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Rationale for ambulatory and home blood pressure monitoring thresholds in the 2017 American College of Cardiology/American Heart Association guideline

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The 2017 American College of Cardiology/American Heart Association (ACC/AHA) Guideline for the Prevention, Detection, Evaluation and Management of High Blood Pressure (BP) in Adults recommends classifying BP into one of four levels: normal BP, elevated BP and stage 1 and 2 hypertension based on the average of two or more measurements obtained in the office setting on two or more occasions (Table 1).^{1, 2} Hypertension is defined in the guideline as a mean office systolic BP (SBP) ≥ 130 mm Hg or a mean office diastolic BP (DBP) ≥ 80 mm Hg. To confirm the presence of hypertension, the ACC/AHA guideline recommends measuring BP outside of the office setting using daytime ambulatory blood pressure monitoring (ABPM) or home blood pressure monitoring (HBPM). The recommendation to use out-of-office BP measurements to confirm the presence of hypertension is consistent with several other guidelines including those from the UK National Institute for Health and Care Excellence, the Canadian Hypertension Education Program, National Heart Federation of Australia and the United States Preventive Services Task Force Recommendation Statement on High Blood Pressure Screening in Adults.^{3–6} The ACC/AHA guideline recommends that adults not taking antihypertensive medication with SBP ≥ 130 but <160 mm Hg or DBP ≥ 80 mm Hg but <100 mm Hg should be screened with ABPM or HBPM for white coat hypertension (Figure 1, **left panel**). It also recommends screening adults not taking antihypertensive medication with SBP between 120 and 129 mm Hg or DBP between 75 and 79 mm Hg for masked hypertension (Figure 1, **right panel**). ABPM and HBPM are also recommended to identify a white coat effect and masked uncontrolled hypertension among adults taking antihypertensive medication (Figure 2).

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In 2003, the Seventh Report of the Joint National Committee (JNC7) guideline provided BP thresholds on ABPM for defining hypertension in US adults.⁷ In the JNC7 guideline, awake and asleep hypertension were defined by mean SBP/DBP levels 135/85 mm Hg and 120/75 mm Hg, respectively. These thresholds were determined assuming office SBP/DBP readings 140/90 mm Hg as the reference point for the definition of hypertension rather than the office SBP/DBP 130/80 mm Hg recommendation adopted in the 2017 ACC/AHA guideline. Many scientific statements and guidelines have published BP thresholds for defining hypertension based on ABPM and HBPM since the JNC7 guideline.^{8, 9} In the current manuscript, we describe how out-of-office BP thresholds based on ABPM and HBPM corresponding to BP levels in the office setting were selected by the 2017 ACC/AHA writing committee. To provide the context for the writing committee's decisions, we describe three approaches that have been used in epidemiological studies to identify ABPM and HBPM BP thresholds that are deemed high or that correspond to values obtained in an office setting. We also review data gaps and future research needs.

Approaches for defining high BP on ABPM/HBPM

In the early 1990s, BP thresholds for ABPM were identified based on populations' distributions, a method called the distribution-based approach.^{10, 11} For example, in one study, BP above the 95th percentile or two standard deviations above the mean was identified as being significantly elevated and a BP between one and two standard deviations above the mean was considered to be marginally elevated.¹⁰ In another study, the percentage of participants with an office SBP/DBP 140/90 mm Hg was identified and ABPM SBP and DBP values with a similar percentage of participants above these levels were identified and used as the upper limit of normotension.¹² The ABPM thresholds used to define elevated or high BP with the distribution-based approach varied markedly across populations.^{11, 13, 14} This likely reflects the enrollment of populations with different characteristics including the proportion taking antihypertensive medication and office BP levels. Furthermore, there is no scientific basis to assume that a fixed percentage of the population has high BP on ABPM or HBPM.

A second approach, the regression-based approach, uses regression models to estimate the ABPM or HBPM BP levels for any given office BP value.¹⁵⁻¹⁸ In many, but not all, prior studies, a standard ordinary least squares regression model has been used to regress out-of-office BP on office BP. An issue with this approach is the measurement error of office BP, the independent variable, results in an attenuated slope between office and out-of-office BP. To address this issue, models for continuous outcomes that address measurement error in the exposure variable (e.g., Deming regression or ordinary least products regression), should be used instead of ordinary least squares regression. Using the intercept and beta coefficient from the regression model, the level of awake SBP that is equivalent to a specific office SBP level (e.g., 120, 130, 140 and 160 mm Hg) can be estimated. Another issue with the regression-based approach is that the risk for CVD associated with ABPM and HBPM BP values may not correspond accurately to office BP due to white coat and masked effects.

