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Comparison of blood pressure measurements on the bare arm, over a sleeve and over a rolled-up sleeve in the elderly

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Abstract

Background. Although guidelines recommend that blood pressure (BP) should be measured on a bare arm, BP is sometimes measured over clothing in clinical settings.
Objective. To assess the accuracy of BP measurements over clothing rolled up to the elbow in clinical settings.
Methods. This was a cross-sectional study to a total of 186 individuals recruited from a primary care clinic and two day-care facilities between July and September 2014. Main outcome measures were BP measurements on (i) a bare arm, (ii) over the sleeve of a cardigan and (iii) over the sleeve of a cardigan rolled up to the elbow. BP was compared across measurement conditions using the paired *t*-test and multiple analysis of variance adjusting for age, sex, measurement order and interaction between clothing condition and measurement order.
Results. Of 186 subjects, 38.5% were male. Mean age was 74.6 years. Mean BP with a bare arm, over a sleeve and over a rolled-up sleeve was 128.9 (SD 19.1)/67.4 (10.8) mmHg, 132.8 (21.0)/72.6 (11.5) mmHg and 133.4 (21.3)/74.4 (12.1) mmHg, respectively. There were significant differences in BP between the bare arm and over a cardigan sleeve ($P < 0.001$) and the bare arm and over a rolled-up cardigan sleeve ($P < 0.001$). BP differences were significant even after adjusting for age group, sex, measurement order and interaction between clothing condition and measurement order.
Conclusions. Although previous studies have suggested BP measurements over clothing are acceptable, our results suggest that BP should be measured on bare arms as recommended by guidelines whenever feasible.

Key words: Aged, blood pressure, blood pressure determination, clothing, family practice, guideline adherence.

Introduction

In primary care settings, blood pressure (BP) measurement is one of the most essential physical examination procedures. Accurate measurement is necessary. Guidelines include standards for accurate BP measurement; for example, the 2014 Guideline for the Management of High Blood Pressure issued by the Eighth Joint

National Committee (1) recommends that BP should be measured on a bare upper arm with a cuff of appropriate size.

In actual clinical settings, however, it is sometimes not feasible to adhere to these guidelines (2,3) because the patient's condition makes it difficult to undress, there is insufficient time for resting, there are environmental factors such as a home visit or the cuff size is inappropriate (4,5). The feasibility of measuring BP with a bare arm is reduced, especially among frail elderly people. Patients sometimes wear many layers of thick clothing so it is too time-consuming to undress completely. Consequently, physicians alternatively put the BP cuff over sleeves or roll up sleeves to the elbow for auscultation of Korotkoff sounds and put the cuff over the rolled-up sleeve.

Several studies have challenged recommended standard measurement methods by assessing the accuracy of BP measurements over clothing. It has been reported that thin sleeves, e.g. on a shirt, do not seriously affect BP measurements. Previous studies have found that there is no significant difference in BP measured on the bare arm and over clothing that is <1.7 (6) or 2 mm (7) thick. When Ma *et al.* (8) randomly assigned 376 patients into two groups, bare arm versus sleeved arm with a mean clothing thickness of 4.3 mm (SD 1.6), they found no significant differences in BP measurements. However, the extent to which clothing affects BP measurements is unclear.

In this study, we attempted to assess the accuracy of BP measurements with thick clothing. After standardizing clothing thickness and condition, we compared BP measurements from bare arms to those from clothed arms.

Methods

Study subjects

Subjects were 186 adult patients of a primary care clinic and two day-care facilities in Tone, Japan. They were recruited between July and September 2014 based on continuous sampling on days the researchers could perform the study. We excluded patients whose BP could not be measured on the arm, patients with arrhythmia and patients who did not provide informed consent.

BP measurement

BP was measured under three conditions: (i) on a bare arm, (ii) on a sleeved arm and (iii) on an arm with the sleeve rolled up to the elbow. For sleeved arm and rolled-up sleeved arm measurements, if the participant's clothing was thicker than the thickness of one thin cotton shirt (1 mm), they were asked to undress and wear a provided cardigan. The cardigan was a male medium size (Japanese standard) and consisted of 70% wool and 30% nylon. The thickness of the unfolded cardigan sleeve was 1 mm, as measured by a skinfold caliper. The cardigan's sleeve was extended to the wrist for the sleeved arm measurement and rolled up to the elbow for the rolled-up sleeved arm measurement.

