Mean mid-arm circumference and blood pressure cuff sizes for US adults: National Health and Nutrition Examination Survey, 1999–2010

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Background **Accurately measuring blood pressure (BP) requires choosing an appropriate BP cuff size.**

Objectives **This study examined trends in mid-arm circumference (mid-AC) and distribution of BP cuff sizes using 1999–2002, 2003–2006, and 2007–2010 National Health and Nutrition Examination Survey (NHANES) data.**

Methods **NHANES uses a complex multistage probability sample design to select participants who are representative of the entire civilian, noninstitutionalized US population. The analytic sample consisted of 28 233 participants aged 20 years or older. Mid-AC and BP cuff sizes were analyzed across survey years by sex, age, race/ethnicity, hypertension, and diabetic status.**

Results **Data from NHANES 2007–2010 show that the mean mid-AC for men was 34.2 cm and for women was 31.9 cm. Men showed a significant trend in mid-AC (from 33.9 cm in 1999–2002 to 34.2 cm in 2007–2010; $P < 0.05$ for trend). In addition, 42.9% of men and 25.3% of women needed a large adult BP cuff and 1.9% of men and 2.8% of women needed thigh cuffs to be appropriately cuffed. Moreover, 52% of hypertensive men, 38% of hypertensive women, 59.1% of diabetic men, and 53.6% of diabetic women required the use of BP cuffs with sizes different from those of standard adult-sized BP cuffs for accurate BP measurement.**

Conclusion **There was an overall significant trend in the mean mid-AC in cm for men but not for women. On the basis of NHANES 2007–2010 data, ~45% of adult men and ~28% of adult women required the use of BP cuffs with sizes different from those of standard adult-sized BP cuffs for accurate BP measurement.** ***Blood Press Monit*** **18:138–143**

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Introduction

An estimated 30% of adults aged 18 and over in the USA are hypertensive, defined as having a blood pressure (BP) greater than or equal to 140/90 mmHg or on treatment with antihypertensive medications. Although hypertension is a significant risk factor for cardiovascular disease and mortality, it is a modifiable risk factor [1–4]. Effective BP management, resulting in a reduction in BP, has been shown to greatly decrease the incidences of stroke, heart attack, and heart failure [2,5,6]. Therefore, accurate measurement of BP is critical for hypertension screening, as well as for disease management. To accurately measure BP, a BP cuff with an appropriate bladder width must be used. According to the American Heart Association (AHA), an 'ideal' bladder width, which covers 40% of an individual's arm circumference, is needed for accurate BP assessment [7]. Using a cuff with a bladder width that is too narrow for the mid-arm circumference (mid-AC) leads to overestimation of BP, which potentially results in 'cuff hypertension'. In contrast, use of a bladder that is too wide for the mid-AC results in underestimation of or incorrectly low BP readings [8,9].

Changes in mid-AC in adults in the USA has previously been reported with National Health and Nutrition Examination Survey (NHANES) data for the years 1988–2002. The results showed that the mean mid-AC increased significantly between NHANES III and NHANES 1999–2002 for all age groups [10].

This study updates the data presented in the previous study and examines trends in the distribution of mid-AC and the corresponding recommended BP cuff sizes by sex, age, and race/ethnicity across three 4-year survey periods (1999–2002, 2003–2006, and 2007–2010). In addition, the report will provide data on recommended BP cuff sizes for special clinical subpopulations, such as hypertensive and diabetic individuals.

Methods

Survey description

NHANES uses a complex multistage probability sample design to select participants who are representative of the entire civilian, noninstitutionalized US population. Parti-

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cipants are interviewed at their homes and information is obtained on health history, health behaviors, and risk factors. Subsequently, they undergo physical examination at a mobile examination center. The procedures to select the sample and conduct the interview and examination have been described previously [11]. The National Center for Health Statistics Ethics Review Board approved the NHANES protocol. This report is based on an analysis of mid-AC data on US adults aged 20 years or older from NHANES 1999–2010. Informed consent was obtained from all participants.

