REVIEW

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Diagnostic and Predictive Accuracy of Blood Pressure Screening Methods With Consideration of Rescreening Intervals: A Systematic Review for the U.S. Preventive Services Task Force

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Background: Elevated blood pressure (BP) is the largest contributing risk factor to all-cause and cardiovascular mortality.

Purpose: To update a systematic review on the benefits and harms of screening for high BP in adults and to summarize evidence on rescreening intervals and diagnostic and predictive accuracy of different BP methods for cardiovascular events.

Data Sources: Selected databases searched through 24 February 2014.

Study Selection: Fair- and good-quality trials and diagnostic accuracy and cohort studies conducted in adults and published in English.

Data Extraction: One investigator abstracted data, and a second checked for accuracy. Study quality was dual-reviewed.

Data Synthesis: Ambulatory BP monitoring (ABPM) predicted long-term cardiovascular outcomes independently of office BP (hazard ratio range, 1.28 to 1.40, in 11 studies). Across 27 studies, 35% to 95% of persons with an elevated BP at screening remained hypertensive after nonoffice confirmatory testing. Cardiovascular outcomes in persons who were normotensive after confirmatory testing (isolated clinic hypertension) were similar to outcomes in those who were normotensive at screening. In 40 studies, hypertension incidence after rescreening varied considerably at each yearly interval up to 6 years. Intrastudy comparisons showed at least 2-fold higher incidence in older adults, those with high-normal BP, overweight and obese persons, and African Americans.

Limitation: Few diagnostic accuracy studies of office BP methods and protocols in untreated adults.

Conclusion: Evidence supports ABPM as the reference standard for confirming elevated office BP screening results to avoid misdiagnosis and overtreatment of persons with isolated clinic hypertension. Persons with BP in the high-normal range, older persons, those with an above-normal body mass index, and African Americans are at higher risk for hypertension on rescreening within 6 years than are persons without these risk factors.

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Nearly 1 in 3 U.S. adults has high blood pressure (BP), including two thirds of those aged 60 years or older (1). Elevated BP is the largest contributing risk factor to all-cause and cardiovascular mortality (2). Despite the clear importance of accurate diagnosis of high BP, recommendations for BP measurement protocols and rescreening intervals are not based on systematic reviews of the literature (3, 4), and recommended protocols, such as repeated measurements, are rarely followed in routine health care settings (5–9). To help address these issues, newer measurement methods have been developed to reduce error, simplify performance of repeated measurements, evaluate BP throughout the 24-hour cycle, and allow use in nonmedical settings. Evidence-based measurement methods and rescreening intervals could improve the benefits and efficiency of BP screening.

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In 2007, the U.S. Preventive Services Task Force (USPSTF) reaffirmed its 2003 A recommendation to screen for high BP in adults aged 18 years or older (10). In 2003, a synthesis of indirect evidence for BP screening found good-quality evidence that treatment of high BP in adults substantially decreases the incidence of cardiovascular events (11). Both reviews found that screening and treatment for high BP cause few major harms (11, 12). Given the strong evidence base for the previous recommendations and recently updated guidelines for BP control (4, 13), the USPSTF did not believe that updating the indirect evidence path was necessary. However, the previous systematic reviews did not identify a BP measurement reference standard, address diagnostic accuracy of BP measurement methods and protocols, or determine the most appropriate rescreening interval. Our evidence review was designed to address these important aspects of screening for high BP and update the direct evidence of benefits and harms of screening.

Methods

To conduct this review, we developed an analytic framework with 5 key questions (**Appendix Figure 1**, available at www.annals.org) that examined direct evi-

dence for the benefits and harms of screening for high BP (key questions 1 and 5, respectively), diagnostic accuracy of office BP measurement (OBPM) (key question 2), prediction of cardiovascular events by BP method and diagnostic accuracy of nonoffice measurement (key question 3), and rescreening interval (key question 4). Detailed methods are available in our full evidence report (14). The analytic framework, review questions, and methods for locating and qualifying evidence were posted on the USPSTF Web site for public comment before we started the review, and the final versions reflect public input.

Data Sources and Searches

We searched MEDLINE, PubMed, the Cochrane Central Register of Controlled Trials, and CINAHL from 2003 through 8 August 2014 to update benefits and harms of screening for high BP. We searched the same databases (excluding CINAHL) through 24 February 2014 as follows: starting in 1992 (to allow for implementation of the first guidelines for validation of BP monitoring devices [15]) for prediction of cardiovascular events by BP method and diagnostic accuracy of nonoffice measurement, and starting in 1966 (the beginning of MEDLINE) for rescreening interval. On the basis of the findings from these updated searches, we did not further update them because any studies we found would probably not have changed the overall conclusions. We also searched bibliographies of relevant reviews, included studies, and publication lists of highly referenced studies.

Study Selection

Two investigators independently reviewed abstracts and full-text articles against prespecified inclusion and exclusion criteria (14). We required all studies to have enrolled untreated adults and to have been conducted in countries rated as "very high" on the 2013 Human Development Index (16). For prediction of cardiovascular events, we allowed studies that included treated patients because a proportion of persons followed over time would inevitably begin treatment. Ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM) devices were eligible for use in confirming an initially elevated OBPM result. For screening benefits and harms, cardiovascular events we analyzed included fatal or nonfatal myocardial infarction; sudden cardiac death; stroke; heart failure; atrial fibrillation; transient ischemic attack; end-stage kidney disease; or a composite of any of the aforementioned events, excluding cardiovascular symptoms, angina, revascularization, carotid intima–media thickness, and left ventricular hypertrophy.

For diagnostic accuracy of OBPM, we included studies that compared different office-based devices or measurement protocols and reported sensitivity, specificity, predictive values, or concordance (for example, κ). For diagnostic accuracy of confirmatory BP measurement methods, eligible study populations had an initial elevated office BP at screening, which allowed for reporting or calculation of the positive predictive value (PPV).

For prediction of cardiovascular events, eligible studies followed a cohort of patients over time and reported the associations (hazard or risk ratios) of BP as a continuous variable, measured by at least 2 methods at baseline, with data on overall mortality or cardiovascular events collected during follow-up. For rescreening interval, we included studies that followed cohorts of initially nonhypertensive adults over time and reported hypertension incidence at rescreening intervals of up to 6 years.

Data Extraction and Quality Assessment

One investigator abstracted data from all included studies, and a second checked for accuracy. Two investigators independently assessed the quality of included studies by using predefined, design-specific criteria (17–19). We rated study quality as good, fair, or poor and excluded all poor-quality studies (17). We resolved disagreements about quality through discussion with a third investigator. Where reported, studies with various threats to internal validity were downgraded to fair-quality according to USPSTF standards (17).