The participants were seated for 5 minutes on a chair or wheelchair with back support, with their feet resting on floor or the wheelchair's leg rest. They placed their arm on a table to keep the upper arm at the height of the heart. Smoking was avoided for at least 30 minutes prior to BP measurements.

We asked participants about their age, sex, smoking status and co-morbidities. Height and weight were measured using either a scale in the clinic or a scale that we prepared. Participants were considered smokers if they smoked one or more cigarettes per day. They were considered to have hypertension or diabetes if they were taking medications for these conditions.

For each measurement condition, systolic and diastolic BP was measured three times, and the average was used as the BP value. Overall, we performed BP measurements nine times for each participant. We designed six patterns of measurement order for the three conditions and assigned participants to them in a continuous order. We used an automated BP machine (Omron HEM-907) that is validated for accuracy (9). We used the same cuff for all measurements in all the participants, which surrounded the cardigan.

We did not change the cardigan during BP measurements for a given participant. A single researcher prepared for the participants' clothing condition, while measurement conditions were being changed.

Statistical analysis

We used the paired *t*-test to compare the mean BP between bare and sleeved arms and between bare and rolled-up sleeved arms. The *t*-test was used to compare BP across variables. We used analysis of variance (ANOVA) to compare BP values by age group (under 65, 65–74 and 75 years or older) and measurement order. We made Bland–Altman plots (10) for differences in systolic BP (i) between bare and sleeved arms and (ii) between bare and rolled-up sleeved arms. We made scatter plots with regression lines for BP difference (i) between bare and sleeved arms and (ii) between bare and rolled-up sleeved arms by age.

The Association of Advancement of Medical Instrumentation (AAMI) standard for comparing BP measurement methods defines good agreement between measurements as a mean difference of 5 mmHg or less, with a standard deviation of 8 mmHg or less (11). We calculated the proportion of participants whose difference in systolic BP between measurements was below 5 mmHg.

We estimated the difference in BP across clothing conditions using multivariate ANOVA while adjusting for age group, sex, measurement order and interaction between clothing condition and measurement order. All analyses were performed using SPSS software, version 22.0.

Results

Of the 186 participants, 77 (38.5%) were male. The mean age was 74.6 years (SD 13.8). The prevalence of hypertension and diabetes was 127/186 (63.5%) and 16/186 (8.0%), respectively. Characteristics of the study participants are shown in Table 1.

Mean BP measured with bare arms, sleeved arms and rolled-up sleeved arms was 128.9 (SD 19.1)/67.4 (10.8) mmHg, 132.8 (21.0)/72.6 (11.5) mmHg and 133.4 (21.3)/74.4 (12.1) mmHg, respectively (Table 2). Systolic and diastolic BP measurements with sleeved and rolled-up sleeved arms were significantly higher than measurements with bare arms ($P < 0.001$). The mean difference in systolic BP readings was 3.76 mmHg (SD 9.96) between bare and sleeved arms and 4.39 mmHg (SD 11.89) between bare and rolled-up sleeved arms. There was no significant difference between BP between measured on sleeved and rolled-up sleeved arms. Measurement order significantly affected systolic and diastolic BP measurements. The first condition resulted in the highest BP, followed by the second and third conditions. Figure 1 shows Bland–Altman plots of differences in systolic BP between (i) bare and sleeved arm conditions and (ii) bare arm and rolled-up sleeved arm conditions. A difference in systolic BP of <5 mmHg between bare and sleeved arms was seen in 38.2% of patients, compared to 32.3% between bare and rolled-up sleeved arms.

Table 1. Baseline characteristics of study participants from a primary care clinic and two day-care facilities in Japan (n = 186)

	Total (n = 186)	Setting		
		Primary care clinic (n = 135)	Day-care facility 1 (n = 10)	Day-care facility 2 (n = 41)
Age (years)	76.4 (11.9)	72.7 (11.5)	86.9 (5.6)	86.3 (5.2)
Sex, male (%)	72 (38.7)	57 (42.2)	4 (40.0)	11 (26.8)
Height (cm)	152.4 (11.1)	155.5 (9.4)	144.7 (10.9)	144.2 (11.3)
Weight (kg)	53.5 (11.2)	56.2 (11.0)	46.8 (9.7)	46.4 (7.8)
BMI (kg/m^2)	22.9 (3.2)	23.1 (3.4)	22.3 (3.2)	22.3 (2.6)
Hypertension (%)	122 (65.6)	95 (70.4)	7 (70.0)	20 (48.8)
Diabetes mellitus (%)	15 (8.1)	12 (8.9)	2 (20.0)	1 (2.4)
Smoking (%)	10 (5.4)	9 (8.9)	0 (0.0)	1 (2.4)

Unless otherwise indicated, values are means (SD). BMI, body mass index.