Sample

A total of 43 426 individuals aged 20 years or older were included. Of these, 32 464 (75%) were interviewed and 30 752 (71%) were examined. Of those examined, 2519 individuals were excluded because of the following reasons: 1222 because of pregnancy and 1297 because of missing data on mid-AC. These exclusions resulted in a final analytic sample of 28 233 participants aged 20 years or older.

Outcome variables

Mid-arm circumference

During the physical exam, the participant's right arm circumference was measured by a trained examiner at the level of the upper arm mid-point mark. The examiner made this mark on the posterior surface of the arm immediately after measuring the upper arm length. The arm mid-point mark was the level at which the measurement was taken, to the nearest 0.1 cm, using a steel measuring tape. The measuring tape fit snugly against the skin for the entire circumference of the arm without indenting the skin. For more details see the Anthropometry Procedures Manual on the NHANES website [12].

Blood pressure cuff sizes

Because the cuff size recommendations can vary according to the manufacturer, we used the AHA scientific statement definitions for recommended BP cuff sizes [7]. Specifically, the mid-AC range for the small adult BP cuff size (dimensions: 12 cm bladder width by 22 cm length) was 22–26 cm, for the adult size (dimensions: 16 cm bladder width by 30 cm length) was 27–34 cm, for the large adult size (dimensions: 16 cm bladder width by 36 cm length) was 35–44 cm, and for the adult thigh size (dimensions: 16 cm bladder width by 42 cm length) was 45–52 cm. Mid-AC of less than 22 cm (corresponding to infant BP cuff sizes) represented 0.2% (78 individuals) of the cuff fit needs of all survey participants. These individuals were excluded from the cuff size analysis but were included in the mid-AC analysis.

Demographic variables

Participants were categorized on the basis of age into the following groups: 20–39, 40–59, and 60 years or older. On the basis of race/ethnicity, as per self-reported information, participants were classified as non-Hispanic white, non-Hispanic black, or Mexican-American. Participants not fitting the above self-classification were classified as 'other.' Data for the 'other' group, including individuals who reported multiple races, were included in the total sample results but are not reported separately in the data tables.

Other covariates

A participant was defined as having hypertension if at least one of the following conditions applied: a systolic BP of 140 mmHg or greater; a diastolic BP of 90 mmHg or greater; or currently under treatment with prescribed medications for high BP. An average of up to three systolic and diastolic BP readings was used in applying this definition to data [13]. Participants were defined as being 'diabetic' if they reported during the home interview that they had been told by a doctor that they had diabetes [13].

Statistical analyses

SUDAAN (SUDAAN Research Triangle Institute, Research Triangle Park, North Carolina, USA) was used for data analysis. All analyses used the mobile examination center sample weights, and Taylor Series linearization was used to calculate SEs and 95% confidence intervals (CIs). Trends in mid-AC across the three 4-year survey periods were tested using orthogonal linear contrast [14]. The stated null hypothesis was that there was no linear trend in the mid-AC. Rejection of this hypothesis implied the existence of a linear trend.

Satterthwaite-adjusted χ^2-statistics were used to test the association of the four BP cuff sizes and the three 4-year survey periods by covariates [15]. A P-value of less than 0.05 was considered statistically significant.

In this analysis, if the relative standard error of an estimated mean or percentage was greater than 30%, it was considered to be marked and the estimate was designated as unreliable [11]. Relative standard error is defined as the ratio of the standard error of the estimate divided by the estimate multiplied by 100 [11].

Results

Table 1 presents the mean values and changes in mid-AC across the three 4-year survey periods by sex, age groups, and race/ethnicity. For men, the overall mean mid-AC increased from 33.9 cm in 1999–2002 to 34.1 cm in 2003–2006 and 34.2 cm in 2007–2010 ($P < 0.05$, significant for trend). For women, the overall mean mid-AC was 32.0 cm in 1999–2002, 31.9 cm in 2003–2006, and 31.9 cm in 2007–2010, with no significant trend. Among men, there were significant increases in the mean mid-AC in individuals aged 60 years and over, Mexican-American individuals, and non-Hispanic black individuals. All of the changes were less than 1 cm. Among non-Hispanic black men, the resulting increases were clinically significant. That