The third approach, the outcomes-based approach, identifies the incidence rate for an outcome (e.g., cardiovascular disease [CVD]) associated with a range of office-based BP

levels (e.g., SBP 140 mm Hg). Then, the corresponding range of BP on ABPM that is associated with a similar incidence rate is identified (e.g., SBP 135 mm Hg).¹⁹

Each of these approaches can identify ABPM or HBPM SBP and DBP thresholds that correspond to BP measured in the office setting. Also, multiple ABPM and HBPM BP thresholds can be identified (e.g., BP levels corresponding with normal BP, elevated BP, and hypertension). BP measured by ABPM and HBPM maintains a stronger association with CVD events compared to BP measured in the office setting.²⁰ ABPM and HBPM also can be used to identify white coat hypertension and masked hypertension.⁹ Therefore, the ACC/AHA writing committee sought to identify ABPM and HBPM threshold levels associated with the office BP levels that were selected for BP classification. There is general consensus that ABPM and HBPM BP thresholds should be based on outcomes data and the ACC/AHA writing committee agreed that this method is currently the best approach available.

Selection of thresholds values in the 2017 ACC/AHA guideline

The 2017 ACC/AHA guideline provides HBPM SBP and DBP values and ABPM daytime, nighttime and 24-hour SBP and DBP values that correspond to office-measured SBP and DBP levels (Table 2). These BP levels were selected based on a review of large published prospective cohort studies of ABPM and HBPM.^{14, 21–23} When available, the outcomes-based approach was used to identify ABPM and HBPM BP levels that corresponded to BP measured in an office setting.^{14, 21–23} BP thresholds identified in studies that used the regression-based approach were considered when data from the outcomes-based approach were not identified.¹⁸ Given there were very few studies identified and the studies that were available provided very consistent results, the writing committee decided there was no need to meta-analyze the data. The ACC/AHA writing committee also reviewed guidelines and scientific statements that reported HBPM and ABPM BP levels corresponding to measurements obtained in an office setting.^{8, 24–28} Table 3 provides the ABPM thresholds identified from outcomes-based studies and from several prior guidelines and scientific statements. Table 4 provides corresponding information for HBPM. Although there were some discrepancies between the BP levels in the published research studies and prior guidelines/scientific statements, these differences were small (i.e., within 5 mm Hg).

Evidence gaps

The BP thresholds selected by the ACC/AHA writing committee were based on the best evidence available at the time the guideline was prepared. However, gaps in knowledge exist. For example, none of the outcomes-based studies included African Americans, a population with a high prevalence of hypertension. A 2017 analysis from the Jackson Heart Study, a cohort comprised exclusively of African-American adults, evaluated ABPM SBP thresholds that corresponded with office SBP values among 441 adults not taking antihypertensive medication and 575 adults taking antihypertensive medication.¹⁹ DBP thresholds were not evaluated using the outcomes-based approach because DBP, when measured in an office setting, was not associated with CVD risk in this study. Using the outcomes-based approach, the ABPM SBP levels that corresponded to office-measured SBP

values of 120, 130, 140 and 160 mm Hg were higher than those recommended in the ACC/AHA guideline. These data highlight the need for additional studies to evaluate thresholds for ABPM and HBPM that correspond to BP measured in an office setting in different populations, including racial/ethnic minorities. Additionally, it is unclear whether the ABPM and HBPM BP thresholds should be uniform across different age groups, for men and women, and for adults taking and not taking antihypertensive medication.^{29–31} In contrast to the ACC/AHA guideline, which recommends using daytime BP on ABPM, recent studies and a 2013 European Society of Hypertension position paper on ABPM suggest that 24-hour BP or daytime, nighttime and 24-hour BP should be considered when defining white coat hypertension, masked hypertension, white coat effect, and masked uncontrolled hypertension.^{32–34} Additional studies are needed to determine the risk for CVD and the benefits of antihypertensive medication for individuals with these phenotypes when they are defined using BP measurements from different time periods. Also, studies are needed to identify whether alternative methods to the outcomes-based approach are available to identify ABPM and HBPM BP thresholds.