Data Synthesis and Analysis

We qualitatively described the results on the benefits and harms of screening. Per our protocol, we first calculated the diagnostic accuracy of OBPM by using the recommendations of the American Heart Association as the reference standard because there is no gold standard for BP measurement (3). With the subsequent identification of ABPM as the best predictor of cardiovascular events, we calculated the diagnostic accuracy of OBPM and confirmatory BP measurement methods by using ABPM as the reference standard where possible. We qualitatively described all diagnostic accuracy results because data were insufficient for quantitative synthesis.

For prediction of cardiovascular events, we combined fatal and nonfatal events within outcome categories (cardiovascular, stroke, and cardiac). Risk was most commonly reported as the hazard ratio associated with each 10–mm Hg increase in systolic BP and each 5–mm Hg increase in diastolic BP. We converted hazard ratios to these common increments if they were reported differently (14). We depicted the hazard ratios in forest plots for qualitative evaluation; because of the small numbers of studies for each outcome and heterogeneity across studies, we did not calculate summary meta-analytic estimates of risk to determine the best BP measurement method for prediction. We conducted exploratory meta-analyses to compare ABPM protocols (24-hour, daytime, and nighttime) by generating estimates of cardiovascular events or mortality risk for each protocol by using the DerSimonian–Laird random-effects method (20). In sensitivity analyses, these results were compared to estimates generated by using profile likelihood (21) and Knapp–Hartung methods (22).

For rescreening, we pooled reported incidence rates across all studies to generate a weighted mean incidence at yearly intervals (reported within ± 0.5 year). We qualitatively examined within-study comparisons among a priori subgroups of age, BP, sex, body

mass index (BMI), smoking status, and race/ethnicity (14).

When constructing the overall summary of evidence (**Appendix Table 1**, available at www.annals.org), we evaluated included studies within the context of each review question for consistency of results for important outcomes and relevance to primary care.

Role of the Funding Source

Staff from the Agency for Healthcare Research and Quality (AHRQ) provided oversight for the project and assisted in external review of the companion draft evidence synthesis. Liaisons for the USPSTF helped to resolve issues about the scope of the review but were not involved in the conduct of the review.

RESULTS

We reviewed 19 309 abstracts and 1171 articles for possible inclusion (**Appendix Figure 2**, available at www.annals.org).

Benefits of Screening for High BP

For direct evidence of screening benefit, we included only randomized, controlled trials (RCTs) that reported changes in health outcomes as a result of screening for hypertension compared with no screening. We identified 1 good-quality cluster RCT of a community pharmacy–based BP screening program targeting adults aged 65 years or older (23). Trained volunteer health educators also provided participants with educational materials and resources to support self-management. This trial found fewer annual composite cardiovascular-related hospitalizations in the intervention group than in the control group (rate ratio, 0.91 [95% CI, 0.86 to 0.97]; $P = 0.002$). When the data were analyzed by the number of unique patients hospitalized, only the reduction in admissions for acute myocardial infarction was statistically significant (rate ratio, 0.89 [CI, 0.79 to 0.99]; $P = 0.03$). End-stage kidney disease outcomes were not reported. Summaries of the limitations, consistency, and applicability of the evidence for all key questions can be found in **Appendix Table 1**.

Diagnostic Accuracy of OBPM

We identified 4 good-quality (24–27) and 3 fair-quality (28–30) studies examining the diagnostic accuracy of OBPM methods or protocols in untreated screening populations. Four of these studies (25–28) examined how well automated oscillometric OBPM (1 to 3 measurements) predicted results from manual sphygmomanometry (the reference standard). Among these, 3 studies (26–28) reported sensitivities of oscillometric OBPM ranging from 51% to 68% for elevated BP (systolic BP ≥140 mm Hg or diastolic BP ≥90 mm Hg), as measured by the reference method. The fourth study (25) reported a sensitivity of 91% but differed from the others in that it used a higher threshold in its definition of elevated BP (systolic BP ≥160 mm Hg or diastolic BP ≥95 mm Hg) and used a research design that minimized human error in manual BP measurement. The fair-quality study (28) reported the lowest sensitivity and used 3 different oscillometric devices, with no attempt to ensure comparability or validity among them. Overall, these 4 studies reported more consistent specificities (97% to 98%) and PPVs (76% to 84%). In 3 studies (31–33) that compared manual and automated OBPM with ABPM as the reference standard, neither manual nor automated systolic OBPM results were clearly favored.

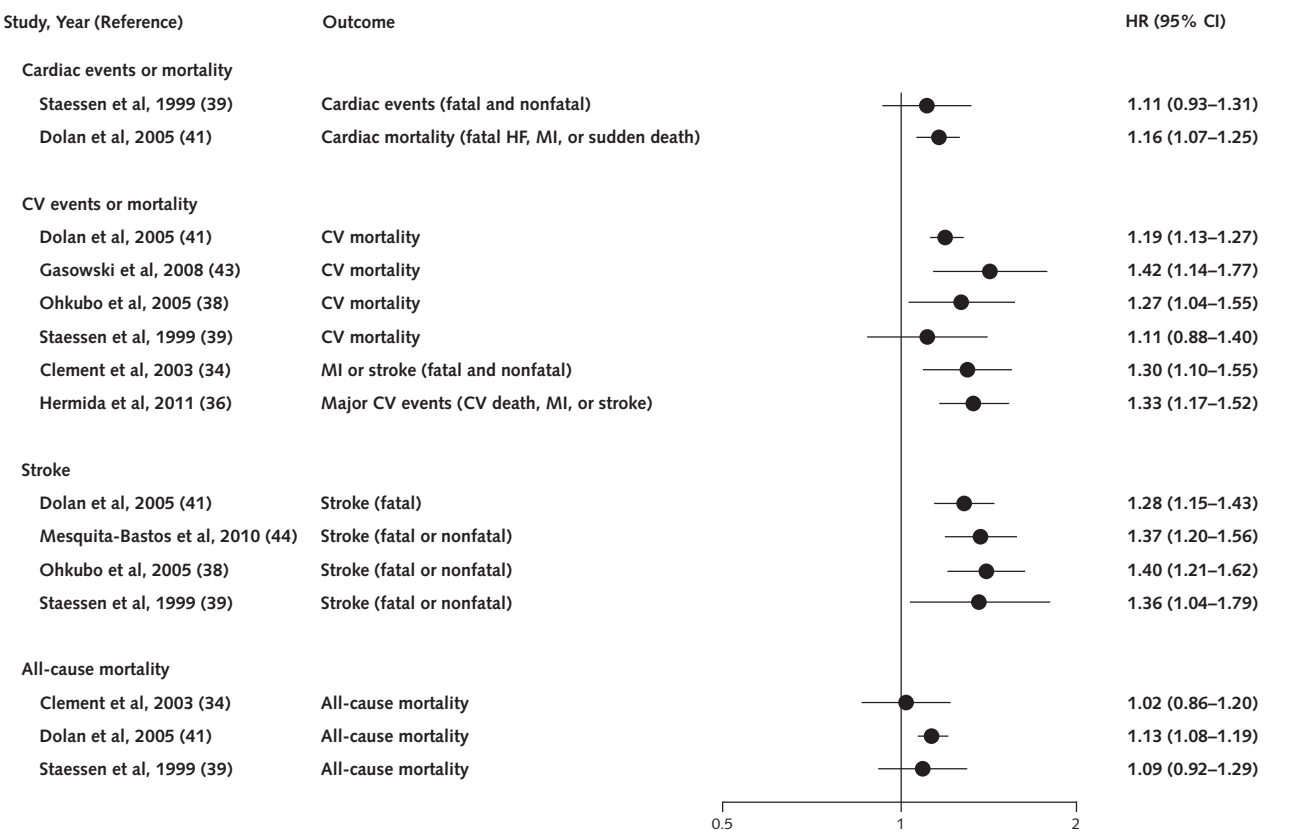
Three diagnostic accuracy studies examined the effect of different aspects of recommended protocols for OBPM (24, 29, 30) in untreated screening populations. For investigating the value of repeated measurements, a single manual BP measurement had a high sensitivity (95%) but a moderate PPV (76%) for the average of the second and third measurements in 1 study with a protocol that included a 5-minute premeasurement rest (24). One small study found elevated BP within the normal range among normotensive participants whose legs were crossed during measurement (29), and another found falsely elevated BP above the hypertensive threshold 40 minutes after caffeine ingestion among 17% of normotensive participants (30).