Table 2. Blood pressure measurements by setting

Variable		Mean systolic blood pressure		Mean diastolic blood pressure		Statistical test
Total (n = 186)		131.7 ± 20.5		71.4 ± 11.8		
Sex	Male (n = 72)	133.2 ± 20.9	P = 0.188	71.6 ± 11.7	P = 0.840	t-test
	Female (n = 114)	130.8 ± 20.3		71.4 ± 11.8		
Age	≤64 years (n = 23)	127.5 ± 17.3		77.7 ± 14.0		ANOVA
	65–74 years (n = 45)	130.8 ± 16.3	P = 0.118	73.6 ± 10.1	P < 0.001	
	≥75 years (n = 118)	132.9 ± 22.4		69.4 ± 11.4		
Smoking	Yes (n = 10)	133.3 ± 20.8	P = 0.661	72.8 ± 13.4	P = 0.516	t-test
	No (n = 176)	131.6 ± 20.5		71.4 ± 11.7		
Hypertension	Yes (n = 122)	135.2 ± 20.3	P < 0.001	71.8 ± 11.7	P = 0.383	
	No (n = 64)	125.1 ± 19.3		70.8 ± 12.0		
Diabetes	Yes (n = 15)	132.2 ± 21.3	P = 0.882	67.4 ± 9.5	P = 0.017	
	No (n = 171)	131.7 ± 20.5		71.8 ± 11.9		
Measurement method	Bare arm	128.9 ± 19.1		67.4 ± 10.8		paired t-test vs. bare arm
	Sleeved arm	132.8 ± 21.0	P < 0.001	72.6 ± 11.5	P < 0.001	
	Rolled-up sleeved arm	133.4 ± 21.3		74.4 ± 12.1		
Measurement order	#1	135.2 ± 22.0		73.7 ± 12.7		ANOVA
	#2	130.6 ± 20.0	P = 0.015	70.8 ± 11.1	P = 0.005	
	#3	129.3 ± 19.1		69.8 ± 11.2		

ANOVA, analysis of variance.

Scatter plots with regression lines of systolic and diastolic BP differences between bare and sleeved arm conditions and bare and rolled-up sleeved arm conditions by age are shown in Figure 2. The variation in BP difference between clothing conditions appeared to increase as age increased. For participants aged younger than 65 years, the mean BP on bare, sleeved and rolled-up sleeved arms was 126.3 (SD 17.5)/74.4 (12.8) mmHg, 129.4 (17.3)/79.0 (14.5) mmHg and 126.8 (17.7)/79.7 (14.6) mmHg, respectively. For participants aged 65–74 years, it was 127.6 (16.1)/70.1 (8.8) mmHg, 131.4 (17.2)/74.0 (9.4) mmHg and 133.4 (15.5)/76.8 (10.9) mmHg, respectively. For participants aged 75 years or older, it was 129.9 (20.4)/65.0 (10.3) mmHg, 134.0 (22.9)/70.8 (11.1) mmHg and 134.7 (23.6)/72.4 (11.6) mmHg, respectively. In all age groups, mean BP values for sleeved and rolled-up sleeved arms were significantly higher than those for bare arms (P < 0.05), except for rolled-up sleeved arms in participants aged younger than 65 years (P = 0.72).

Multivariate ANOVA results are shown in Table 3. We introduced an interaction term between measurement condition and measurement order into the multivariate model because the association between measurement order and BP varied across clothing conditions. In the multivariate model, systolic BP measured over rolled-up sleeved arms and diastolic BP measured over sleeved and rolled-up sleeved arms were significantly higher than measurements on bare arms.

Discussion

In contrast to previous studies, we observed that BP measured with a sleeved arm or a rolled-up sleeved arm was higher than BP measured on a bare arm. In addition, the variation in BP differences across measurement conditions was not small. Approximately one-third of the participants had BP differences within 5 mmHg. As shown in Figure 2, older age may contribute to variations in BP difference by clothing condition.