The thresholds used to define normal and elevated BP and hypertension in the ACC/AHA guideline were based on office measurements.^{1, 2} The analogous ABPM and HBPM BP thresholds were determined using office measurements as the referent standard as described in this article. This approach may seem counterintuitive as the association of BP with CVD outcomes is stronger for measurements obtained by ABPM and HBPM compared to readings obtained in the office setting.²⁰ Additionally, ABPM is considered the best technique to confirm the presence of hypertension.³ However, large-scale outcome trials comparing antihypertensive medication versus placebo and trials that have compared different intensities of treatment have used office BP to determine participant eligibility and BP goal achievement. There is a lack of data from randomized controlled trials using ABPM and HBPM BP levels to guide antihypertensive medication initiation and intensification. Such data will allow BP thresholds used for classification to be directly determined from ABPM and HBPM.

Perspectives

In summary, the 2017 ACC/AHA guideline provides ABPM and HBPM BP thresholds that correspond to normal BP, elevated BP, and stages 1 and 2 hypertension in an office-based setting. Additionally, thresholds corresponding to an average SBP and DBP of 160 mm Hg and 100 mm Hg, respectively, are provided. These thresholds should be used to identify adults with white coat hypertension and masked hypertension.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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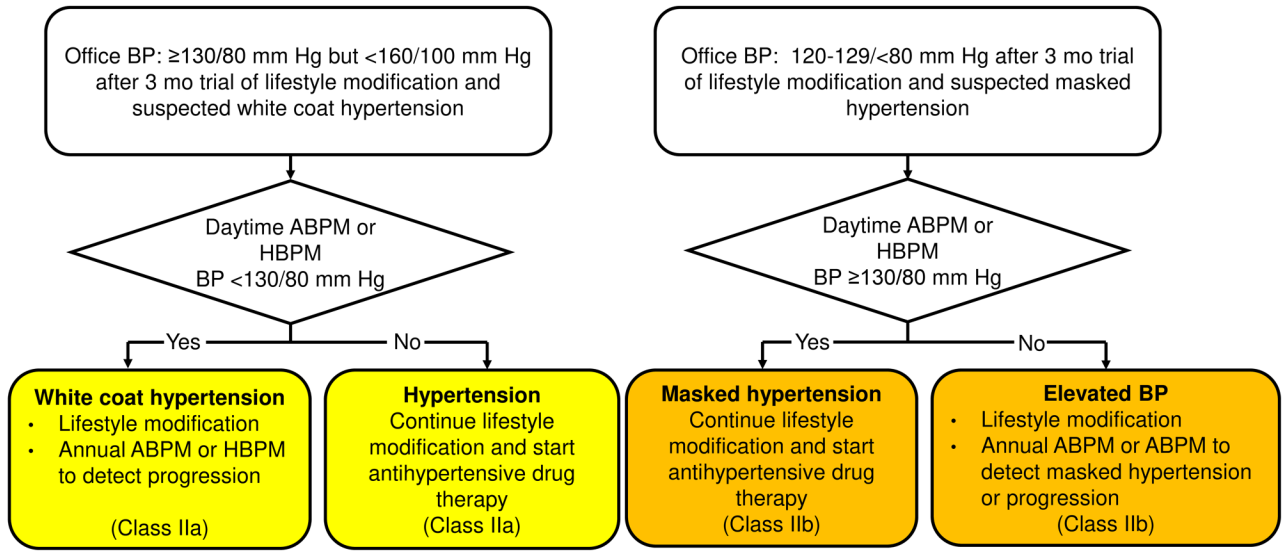


Figure 1.

Algorithm to screen for white coat hypertension and masked hypertension among adults not taking antihypertensive medication in the 2017 American College of Cardiology/American Heart Association blood pressure guideline.

ABPM – Ambulatory blood pressure monitoring; HBPM – home blood pressure monitoring; BP – blood pressure.