Prediction of Cardiovascular Events by BP Measurement Method

We identified a reference standard for BP measurement by comparing the accuracy of ambulatory and home-based confirmatory measurement methods with office-based methods for predicting overall mortality and cardiovascular outcomes.

We evaluated the predictive value of ABPM methods for long-term cardiovascular events, after adjustment for OBPM, in 6 good-quality (34–39) and 5 fair-quality (40–44) studies. The ABPM devices used in the included trials are generally still available in the United States and have been validated against at least 1 recognized protocol (www.dableducational.org). Where reported, all ABPM devices were oscillometric and typically took measurements every 15 to 30 minutes during the day and every 30 to 60 minutes at night (**Appendix Table 2**, available at www.annals.org). Outcomes for 24-hour, daytime, and nighttime monitoring cycles were reported in 8, 10, and 9 studies, respectively. One study that monitored BP for 48 hours was grouped with those monitoring for 24 hours (36). Results did not seem to vary by geographic region or population baseline characteristics. Each 10–mm Hg increment in 24-hour systolic ABPM, adjusted for OBPM, was consistently and statistically significantly associated with an increased risk for fatal and nonfatal stroke in 4 studies (38, 39, 41, 44). Hazard ratios ranged from 1.28 to 1.40 (**Figure 1**). In 6 studies, each 10–mm Hg increment in 24-hour systolic ABPM, adjusted for OBPM, was associated with an increased risk for fatal and nonfatal cardiovascular events. These results were statistically significant in 5 studies (**Figure 1**) (34, 36, 38, 41, 43). Hazard ratios ranged from 1.11 to 1.42. One additional study (42) reported only that ABPM predicted cardiovascular mortality in a model that included OBPM ($P <$ 0.001). Estimates of hazard ratios for each 5–mm Hg

Figure 1. Risk for cardiovascular and mortality outcomes: systolic 24-h ABPM, adjusted for OBPM.



Results of included studies for key question 3a. ABPM = ambulatory blood pressure monitoring; CV = cardiovascular; HF = heart failure; HR = hazard ratio; MI = myocardial infarction; OBPM = office blood pressure measurement.

increment in diastolic 24-hour ABPM, adjusted for OBPM, were also generally statistically significant but were more attenuated (data not shown) (14).

We conducted an unplanned, exploratory meta-analysis to look for relative differences among ABPM protocols. This analysis showed no apparent differences in hazard ratios for each 10–mm Hg increase in systolic BP (24-hour ABPM hazard ratio, 1.24 [CI, 1.17 to 1.30; I^2 = 8.7%]; daytime ABPM hazard ratio, 1.20 [CI, 1.12 to 1.28; I^2 = 33.3%]; nighttime ABPM hazard ratio, 1.24 [CI, 1.17 to 1.31; I^2 = 25.6%] [all controlled for OBPM]). A sensitivity analysis that used 2 additional meta-analytic methods also did not show any differences among protocols.

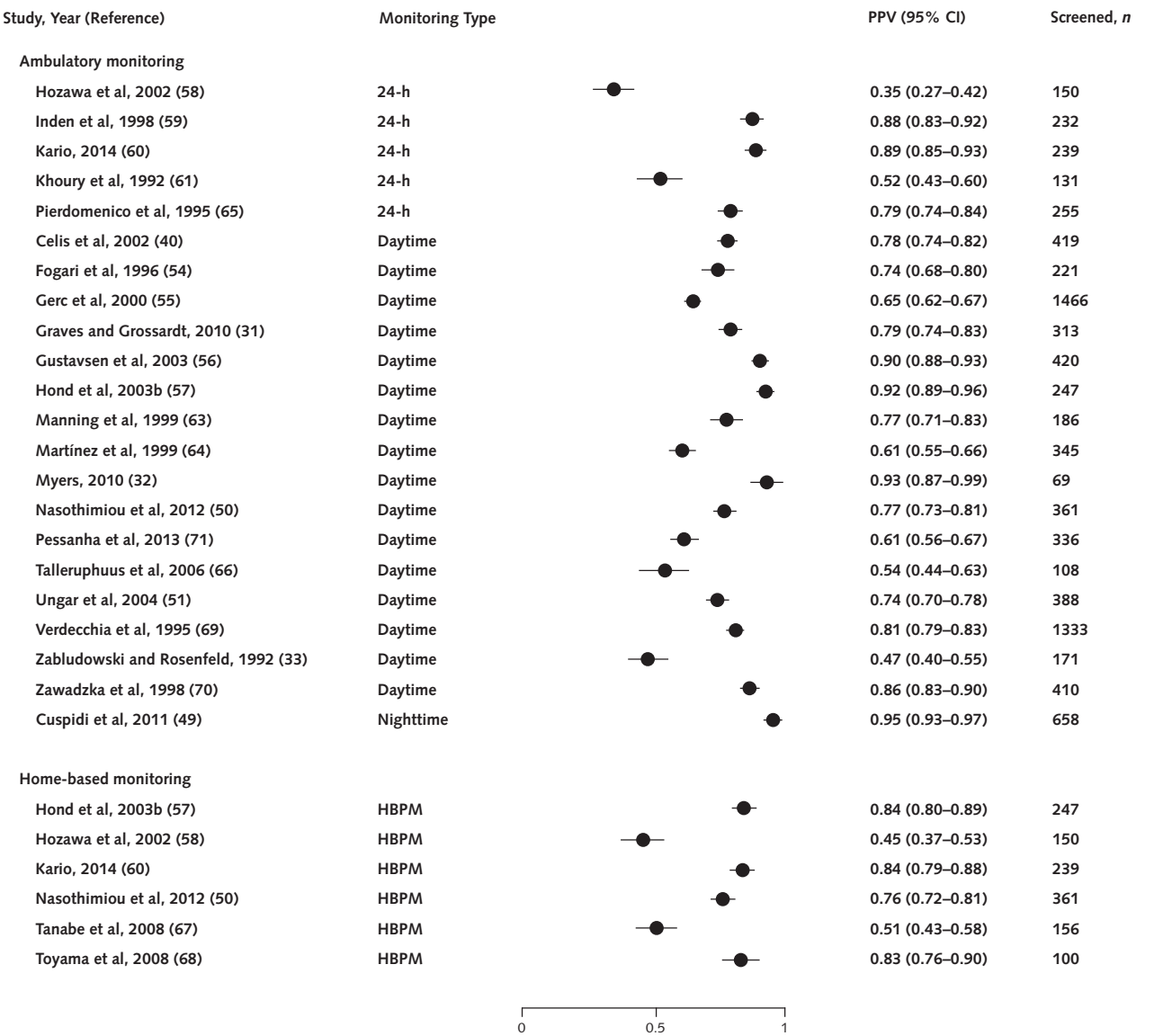
We also evaluated the predictive value of HBPM for long-term cardiovascular events in 5 good-quality studies (35, 45–48), 4 of which adjusted for OBPM. All showed statistically significant associations with an increased risk for cardiovascular and mortality outcomes, with hazard ratios ranging from 1.17 to 1.39 (Appendix Figure 3, available at www.annals.org).