Our results were not compatible with past studies that suggested that measuring BP over clothing was acceptable. Age could be a factor that explains why our results differed from those in previous studies. Whereas the mean age of subjects was 45 years (SD 23.7) in the study by Liebl *et al.* (7) and 46 years (SD 16.0) in the study by Kahan *et al.* (6), it was 74.6 years (SD 13.8) in our study. Aging increases arterial stiffness and reduces compliance, leading to BP variability in the elderly (12). As shown in Figure 2, the variation in BP differences among clothing conditions appears to increase with age. Therefore, BP measurements in the elderly might be more susceptible to clothing conditions.

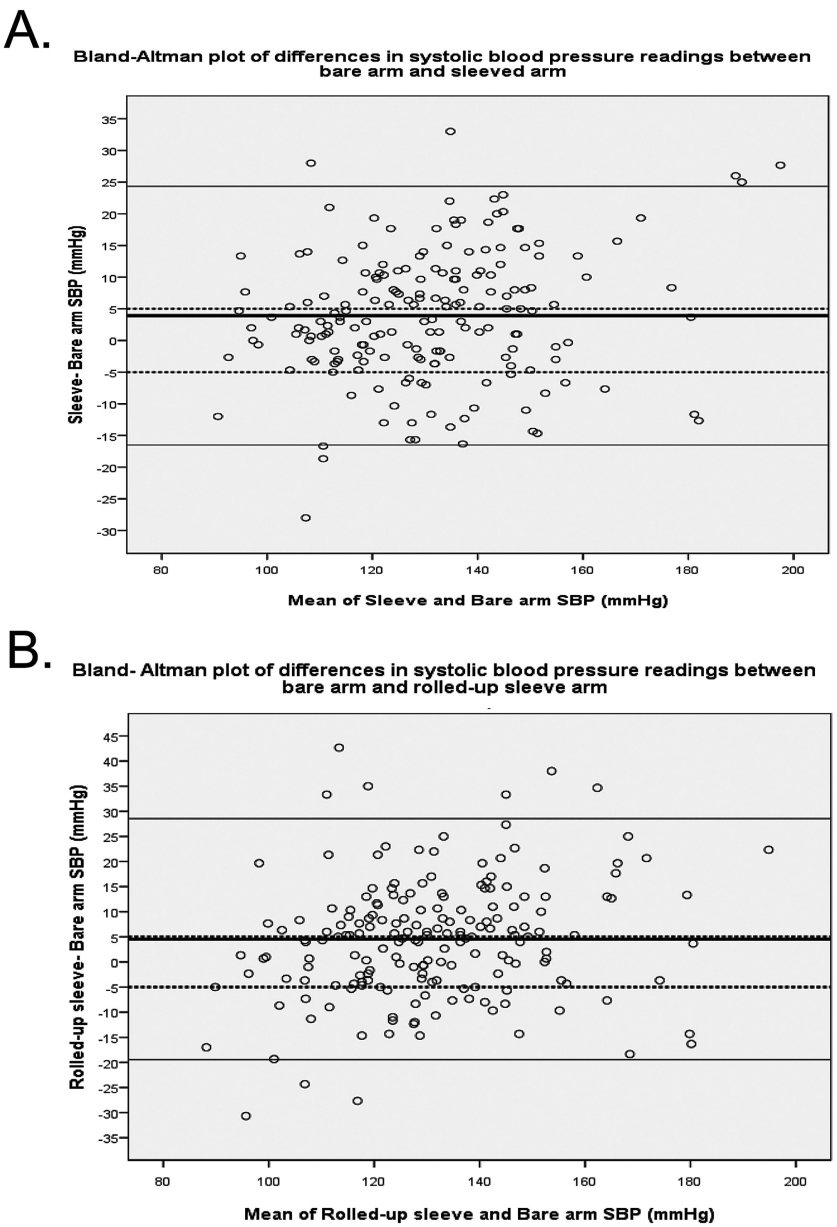

Figure 1. **A**. Bland–Altman plot of differences in systolic blood pressure readings between bare and sleeved arms; **B**. Bland–Altman plot of differences in systolic blood pressure readings between bare and rolled-up sleeved arms.