Table 1 Trends in the mean arm circumference (in cm) of US adults by demographic characteristics: NHANES 1999–2010

	Survey period						
	1999–2002		2003–2006		2007–2010		
	n	Mean (SE)	*n*	Mean (SE)	*n*	Mean (SE)	*P*-value*
Men							
Total	4295	33.9 (0.1)	4349	34.1 (0.1)	5456	34.2 (0.1)	<0.05
Age group (years)							
20–39	1408	33.9 (0.1)	1517	34.1 (0.2)	1774	34.1 (0.2)	>0.05
40–59	1362	34.4 (0.1)	1321	34.7 (0.2)	1822	34.8 (0.1)	>0.05
60 or more	1525	32.7 (0.1)	1511	32.9 (0.1)	1860	33.3 (0.1)	<0.05
Race/ethnicity							
Mexican-Americans	1025	33.2 (0.2)	880	33.3 (0.2)	967	33.7 (0.2)	<0.05
Non-Hispanic white	2131	34.0 (0.1)	2264	34.2 (0.1)	2649	34.3 (0.1)	>0.05
Non-Hispanic black	803	34.4 (0.2)	908	35.0 (0.2)	1039	35.2 (0.1)	<0.01
Women							
Total	4306	32.0 (0.1)	4195	31.9 (0.2)	5632	31.9 (0.1)	>0.05
Age group (years)							
20–39	1369	31.4 (0.2)	1337	31.2 (0.2)	1830	31.7 (0.2)	>0.05
40–59	1374	32.7 (0.2)	1358	32.8 (0.2)	1882	32.3 (0.2)	>0.05
60 or more	1563	31.8 (0.1)	1500	31.7 (0.1)	1920	31.7 (0.1)	>0.05
Race/ethnicity							
Mexican-Americans	1019	31.9 (0.2)	798	32.2 (0.2)	1011	32.2 (0.1)	>0.05
Non-Hispanic white	2060	31.7 (0.2)	2158	31.7 (0.2)	2634	31.7 (0.2)	>0.05
Non-Hispanic black	858	34.2 (0.2)	925	34.4 (0.3)	1071	34.4 (0.2)	>0.05

NHANES, National Health and Nutrition Examination Survey.
**P*-value for test of linear trend.

is to say, this increase corresponded to a change in the BP cuff size from a standard adult size in 1999–2002 (34.4 cm) to a large adult cuff size in 2007–2010 (35.2 cm) [7].

Tables 2 and 3 examine the percentage distributions of AHA-recommended BP cuff sizes across the three 4-year survey periods for men and women, respectively. During 2007–2010, among men, 2.6% needed a small adult cuff, 52.7% needed an adult cuff, 42.9% needed a large adult cuff, and 1.9% needed a thigh cuff. There was no significant difference between 1999–2002 and 2003–2006 ($P > 0.05$). Among race/ethnicity subgroups, there were associations between survey period and appropriate cuff size. Specifically, among Mexican-American men, the percentage of individuals who required large adult or thigh cuff sizes increased from 35.2% in 1999–2002 to 38.2% in 2007–2010. In addition, among non-Hispanic black men, the percentage of individuals who required large adult or thigh cuff sizes increased from 46.6% in 1999–2002 to 53.5% in 2007–2010.

Among women, during 2007–2010, 13.5% needed a small adult cuff, 58.4% needed an adult cuff, 25.3% needed a large adult cuff, and 2.8% needed a thigh cuff. There was no significant association between BP cuff sizes and the overall survey period, age group, or race/ethnicity.

Table 4 examines the percentage distributions of AHA-recommended BP cuff sizes for men and women by hypertension and diabetic status for survey years 2007–2010. Among hypertensive individuals, 52% of men and 38.4% of women needed a cuff size greater than the standard adult cuff size. Among diabetic individuals, 59.1% of men and 53.6% of women needed a cuff size greater than the standard adult cuff size.