Diagnostic Accuracy of Methods to Confirm Elevated Office BP

We considered confirmatory BP measurement methods separately from screening OBPM to identify persons who have an elevated BP at screening but are normotensive after confirmatory testing in a nonmedical setting (isolated clinic hypertension). Without confirmatory follow-up, this group may be harmed by misdiagnosis and unnecessary treatment.

We evaluated the diagnostic accuracy of confirmatory BP measurement methods by using ABPM as the reference standard, where available, subsequent to an elevated BP at screening in 6 good-quality (32, 49–53) and 21 fair-quality (31, 33, 40, 54–71) studies. Across 24 comparable studies allowing calculation, the proportion of persons with an elevated BP at screening who were hypertensive on confirmatory testing by ABPM or HBPM ranged from 35% to 95% (Figure 2). Four studies also confirmed hypertension in 58% to 96% of persons who repeated BP measurement at subsequent office visits with the same methods used at the initial screening (data not shown). Study population characteristics related to increased hypertension prevalence, such as older average age, a higher number of abnormal screening results before confirmatory testing, and a higher BP at screening, seemed to be qualitatively associated with a higher PPV for ABPM-confirmed hypertension. On the basis of screening measurement alone, the likelihood of misdiagnosis of hypertension is greater as measurements approach the threshold for a diagnosis of hypertension.

Figure 2. Proportion of elevated OBPM results confirmed by ABPM or HBPM.



Results of included studies for key question 3b. ABPM = ambulatory blood pressure monitoring; HBPM = home blood pressure monitoring; OBPM = office blood pressure measurement; PPV = positive predictive value.

We investigated whether using different screening and confirmatory measurement methods improves diagnostic accuracy. We found 2 studies that enrolled persons with an elevated office BP and followed up with both ABPM and repeated OBPM by the same screening method at a separate visit, but the results did not consistently show improved results with confirmatory testing (data not shown) (54, 61).

Harms of Screening for High BP

We examined several potential harms in addition to misdiagnosis and unnecessary treatment. One good-quality (72) and 3 fair-quality (73–75) trials found no statistically significant differences in psychological distress or quality of life among participants who were labeled as hypertensive or prehypertensive. One fair-quality cohort study conducted among persons who were previously unaware of their hypertension status found increases in overall absenteeism from work, absenteeism due to illness, and number and duration of illness episodes after labeling that were statistically significant at 1 year (76) and 4 years (77) of follow-up. Four fair-quality cohort studies reported sleep disturbances, discomfort, and restrictions in daily activities during the use of an ABPM device (78–81).

Rescreening Interval and Hypertension Incidence in Screened Normotensive Persons

We identified 15 good-quality (82–96) and 25 fair-quality (53, 97–120) studies that reported hypertension incidence after rescreening, and 39 of these reported

incidence by a priori subgroups of interest. Studies enrolled between 275 and 115 736 participants at baseline and evaluated screening intervals of up to 6 years. The largest number (16 studies) reported results for a 5-year interval, and only 2 studies provided data for more than 1 rescreening interval (88, 99). Most studies used a diagnostic threshold of at least 140/90 mm Hg and considered the use of antihypertensive medications equivalent to a BP exceeding the diagnostic threshold. Included studies were conducted in Asia (19 studies), the United States (8 studies), Europe (10 studies), the United Kingdom, and Australia. Twenty-one studies were community-based, 12 were employment-based, and 6 were conducted in clinics.

Incidence estimates varied widely at each rescreening interval (2.2% to 4.4% at 1 year and 2.1% to 28.4% at 5 years) (**Figure 3**). Studies that diagnosed hypertension on the basis of multiple office visits generally showed lower incidence than those that measured BP at 1 visit. In 2 studies that reported hypertension incidence both with and without repeated OBPM at confirmatory visits, about 55% of first-visit incident hypertension cases were not confirmed (53, 97), which suggests that true incident hypertension at various intervals is likely to be at the lower end of these estimates.

The substantial variation in hypertension incidence across studies is related in part to the criteria used to diagnose, and in some studies confirm, incident hypertension. Some variation probably also arises from differences in study populations, which highlights the importance of identifying subpopulations with a higher risk for incident hypertension that may benefit from targeted or more intensive rescreening.

Rescreening Interval in Subpopulations

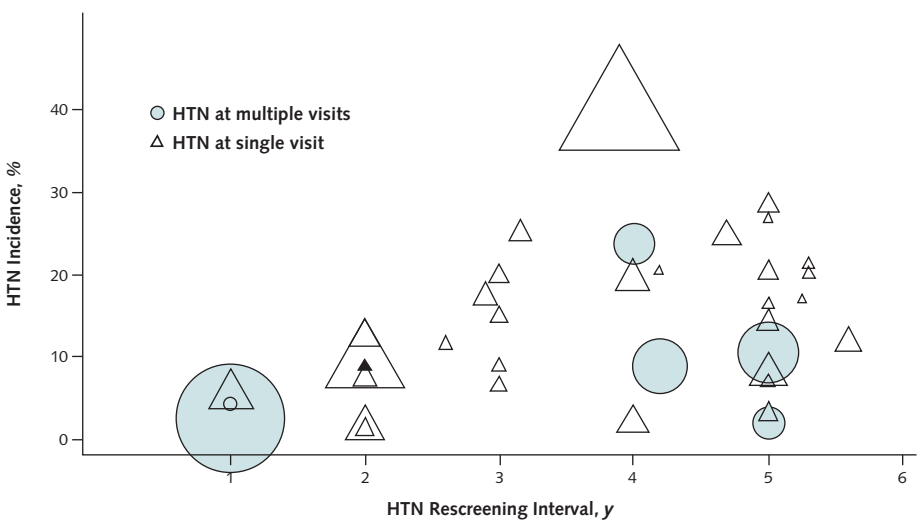
Appendix Table 3 (available at www.annals.org) shows weighted mean hypertension incidence across studies at rescreening intervals of 1 to 5 years, stratified by a priori subpopulations. We focused our detailed evaluation on studies providing direct within-study comparisons.