Differences in study design may be another reason why our results differed from those of past studies. The study by Ma *et al*. (8), which resulted in no significant difference between bare arm and clothed arm measurements, assigned 376 patients to one of two measurement groups and compared the BP measurements of the groups. If the two groups were not sufficiently comparable, it is possible that differences in the characteristics of the study participants masked BP differences based on measurement method. The study by Holleman *et al*. (13) compared BP measured in the same individual with bare and clothed arms but it had only 36 subjects, which may have not been sufficient to identify a significant difference. In addition to the small sample size, their complicated design may have obscured true differences by clothing condition. In addition, all the studies mentioned above used the participants' own clothing for BP measurements over sleeves, whereas we standardized clothing condition providing a standard cardigan.

Clothing thickness may also affect BP measurements over clothing. Multivariate ANOVA showed that sleeved arms had a β-estimate of 6.16 for systolic BP and 5.24 for diastolic BP, and rolled-up sleeved arms had β-estimates of 12.37 and 10.09, respectively, indicating that thicker sleeves may produce higher BP differences (Table 3). For sleeved arm measurements, the participants wore a cardigan with a thickness of 1 mm as measured by a skinfold caliper. For rolled-up sleeve measurements, the participants wore the same cardigan but with the sleeve rolled up to the elbow. The measured thickness of thick and overlapping clothing with a skinfold caliper varied by location of measurement, so we believe measurements of rolled-up sleeve thickness with a skinfold caliper might be inaccurate. Although we could not provide an accurate measurement of the thickness of the rolled-up sleeve, we created a relatively thick clothing layer under the cuff.