Discussion

During 2007–2010, ~45% of all adult male individuals and ~27% of all adult female individuals, aged 20 years or older, required a BP cuff larger than the standard adult BP cuff size. The only significant association between recommended BP cuff sizes and the survey period was found among Mexican-American men, non-Hispanic black men, and men 60 years or older. In these subgroups there was an increase in the percentage of individuals requiring a large adult or thigh BP cuff from 1999–2002 to 2007–2010. We speculate that the reported increase in obesity among men over this time period may be associated with the increased mid-AC [10]. Specifically, in 1999–2000 27.5% of men were obese and by 2009–2010 the prevalence had increased to 35.5% [16–18]. In the same vein, it is suggested that increases in cuff sizes are also associated with the reported increase in prevalence of obesity among Mexican-American men, 28.9% of whom were obese in 1999–2000, which increased to 36.6% by 2009–2010 [18]. Similarly, 27.9% of non-Hispanic black men were obese in 1999–2000, which increased to 38.8% by 2009–2010 [18]. Among women, the overall mean of mid-AC and recommended BP cuff sizes showed no significant linear trend over the 12-year period from 1999 through to 2010. This finding may reflect the fact that there was no significant linear trend in obesity among women from 1999–2010. Specifically, 33.4% of women were obese in 1999–2000 with no significant change in 2009–2010 (35.8%) [18].

To further investigate the relationship between BMI and recommended BP cuff sizes, adjusted odds ratios (ORs) and 95% CIs were calculated using an ordered logistic regression model (Proc Multilog, SUDAAN). The model

Table 2 Percentage and SE of adult men by AHA-recommended blood pressure cuff sizes[a] and demographic characteristics: NHANES 1999–2010

		Percentage (SE)				
	n	Small adult	Adult	Large adult	Thigh	*P*-value†
Total						>0.05
1999–2002	4293	2.4 (0.3)	55.6 (1.0)	40.5 (0.9)	1.5 (0.2)	
2003–2006	4344	2.9 (0.3)	53.7 (1.3)	41.8 (1.4)	1.6 (0.2)	
2007–2010	5452	2.6 (0.3)	52.7 (1.2)	42.9 (1.1)	1.9 (0.2)	
Age group (years)						
20–39						>0.05
1999–2002	1408	2.4 (0.4)	56.2 (1.6)	39.5 (1.4)	1.9 (0.4)	
2003–2006	1517	2.9 (0.5)	54.1 (1.9)	40.9 (1.9)	2.0 (0.3)	
2007–2010	1773	2.5 (0.6)	53.1 (1.7)	41.8 (1.5)	2.6 (0.4)	
40–59						>0.05
1999–2002	1361	1.7 (0.4)	49.9 (1.8)	46.8 (1.6)	1.7 (0.4)	
2003–2006	1321	1.7 (0.3)	48.7 (1.9)	47.9 (1.9)	1.4 (0.4)	
2007–2010	1822	1.9 (0.4)	48.5 (1.6)	47.9 (1.5)	1.7 (0.3)	
60 or more						>0.05
1999–2002	1524	3.8 (0.5)	65.3 (1.6)	30.6 (1.7)	0.3 (0.2)[b]	
2003–2006	1506	5.3 (0.5)	62.3 (1.7)	31.6 (1.6)	0.8 (0.3)[b]	
2007–2010	1857	3.9 (0.6)	59.6 (1.9)	35.7 (1.9)	0.9 (0.3)[b]	
Race/ethnicity						
Mexican-American						<0.05
1999–2002	1025	2.3 (0.5)	62.4 (1.8)	34.4 (1.9)	0.8 (0.3)[b]	
2003–2006	880	2.3 (0.5)	62.5 (2.3)	35.1 (2.3)	0.2 (0.1)[b]	
2007–2010	967	1.3 (0.4)[b]	60.5 (2.0)	36.6 (1.8)	1.6 (0.5)[b]	
Non-Hispanic white						>0.05
1999–2002	2131	2.3 (0.3)	54.2 (1.1)	42.0 (1.0)	1.5 (0.3)	
2003–2006	2260	3.0 (0.4)	52.7 (1.5)	42.9 (1.6)	1.5 (0.3)	
2007–2010	2646	2.0 (0.3)	51.1 (1.5)	44.7 (1.3)	1.6 (0.3)	
Non-Hispanic black						<0.01
1999–2002	801	2.8 (0.6)	50.7 (1.8)	44.1 (1.9)	2.5 (0.5)	
2003–2006	907	2.5 (0.4)	47.5 (2.2)	45.0 (2.0)	5.0 (0.7)	
2007–2010	1039	2.6 (0.3)	44.0 (1.4)	48.7 (1.3)	4.8 (0.6)	