Four studies reported incidence by age strata (**Appendix Table 4**, available at www.annals.org) (53, 87, 89, 109). Hypertension incidence was as much as 2- to 4-fold higher in older persons (aged 40 or 45 to 60 or 65 years) than in younger persons (aged 18 to 40 or 45 years). Similarly, hypertension incidence increased with increasing baseline BP (**Appendix Table 5**, available at www.annals.org) (85, 90, 91, 95, 107). Incidence consistently tripled between optimal (<120/80 mm Hg) and normal (120 to 129/80 to 84 mm Hg) BP categories and approximately doubled between normal and high-normal (130 to 139/85 to 89 mm Hg) categories. For example, persons with optimal BP had a low probability (2% to 9%) of developing hypertension over a 5-year period.

Hypertension incidence was generally higher among men than women, especially in younger populations (**Appendix Table 6**, available at www.annals.org). Although incidence was also 2-fold higher in overweight persons and 3-fold higher in obese persons compared with normal-weight persons (**Table 1**) (53, 111), it was not increased in smokers versus nonsmokers or former smokers (data not shown) (14).

Five studies conducted in the United States reported hypertension incidence at rescreening intervals by race/ethnicity (**Table 2**) (84, 86, 88, 97, 105). In each study, the incidence for African Americans was nearly 2 or more times higher than for white persons at all intervals. Only 1 study directly compared additional racial or ethnic categories; it reported higher incidence rates for African Americans at 5 years (27.5%) than for Asian, white, or Hispanic persons (16.2% to 21.2%) (86).

Figure 3. Scatterplot of hypertension incidence, by rescreening interval.



Results of included studies for key question 4a. The size of the symbol represents the number of participants in the study. HTN = hypertension.

Table 1. Hypertension Incidence at Various Rescreening Intervals, by BMI*

Study, Year (Reference)	Quality	Mean Age (Range), *y*	Diagnostic Threshold	Mean Baseline Office BP, *mm Hg*	Rescreening Interval, *y*
Radi et al, 2004 (53)†	Fair	NR	≥140/90 mm Hg	NR	1
Matsuo et al, 2011 (111)	Fair	41.2 (30.0–59.0)	≥140/90 mm Hg or use of antihypertensive medications	121.8/73.8	3

BMI = body mass index; BP = blood pressure; NR = not reported.
* Results of studies included for key question 4b, sorted by rescreening interval. Baseline characteristics are reported for the overall study population and are not further stratified by subgroup. All studies were done in the United States.
† Measure based on >1 visit or involved an additional confirmation step.

DISCUSSION

An earlier review of indirect evidence and the resulting USPSTF recommendation found that treatment of high BP substantially decreases the incidence of cardiovascular events (10, 12). We examined direct evidence of benefits and harms of screening programs to identify adults with high BP and found a single RCT that targeted adults aged 65 years or older. Among those randomly assigned to screening, there was a small but statistically significant reduction in hospitalizations for acute myocardial infarction. Although the results do not apply to all age groups and were potentially confounded by additional management interventions, they provide supportive evidence for the effects of a BP screening program on target cardiovascular disease events.

We then focused most of our review efforts on BP screening methods and rescreening intervals to determine accurate and timely methods for identifying persons with elevated BP who are likely to benefit from treatment. We first examined BP measurement methods used for initial, office-based screening. Surprisingly, few studies provided sufficient data to compare the diagnostic accuracy of manual sphygmomanometry with that of automated methods in screening populations. Similarly, few studies of OBPM protocols were eligible, and those that were provided limited support for repeating BP measurement at a single visit, avoiding caffeine ingestion before measurement, and keeping legs uncrossed during measurement. Studies that seemed to provide support for other recommendations, such as proper arm positioning (121–123), cuff size (124–126), and cuff deflation speed (127) (but not removal of clothing before cuff placement [122, 128, 129]), primarily reported results in terms of mean values rather than diagnostic categories or enrolled hypertensive populations. Although automated OBPM methods offer the advantages of repeated measurements in the absence of medical personnel, future evidence reviews will need to consider the applicability of the larger number of studies conducted in treated, hypertensive persons to these questions.

Blood pressure measured by mercury sphygmomanometry in the office setting is known to be associated with cardiovascular outcomes (130). We compared ABPM and HBPM with manual office methods and found that systolic ABPM consistently and statistically significantly predicted stroke and other cardiovascular outcomes independently of OBPM. In an exploratory, comparative meta-analysis (n = 13 906), we found no apparent difference among 24-hour, daytime, and nighttime ABPM protocols within our included evidence base. Our results were similar to those of a systematic review by the National Institute for Health and Clinical Excellence (131), which concluded that ABPM was superior for predicting clinical outcomes, with no protocol favored in a qualitative review of the data (n > 17 621). However, we did not evaluate certain outcomes (such as angina or revascularization) or populations with comorbid conditions (such as diabetes or kidney disease) and included only studies conducted in countries rated "very high" on the Human Development Index. Two other large meta-analyses (one that included 13 843 hypertensive patients [132] and one that

Table 2. Hypertension Incidence at Various Rescreening Intervals, by Race/Ethnicity*

Study, Year (Reference)	Quality	Mean Age (Range), *y*	Diagnostic Threshold	Mean Baseline Office BP, *mm Hg*	Rescreening Interval, *y*
Fitchett and Powell, 2009 (105)	Fair	50.0 (42.0–52.0)	BP ≥140/90 mm Hg or use of antihypertensive medications	118.4/NR	2
Levine et al, 2011 (88)	Good	25.1 (18.0–30.0)	BP ≥140/90 mm Hg or use of antihypertensive medications	109.5/68.1	2
Juhaeri et al, 2002 (84)	Good	53.4 (46.0–65.0)	BP ≥140/90 mm Hg or use of antihypertensive medications	113.6/70.0	3
Apostolides et al, 1982 (97)	Fair	NR (30.0–69.0)	DBP >95 mm Hg or use of antihypertensive medications	NR	3
Levine et al, 2011 (88)	Good	25.1 (18.0–30.0)	BP ≥140/90 mm Hg or use of antihypertensive medications	109.5/68.1	5
Lakoski et al, 2011 (86)	Good	59.0 (45.0–84.0)	BP ≥140/90 mm Hg or history of hypertension and use of antihypertensive medications	NR	5

BP = blood pressure; DBP = diastolic blood pressure; NR = not reported.
* Results of studies included for key question 4b, sorted by rescreening interval. Baseline characteristics are reported for the overall study population and are not further stratified by subgroup. All studies were done in the United States.