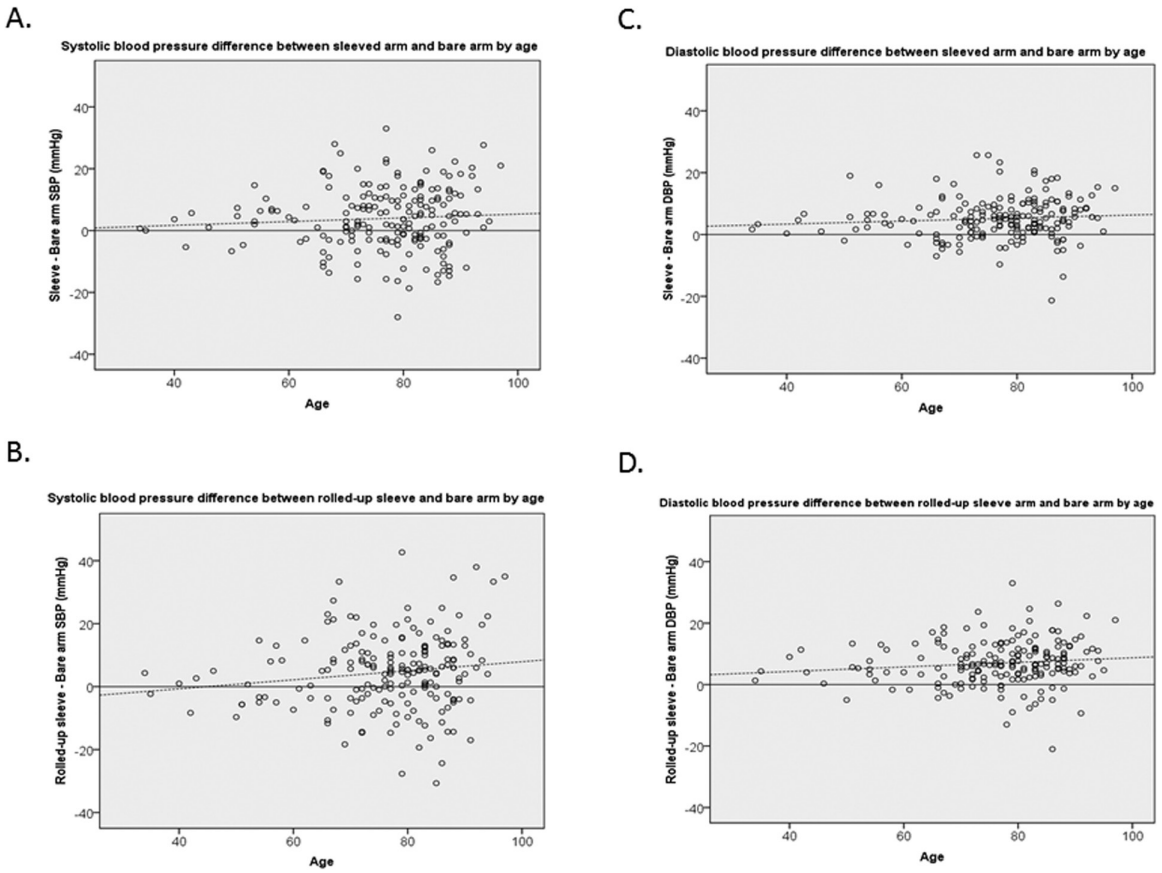

Figure 2. A. Systolic blood pressure (SBP) difference between sleeved and bare arms by age; B. SBP difference between rolled-up sleeved and bare arms by age; C. Diastolic blood pressure (DBP) difference between sleeved and bare arms by age; D. DBP difference between rolled-up sleeved and bare arms by age. The dotted lines indicate regression lines.

Table 3. Differences in blood pressure based on parameters in the multivariate analysis of variance model

Parameter		Systolic blood pressure			Diastolic blood pressure		
		β-estimate	Standard error	*P*-value	β-estimate	Standard error	*P*-value
Measurement method	Bare arm	0	–	–	0	–	–
	Sleeved arm	6.16	3.60	0.087	5.24	1.94	0.007
	Rolled-up sleeve arm	12.37	3.57	0.001	10.09	1.93	<0.001
Age	≤64 years	0	–	–	0	–	–
	65–74 years	2.77	2.96	0.349	−4.52	1.60	0.005
	≥75 years	5.22	2.64	0.048	−8.51	1.42	<0.001
Measurement order	#1	0	–	–	0	–	–
	#2	1.23	3.60	0.685	0.66	1.94	0.736
	#3	−1.45	3.57	0.733	−3.97	1.92	0.039

An interaction term between measurement order and method was also included as a variable.

Measurement order influenced BP, but the difference in BP by clothing condition remained after adjusting for measurement order. A previous study demonstrated that BP can decline substantially in the first 10 minutes before it stabilizes in the clinic setting (14). In our study, we added an interaction term for clothing condition and measurement order as one of the variables in the multivariate ANOVA model, which showed that sleeved and rolled-up sleeved arm measurements were significantly different from bare arm measurements. Since the variation in BP difference across clothing conditions is relatively large, simply increasing the rest time before BP measurements may be insufficient for accurate BP measurements in daily clinical practice.

Our study participants, with mean body mass index (BMI) of 22.9 kg/m^2 and mean BP of 131.7/71.4 mmHg, may be leaner and have lower mean BP (15) than the global population, but we assume that our results are sufficiently generalizable to other nationalities. BMI, mean BP and smoking status of our study participants were relatively similar to those of the standard Japanese population, as reported by the 2014 National Health and Nutrition Survey conducted by the Ministry of Health, Labour and Welfare (16). We analyzed BP difference by clothing condition according to participants' BMI, but BMI did not have a significant impact on the results. In addition, Bland–Altman plots of differences in systolic BP between

bare and sleeved arms (Fig. 2) did not depend on mean systolic BP. Since the effect of BMI and mean BP on our results was small, we assume that our results are generalizable to other populations.

There were some limitations to our study. We might not have had enough younger participants to demonstrate the effect of age on BP difference by clothing condition. Subjects and researchers were not blinded to measurement conditions. Instead, we used an automated sphygmomanometer and randomly assigned the measurement order for each patient. We used a cuff of the same size for all patients despite possible differences in arm circumference.

Our results suggest that BP readings over sleeved and rolled-up sleeved arms are different from measurements on bare arms. In addition, the differences between clothing conditions showed large variations, and age may contribute to this variation in BP differences. Although a mean BP difference of 4 mmHg may not seem clinically significant, the variation shown in the Bland–Altman plots (Fig. 1) indicates that for some patients BP measured over clothing could be either higher or lower than bare arm measurements by 15 mmHg. We recommend that BP should be measured on bare arms as much as feasible, or at least that health care providers take into consideration that BP measured over clothing may differ from bare arm measurements by as much as 15 mmHg, especially in older patients. Further study may be needed to clarify the extent to which clothing on the arm is acceptable for attaining clinically relevant BP measurements and to identify patient factors related to variations in BP measurement differences when they wear different types of clothing.

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Declaration

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Conflict of interest: none.

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