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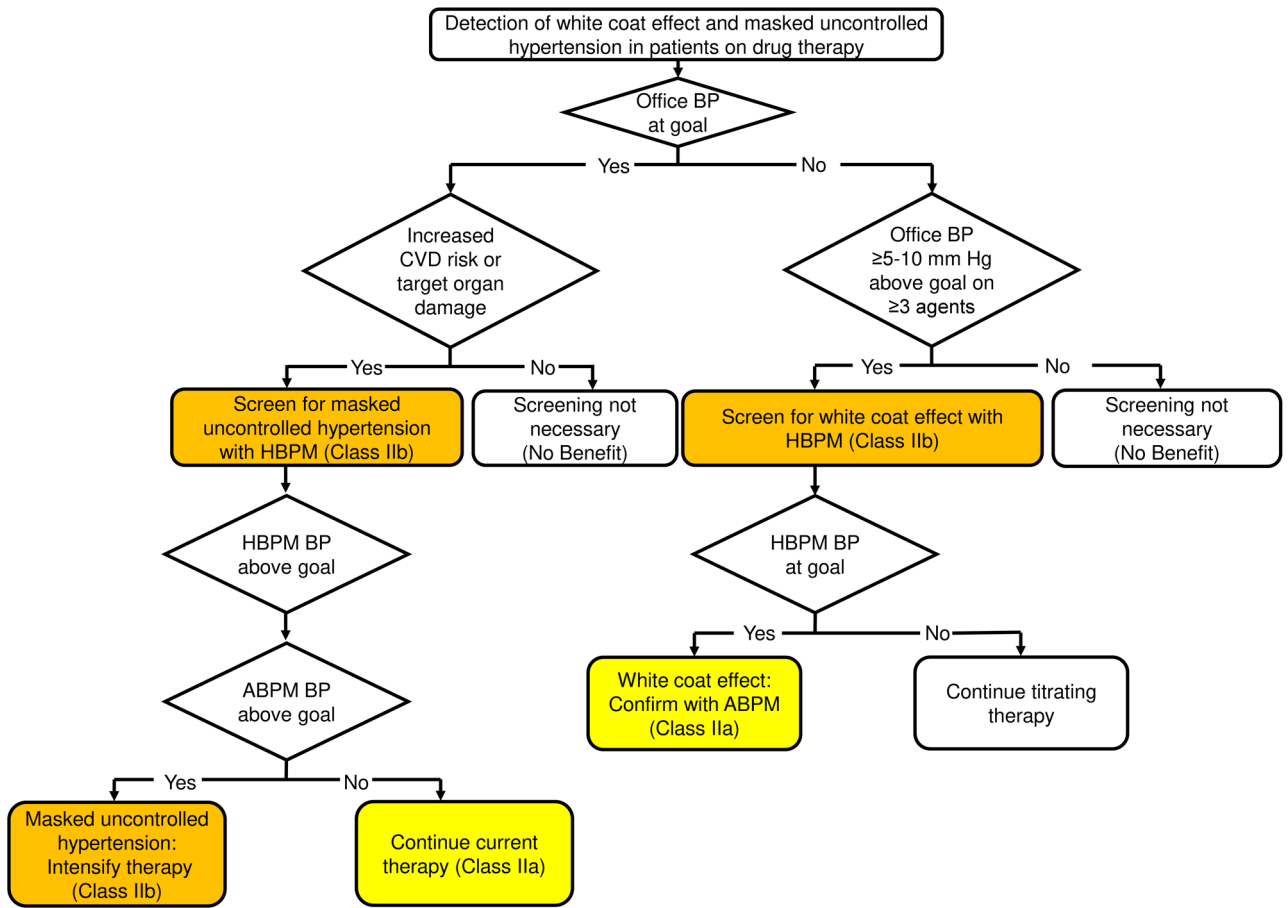


Figure 2. Algorithm to screen for white coat effect or masked uncontrolled hypertension among adults taking antihypertensive medication in the 2017 American College of Cardiology/American Heart Association blood pressure guideline.

ABPM – Ambulatory blood pressure monitoring; HBPM – home blood pressure monitoring; CVD – cardiovascular disease; BP – blood pressure.

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Table 1.

Classification of blood pressure according to the 2017 American College of Cardiology/American Heart Association blood pressure guideline.

Office blood pressure levels			2017 ACC/AHA guideline classification
SBP, mm Hg		DBP, mm Hg	
<120	and	<80	Normal blood pressure
120–129	and	<80	Elevated blood pressure
130–139	or	80–89	Stage 1 hypertension
140	or	90	Stage 2 hypertension

Participants with systolic blood pressure and diastolic blood pressure in two categories (e.g., systolic blood pressure < 120 mm Hg and diastolic blood pressure between 80 and 89 mm Hg) should be designated into the higher category.