Table 1–Continued

Baseline BMI					
18.5–24.9 kg/m²		25.0–29.9 kg/m²		≥30.0 kg/m²	
Participants, *n*	Unadjusted Incidence, %	Participants, *n*	Unadjusted Incidence, %	Participants, *n*	Unadjusted Incidence, %
11 751	1.5	4674	3.9	1040	7.6
3251	13.8	1456	24.9	138	32.6

analyzed 23 856 hypertensive patients and 9641 randomly recruited persons [133]) reported that nighttime systolic ABPM was a stronger predictor of cardiovascular events than daytime ABPM or OPBM. Evidence gaps suggested by these conflicting meta-analyses include the influence of treatment and age (133) and of composite outcomes and population composition on the predictive values of 24-hour, daytime, and nighttime ABPM. We also found that systolic HBPM predicted cardiovascular outcomes in a pattern similar to that of ABPM; however, too few studies were available to allow us to draw firm conclusions about HBPM.

On the basis of the prognostic evidence, we selected ABPM as the reference standard for BP measurement and for evaluating the diagnostic accuracy of other measurement methods. We regarded daytime, nighttime, or 24-hour ABPM protocols as acceptable. Improved prediction with ABPM also suggested the need for confirmation of OBPM. We found that OBPM variably predicted "true" hypertension, as defined by ABPM. Despite this variability, hypertension at screening with OBPM was not confirmed by non-OBPM methods in a large proportion of persons. Measurement error and regression to the mean may contribute to false-positive screening results with OBPM. However, some persons without confirmation of elevated BP at screening have isolated clinic hypertension. Studies have reported that the long-term outcomes of these persons are more similar to those of normotensive persons than to those of patients with sustained hypertension (134). An unplanned analysis of patients with isolated clinic hypertension in our included studies of cardiovascular prognosis also suggested that cardiovascular disease outcomes are more similar to those of persons who are normotensive at baseline than to those of persons with sustained hypertension (data not shown) (14). Given the high variability of OBPM for predicting hypertension at confirmatory testing and the importance of identifying persons who truly require treatment, confirmatory measurement is needed to avoid misdiagnosis. Ambulatory BP monitoring provides multiple measurements over time in a nonmedical setting, which potentially avoids measurement error, regression to the mean, and misdiagnosis of isolated clinic hypertension and is best correlated with long-term outcomes.

Our evidence review shows that overdiagnosis of hypertension from unconfirmed office-based screening could result in unnecessary treatment in a substantial number of persons. Although our scope did not include reviewing evidence to determine rates of harms due to unnecessary treatment and did not directly address the proportion of persons who would have isolated clinic hypertension, these considerations will be important for future reviews. We found no evidence of other serious harms of BP screening.

Finally, we investigated the best interval for rescreening of BP after a normal screening result. Guidelines make recommendations for rescreening intervals, but none are evidence-based. We found that estimates of incident hypertension at annual intervals up to 6 years were highly variable. Qualitative analysis identi-

Table 2–Continued

Asian		African American		White		Hispanic	
Participants, *n*	Unadjusted Incidence, %	Participants, *n*	Unadjusted Incidence, %	Participants, *n*	Unadjusted Incidence, %	Participants, *n*	Unadjusted Incidence, %
–	–	262	17.9	739	5.7	–	–
–	–	1582	1.8	1854	0.8	–	–
–	–	1567	16.4	7752	9.2	–	–
–	–	1222	24.5	1516	7.1	–	–
–	–	1582	4.7	1854	2.0	–	–
470	16.2	713	27.5	1552	17.5	808	21.2

fied a trend toward lower estimates and less variability in studies that required confirmation (for example, by repeated measurements or visits) of elevated BP at rescreening. These findings further support the importance of confirmatory BP measurement, whether initially or at rescreening. We conclude that the wide variation in incident hypertension was at least partly driven by the different population characteristics reported in the studies. The incidence of hypertension was higher in older persons, African Americans, those with an above-normal BMI, and those with a high-normal BP.

In summary, the available evidence suggests that repeated measurements may improve the diagnostic accuracy of OBPM for screening. Initially elevated BP measured by office-based methods is best confirmed by ABPM to avoid potential overdiagnosis of isolated clinic hypertension and the potential harms of unnecessary treatment. Studies of rescreening intervals of up to 6 years found a variably high incidence of hypertension overall. Hypertension incidence at rescreening was also higher at shorter intervals for persons with BP in the high-normal range, for older persons, for those with an above-normal BMI, and for African Americans compared with those without these risk factors. These results suggest that time and resources might be better directed toward improved measurement accuracy and timely measurement in higher-risk persons rather than measurement of all persons at every office visit.

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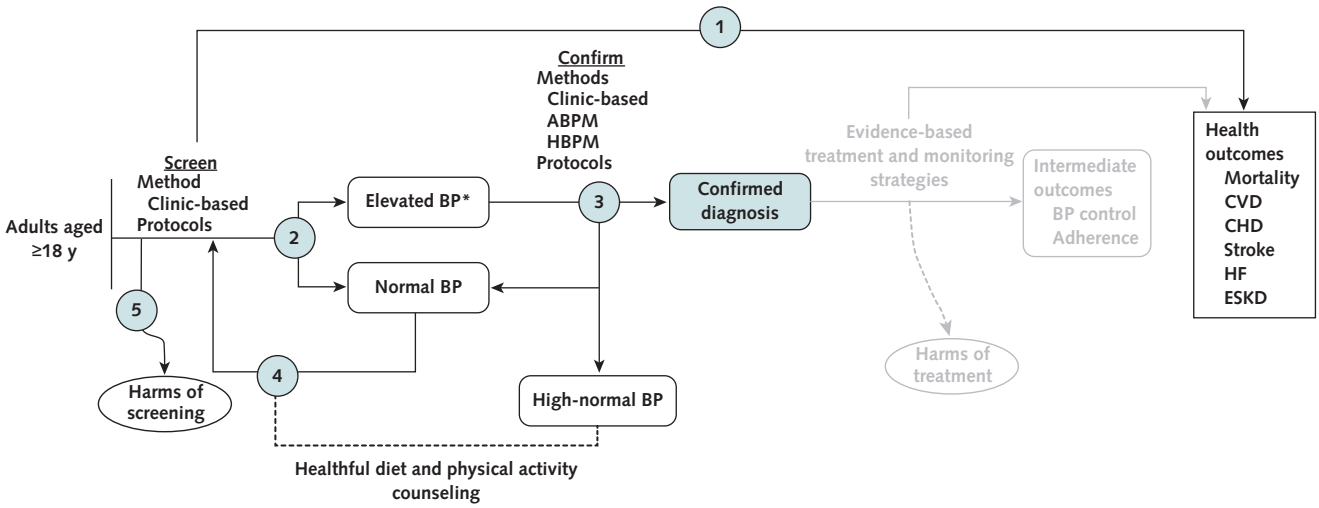
Appendix Figure 1. Analytic framework.