AHA, American Heart Association; BP, blood pressure; NHANES, National Health and Nutrition Examination Survey.
[a]American Heart Association's scientific statement definitions of BP cuff sizes [7].
[b]Estimate does not meet study standards for statistical reliability and precision. The relative standard error is greater than 30%.
†*P*-value from test of independence using Satterthwaite-adjusted χ^2.

assessed the independent relationship between the predictor variables and the response variable, BP cuff size, which was treated as an ordinal variable. The assumption is that BP cuff sizes have a natural ordering from low to high: small adult/child cuff, adult cuff, large adult cuff, and thigh cuff. The result (not shown) suggested that after adjusting for all covariates BMI was significantly associated with BP cuff sizes; with a one unit increase in BMI, the odds of needing a larger BP cuff size increased by 105% for men (OR = 2.05, 95% CI = 1.99, 2.11) and 93% for women (OR = 1.93, 95% CI = 1.87, 1.98).

Alpert [19] in a recent editorial estimated that 'improper cuffs are used at least 30% to 50% of the time'. McKay *et al.* [20] showed that only 29 of 114 (25.4%) doctors surveyed had a large BP cuff available in their clinic for patients requiring such a cuff, and only 13 of 114 (11.4%) doctors surveyed had the full complement of BP cuffs in their clinic. In addition, on the basis of findings from a study on a sample of 831 healthcare providers, Wingfield *et al.* [21] reported that only 27% of the doctors and 32% of the nurses used the appropriate BP cuff size. Finally, as Prineas *et al.* [22] stated, 'Regardless of the origins of the increase in arm size, there is a need to be aware of changing requirements of BP cuff sizes to appropriately match mid-AC and avoid overestimate of actual BP levels. In population samples, this could result in false, secular trends of BP level estimates' (p. 712).

The findings in this report are subject to some limitations. We chose the AHA-recommended BP cuff sizes as the basis of our presentation [7]. Although this is a widely accepted guideline in the USA, the selection of cutoff points for such guidelines, and even the design of BP cuffs themselves, may vary among professional societies and internationally. Both are subjects of continuing scientific debate. For example, whereas the AHA-recommendation suggests that an ideal bladder width cover 40% of an individual's arm circumference for accurate BP assessment, others recommend a 46% ratio as an ideal bladder width [7,23].

Conclusion

Between 1999 and 2010, there was a significant increase in the mean mid-AC (in cm) among all men, those aged 60 years or older, and among Mexican-Americans and non-Hispanic blacks. There was no significant trend in the mean mid-AC among women. During 2007–2010, ~45% of men and 28% of women aged 20 years or older required the use of large-sized or thigh-sized BP cuffs rather than standard adult-sized BP cuffs for accurate BP measurement. The percentage of individuals requiring larger BP

Table 3 Percentage and SE of adult women by AHA-recommended blood pressure cuff sizes[a] and demographic characteristics: NHANES 1999–2010