2017 ACC/AHA guideline - 2017 American College of Cardiology / American Heart Association Guideline for the Prevention, Detection, Evaluation and Management of High Blood Pressure in Adults.

SBP – Systolic blood pressure; DBP – diastolic blood pressure.

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Table 2.

Blood pressure thresholds for home and ambulatory blood pressure monitoring that correspond to office blood pressure levels in the 2017 American College of Cardiology/American Heart Association blood pressure guideline.

Office BP	HBPM	Awake ABPM	Asleep ABPM	24-hour ABPM
120/80	120/80	120/80	100/65	115/75
130/80	130/80	130/80	110/65	125/75
140/90	135/85	135/85	120/70	130/80
160/100	145/90	145/90	140/85	145/90

Numbers in the table are systolic/diastolic blood pressure and are presented in mm Hg.

BP – blood pressure.

HBPM – Home blood pressure monitoring.

ABPM – Ambulatory blood pressure monitoring.

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Table 3.

Awake, asleep and 24-hour blood pressure thresholds for ambulatory blood pressure monitoring that correspond with office blood pressure levels identified from outcomes-based studies and prior guidelines and scientific statements.

Office blood pressure	Awake blood pressure							
		Outcome based studies		Prior guidelines/scientific statements				
	ACC/AHA guideline	Ohasama* (n= 1,542)	IDACO [†] (n=5682)	2005 AHA	2008 ASH	2011 Australia	2013 ESH	2015 Canada
120/80	120/80		125/80	130/80	120/80			
130/80	130/80		133/82	135/85				
140/90	135/85		140/85	140/90	135/85	135/85	135/85	135/85
160/100	145/90 [‡]							
Office blood pressure	Asleep blood pressure							
		Outcome based studies		Prior guidelines/scientific statements				
	ACC/AHA guideline	Ohasama* (n= 1,542)	IDACO [†] (n=5682)	2005 AHA	2008 ASH	2011 Australia	2013 ESH	2015 Canada
	100/65			115/65				
130/80	110/65			120/70				
140/90	120/70		121/70	125/75	120/75	120/70	120/70	
160/100	140/85 [‡]							
Office blood pressure	24-hour blood pressure							
		Outcome based studies		Prior guidelines/scientific statements				
	ACC/AHA guideline	Ohasama* (n= 1,542)	IDACO [†] (n=5682)	2005 AHA	2008 ASH	2011 Australia	2013 ESH	2015 Canada
120/80	115/75		119/74			115/75		
130/80	125/75		125/76					
140/90	130/80	134/79	132/79			130/80		130/80
160/100	145/90 [‡]							

Numbers in the table are systolic/diastolic blood pressure and are presented in mm Hg.

Blank cells indicate office blood pressure levels for which thresholds on ambulatory blood pressure monitoring were not reported.

* Ohkubo et. al. (reference 23). N.B. The Ohasama study population is also included in the IDACO (Kikuya et. al, reference 21).

[†] Kikuya et. al. (reference 21).

[‡] As no data using the outcome-based approach were identified for these BP values, the values were determined from a study using the regression-based approach (Head et. al., reference 18).

BP – blood pressure

IDACO - The International Database of Ambulatory Blood Pressure in relation to Cardiovascular Outcome

ACC – American College of Cardiology

AHA – American Heart Association

ASH – American Society of Hypertension

ESH – European Society of Hypertension

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Table 4.

Blood pressure thresholds for home blood pressure monitoring identified in outcomes-based studies and prior guidelines and scientific statements.

Office blood pressure	Home blood pressure					
		Outcome-based studies		Prior guidelines/scientific statements		
	ACC/AHA guideline	2008 meta-analysis*	IDHOCO [†] (n=6,470)	2013 ESH	2015 Canada	2015 Australia
120/80	120/80	120/80	120/75			
130/80	130/80	130/80	125/75			
140/90	135/85	135/85	130/85	135/85	135/85	135/85
160/100	145/90		145/90			145/90

Numbers in the table are systolic/diastolic blood pressure and are presented in mm Hg.

Blank cells indicate office blood pressure levels for which thresholds on home blood pressure monitoring were not reported.

* Staessen et. al. (reference 14).

[†] Niiranen TJ et. al. (reference 22)

BP – blood pressure

IDHOCO - The International Database of HHome blood pressure in relation to Cardiovascular Outcome.

ESH – European Society of Hypertension.