Key Questions

1. **Does screening for high blood pressure reduce cardiovascular disease and mortality in adults aged 18 years or older?**
2. **What is the best way to screen for high blood pressure in adults in the primary care setting?**
   a. **How accurate (i.e., sensitivity, specificity, and predictive value) are clinic-based blood pressure measurement methods (e.g., manual vs. automated) in provisionally diagnosing hypertension within a single visit?**
   b. **What screening protocol characteristics within a single encounter (e.g., sitting quietly for 5 minutes or number of readings) define the best diagnostic accuracy?**
3. **What is the best way to confirm hypertension in adults who initially screen positive for high blood pressure?**
   a. **How well do home and ambulatory blood pressure monitoring methods predict cardiovascular events compared with clinic-based blood pressure measurement methods? What confirmation protocol characteristics define the best prediction of cardiovascular events? Which methods and associated protocols best predict cardiovascular events?**
   b. **How accurate are other noninvasive blood pressure measurement methods in establishing or confirming the diagnosis of hypertension compared with these best methods and associated protocols? Does diagnostic accuracy vary by protocol characteristics (i.e., characteristics not reviewed in key question 2b, such as the number of visits)?**
   c. **Does changing the measurement method from that used during the initial screening improve diagnostic accuracy for some specific patient subgroups (e.g., those with suspected white coat hypertension)?**
4. **What is the clinically appropriate rescreening interval for patients who have previously been screened and found to have normal blood pressure?**
   a. **What is the shortest interval in which clinically significant, diagnosed hypertension may develop?**
   b. **Does the rescreening interval vary by patient characteristics (e.g., age, sex, race/ethnicity, cardiovascular risk, blood pressure, or screening history)?**
5. **What are the adverse effects of screening for high blood pressure in adults?**

ABPM = ambulatory blood pressure monitoring; BP = blood pressure; CHD = coronary heart disease; CVD = cardiovascular disease; ESKD = end-stage kidney disease; HBPM = home blood pressure monitoring; HF = heart failure.
* Defined as the threshold for pharmacologic treatment.

Appendix Table 1. Overall Summary of Evidence, by Key Question

Key Question	Studies, *n*	Overall Quality	Limitation	Consistency	Primary Care Applicability	Summary of Findings
1 (screening and cardiovascular disease and mortality)	1	Good	Evidence limited to results from 1 good-quality study	NA: 1 study	Moderate: appropriate to an elderly primary care population; screening program evaluated in the context of a universal payer	A cluster RCT (39 clusters; *n* = 140 642) of a BP screening program in Ontario, Canada, targeted to persons aged ≥65 y reported a statistically significant 9% relative reduction in the number of composite cardiovascular events (rate ratio, 0.91 [95% CI, 0.86 to 0.97]; *P* = 0.002). The intervention group had 3.02 fewer annual hospitalizations for CVD per 1000 persons than the control group. When data were analyzed by the number of unique patients hospitalized, there was a significant relative reduction only in the individual outcome of acute MI.
2 (diagnostic accuracy of clinic-based BP measurement methods)	4	Fair to good	Differences in study design; clinically unrealistic design in 1 study; use of different automated devices in 1 study without attempt to ensure comparability or validity	Inconsistent: sensitivity differs greatly in 1 study	High: 3 of 4 studies used clinically applicable protocols to measure the diagnostic accuracy of automated oscillometric BP devices	1 unique study that probably minimized human error more than is possible in the typical clinical setting compared manual BP measurement by sphygmomanometry (reference standard) with automated oscillometric measurement and reported a sensitivity of 91%, specificity of 96%, PPV of 88%, and NPV of 97%. 3 studies of similar comparisons but with more clinically applicable study designs reported lower sensitivities (51% to 68%) and PPVs (76% to 84%).
2 (diagnostic accuracy of protocol characteristic)	3	Fair to good	Different protocol characteristics addressed; populations not uniformly representative of screening populations; in 1 study, a carefully controlled protocol may limit applicability	NA: each study evaluated a different component of BP measurement	Moderate: studies addressed basic questions about BP measurement methods	1 study showed that the first of 3 BP measurements had a high sensitivity (95%) but a moderate PPV (76%) for detecting hypertension compared with the average of the second and third measurements, suggesting that the primary value of repeated measurements is in confirming initially elevated BP. In a study of normotensive persons, different leg positions, including leg crossing, did not result in reclassification to hypertensive. When BP was measured after double-blind administration of oral caffeine, 17% of persons who ingested caffeine were reclassified from normotensive to hypertensive.

Continued on following page

Appendix Table 1–Continued

Key Question	Studies, *n*	Overall Quality	Limitation	Consistency	Primary Care Applicability	Summary of Findings
3 (prediction of events)	15	Fair to good	No study populations based in the United States; limited data for HBPM; only 1 study compared all 3 methods	High	High: ABPM independently predicted cardiovascular outcomes compared with OBPM and can be considered the reference method for BP measurement	24-h ABPM predicted stroke and other cardiovascular fatal and nonfatal events significantly and independently of OBPM. When both were in the model, OBPM added no significant predictive capacity. Results were inconsistently significant for cardiac events, CHF, and all-cause mortality. The pattern of results was similar for nighttime and daytime ABPM compared with OBPM; no single ABPM protocol seemed best. The results of 5 studies suggested that HBPM predicts cardiovascular outcomes significantly and independently of OBPM, but too few studies are available for firm conclusions. Only 1 study compared ABPM with HBPM; the evidence was insufficient for conclusions. Limited evidence suggested that cardiovascular outcomes for the subgroup with isolated clinic hypertension at baseline were more similar to those of normotensive persons than to those of patients with sustained hypertension.
3 (diagnostic accuracy to confirm diagnosis)	27	Fair to good	Factors influencing variability in the proportion of persons with isolated clinic hypertension were not apparent	Limited	High: persons with unconfirmed false-positive results by OBPM (isolated clinic hypertension) could be misdiagnosed and unnecessarily treated	Initial screening by office-based methods variably predicted true hypertension, defined primarily by ABPM; the proportion of persons with an elevated BP on screening who were normotensive on confirmatory testing by ABPM or HBPM ranged from 5% to 65% across all studies; this population had isolated clinic hypertension.
3 (diagnostic accuracy to confirm diagnosis in subpopulations)	27	Fair to good	Factors influencing variability in the proportion of persons with isolated clinic hypertension were not apparent	Limited	High: persons with unconfirmed false-positive results by OBPM (isolated clinic hypertension) could be misdiagnosed and unnecessarily treated; no additional subpopulations identified by the available data; confirmation near threshold for hypertension most important	The subpopulation of persons with isolated clinic hypertension was identified in key question 3b. No associations among reported race/ethnicity, sex, or smoking were qualitatively detected. Increasing baseline BP was associated with increasing PPV (i.e., lower likelihood of misdiagnosis).

