic blood pressure differences. Notably, the blood pressure readings were obtained in this study in optimal conditions by an experienced person. Whether the differences would have been even greater or smaller if the participants had been asked to perform the measurements themselves is unknown.

Our finding of lower wrist than upper arm blood pressures is in agreement with some previous observations [21–24], but this was not the case in the experience of other investigators [18,25–28]. The divergent observations may be related to some extent to the care taken by the investigators and/or the study participants to follow strictly the manufacturer's instructions, in particular with regard to the arm position [29]. It is worth mentioning here the study performed by Stergiou *et al.* [24] using the same wrist device with position sensor as the one used in the present study. The comparison with arm blood pressure measurements was done as in our trial according to a cross-over design. Wrist blood pressures were also found to be substantially lower than arm blood pressures: the difference between the two sets of values was at least 10 mmHg in 34 and 15% of participants for systolic and diastolic measurements, respectively. However, the population was markedly younger (mean age = 56.7 years) than the one described in this paper (mean age = 81.3 years). In fact, none of the studies mentioned above specifically addressed the reliability of wrist blood pressure measurements in elderly participants. The rigidity of arteries increases with age, which could have an impact on blood pressure levels measured at different levels of the arterial tree. Other factors might contribute to the observed blood pressure differences between the upper arm and the wrist, including differences in the oscillometric algorithm used in the two devices. Unfortunately, no information is provided in this respect by the manufacturers. Our data are therefore relevant. They reinforce the position of the recently published guidelines proposed by the European Society of Hypertension and European Society of Cardiology in which preference is still given to blood pressure measurement at the upper arm [2].

The aim of this study was to compare two automated oscillometric devices, from the same manufacturer, one measuring blood pressure at the upper arm and the other one at the wrist. It should be pointed out that the gold standard for determining the accuracy of a device is based on the auscultatory but not the oscillometric method. Our findings are, however, relevant as the use of upper arm oscillometric devices is becoming more and more popular.

Conclusion

We do not recommend on the basis of the present observations the use of wrist blood pressure measuring devices for the diagnosis and management of hypertension in elderly patients, even if the device is equipped

with a position sensor. It appears crucial to validate in the future new blood pressure monitors at the wrist in all age categories, including in the elderly.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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