		Percentage (SE)				
	n	Small adult	Adult	Large adult	Thigh	*P*-value†
Total						>0.05
1999–2002	4286	12.5 (0.7)	59.3 (0.9)	25.4 (0.9)	2.8 (0.4)	
2003–2006	4178	14.0 (0.7)	57.1 (1.0)	26.2 (0.9)	2.7 (0.3)	
2007–2010	5602	13.5 (0.7)	58.4 (0.9)	25.3 (0.7)	2.8 (0.3)	
Age group (years)						
20–39						>0.05
1999–2002	1361	16.8 (1.3)	58.5 (1.3)	22.1 (1.2)	2.6 (0.4)	
2003–2006	1333	18.9 (1.4)	56.3 (1.9)	22.2 (1.4)	2.6 (0.5)	
2007–2010	1820	16.8 (1.3)	56.9 (1.5)	22.8 (1.3)	3.5 (0.4)	
40–59						>0.05
1999–2002	1373	9.5 (0.9)	58.5 (1.6)	28.3 (1.4)	3.7 (0.8)	
2003–2006	1355	10.5 (1.0)	55.4 (1.5)	31.0 (1.4)	3.1 (0.6)	
2007–2010	1878	11.0 (1.1)	58.7 (1.4)	27.4 (1.3)	2.9 (0.4)	
60 or more						>0.05
1999–2002	1552	10.9 (0.9)	61.7 (1.4)	25.8 (1.3)	1.5 (0.3)	
2003–2006	1490	12.5 (1.2)	61.0 (1.4)	24.2 (1.2)	2.3 (0.4)	
2007–2010	1904	12.6 (0.8)	60.2 (1.2)	25.4 (1.0)	1.9 (0.4)	
Race/ethnicity						
Mexican-American						>0.05
1999–2002	1014	9.5 (1.0)	64.9 (1.8)	23.4 (1.9)	2.2 (0.5)	
2003–2006	797	9.5 (1.5)	61.1 (2.1)	28.0 (2.2)	1.3 (0.4)[b]	
2007–2010	1009	8.6 (1.1)	61.7 (1.6)	28.4 (1.5)	1.4 (0.2)	
Non-Hispanic white						>0.05
1999–2002	2048	13.4 (0.9)	59.7 (0.9)	24.6 (1.0)	2.3 (0.4)	
2003–2006	2146	14.6 (0.8)	58.1 (1.0)	24.9 (1.0)	2.4 (0.4)	
2007–2010	2616	14.1 (0.9)	59.5 (1.2)	23.9 (1.0)	2.6 (0.4)	
Non-Hispanic black						>0.05
1999–2002	855	7.7 (0.8)	49.9 (1.8)	35.7 (1.9)	6.7 (1.0)	
2003–2006	922	8.2 (1.3)	45.3 (2.2)	39.6 (1.9)	6.9 (0.8)	
2007–2010	1063	7.4 (1.0)	47.6 (1.9)	38.3 (1.9)	6.7 (0.8)	

AHA, American Heart Association; BP, blood pressure; NHANES, National Health and Nutrition Examination Survey.
[a]American Heart Association's scientific statement definitions of BP cuff sizes [7].
[b]Estimate does not meet study standards for statistical reliability and precision. The relative standard error is greater than 30%.
†*P*-value from test of independence using Satterthwaite-adjusted χ^2.

Table 4 Percentage and SE of adult men and women by AHA-recommended blood pressure cuff sizes[a] and hypertension and diabetic status: NHANES 2007–2010

		Percentage (SE)			
	Sample size	Small adult	Adult	Large adult	Thigh
Men					
Hypertensive	2014	2.6 (0.4)	45.4 (2.1)	48.4 (1.8)	3.6 (0.5)
Women					
Hypertensive	2077	7.7 (0.6)	54.0 (1.1)	33.6 (1.1)	4.8 (0.5)
Men					
Diabetic	660	1.0 (0.4)[b]	40.0 (2.6)	56.0 (2.4)	3.1 (0.7)
Women					
Diabetic	673	4.1 (0.9)	42.3 (2.3)	44.1 (2.7)	9.5 (1.8)

AHA, American Heart Association; BP, blood pressure; NHANES, National Health and Nutrition Examination Survey.
[a]American Heart Association's scientific statement definitions of BP cuff sizes [7].
[b]Estimate does not meet study standards for statistical reliability and precision. The relative standard error is greater than 30%.

cuffs varied according to age and race/ethnicity but was generally the same as that during earlier years. In addition, during 2007–2010 ~52% of hypertensive men, 38% of hypertensive women, 59% of diabetic men, and 54% of diabetic women required the use of large-sized or thigh-sized BP cuffs rather than standard adult-sized BP cuffs for accurate BP measurement.

Acknowledgements

This paper is dedicated to the memory of Dr Lester R. (Randy) Curtin, a friend and a mentor. You are missed.

Conflicts of interest

There are no conflicts of interest.

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