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Appendix Table 1–Continued

Key Question	Studies, *n*	Overall Quality	Limitation	Consistency	Primary Care Applicability	Summary of Findings
4 (shortest rescreening interval)	39	Fair to good	Only 1 study reported rescreening incidence at <1 y, and most reported it at 5 y; most studies done in Asia	Moderate	High: rescreening without confirmation may result in overestimation of hypertension incidence and misdiagnosis	In a few studies that used a separate confirmation step, a significant proportion of cases of incident hypertension were not confirmed. Thus, estimates of the weighted mean incidence of hypertension at yearly intervals >6 y derived from a few studies (except at 5 y) with highly variable results are probably overestimates because most studies did not include a confirmation step. For example, the weighted mean incidence of 14% at 5 y actually ranged from 2% to 28%. Variation resulted from criteria for diagnosis and from study population characteristics.
4 (shortest rescreening interval by patient characteristic)	39	Fair to good	Only 1 study reported rescreening incidence at <1 y, and most reported it at 5 y; most studies done in Asia; limited subgroup reporting	Moderate	High: higher incidence of hypertension was seen in persons with high-normal BP, older persons, those with an above-normal BMI, and African Americans; much lower incidence was seen in those without risk factors	Hypertension incidence increased as much as 2- to 4-fold between the age categories of 18 to 40 or 45 y and 40 or 45 to 60 or 65 y. Hypertension incidence consistently tripled between optimal and normal BP categories in each study and approximately doubled between normal and high-normal categories. Incidence was generally higher in men than women, especially in younger populations. Incidence was 2- and 3-fold higher in overweight and obese persons, respectively, than in normal-weight persons but did not increase in smokers compared with nonsmokers or former smokers. Black persons had a consistently higher incidence of hypertension at rescreening than white persons.

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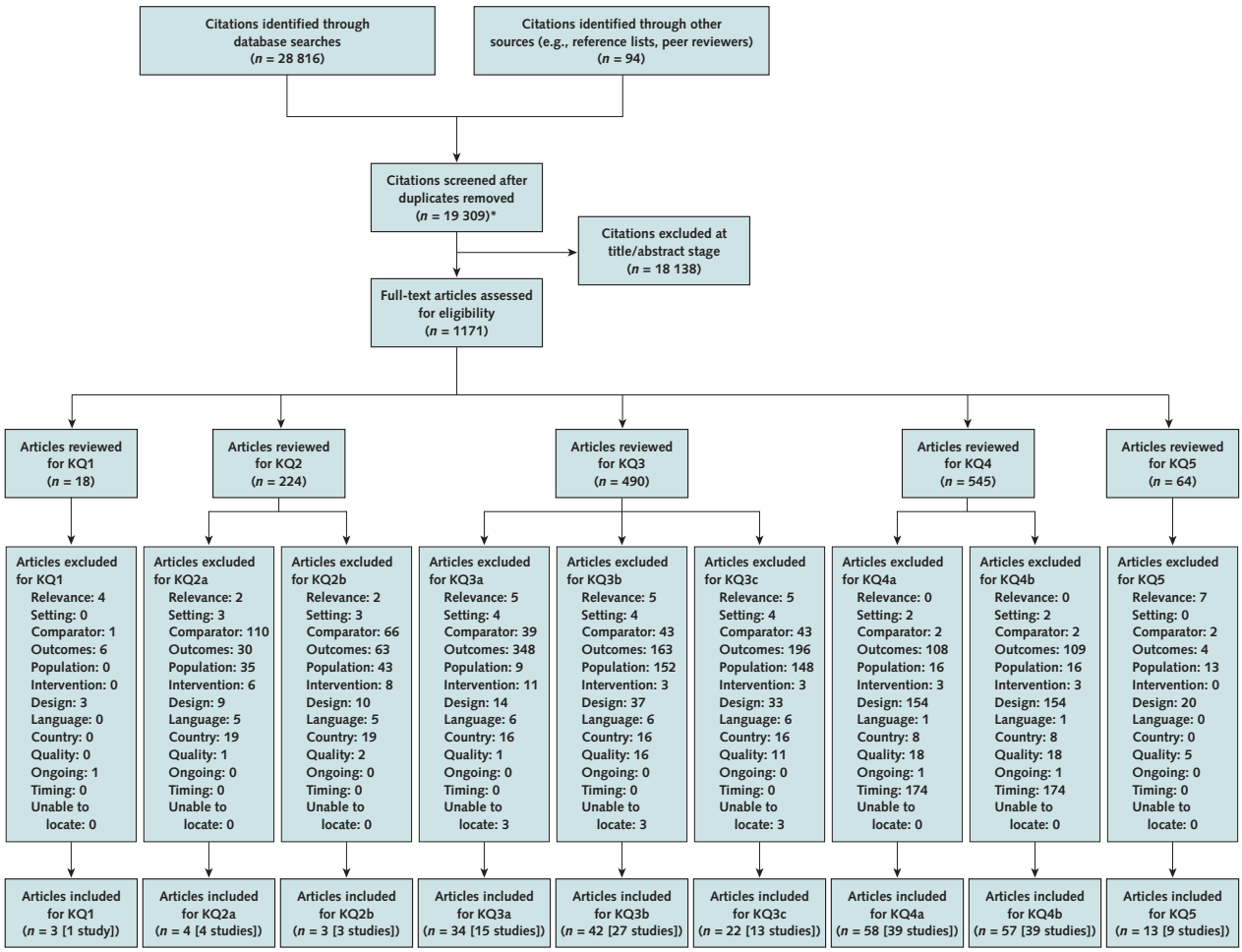
Appendix Table 1–Continued

Key Question	Studies, *n*	Overall Quality	Limitation	Consistency	Primary Care Applicability	Summary of Findings
5 (adverse effects)	9	Fair to good	Different study designs and outcomes assessed; difficult to compare results across studies	NA: studies addressed different outcomes	Moderate: sleep disturbance and physical discomfort are associated with ABPM use	3 trials found no significant differences in psychological distress or quality of life after persons were labeled as hypertensive or prehypertensive. 1 trial reported significantly decreased mood, general physical state, sexual functioning, and sleep quality after labeling. 1 cohort study reported significantly increased absenteeism from work ≤4 y after labeling compared with the preceding year. 3 cohort studies reported significant sleep disturbances associated with ABPM use, and 2 studies reported that significant proportions of ABPM users had pain, skin irritation, and overall discomfort.

ABPM = ambulatory blood pressure monitoring; BMI = body mass index; BP = blood pressure; CHF = congestive heart failure; CVD = cardiovascular disease; HBPM = home blood pressure monitoring; MI = myocardial infarction; NA = not applicable; NPV = negative predictive value; OBPM = office blood pressure measurement; PPV = positive predictive value; RCT = randomized, controlled trial.

Appendix Figure 2. Summary of evidence search and selection.



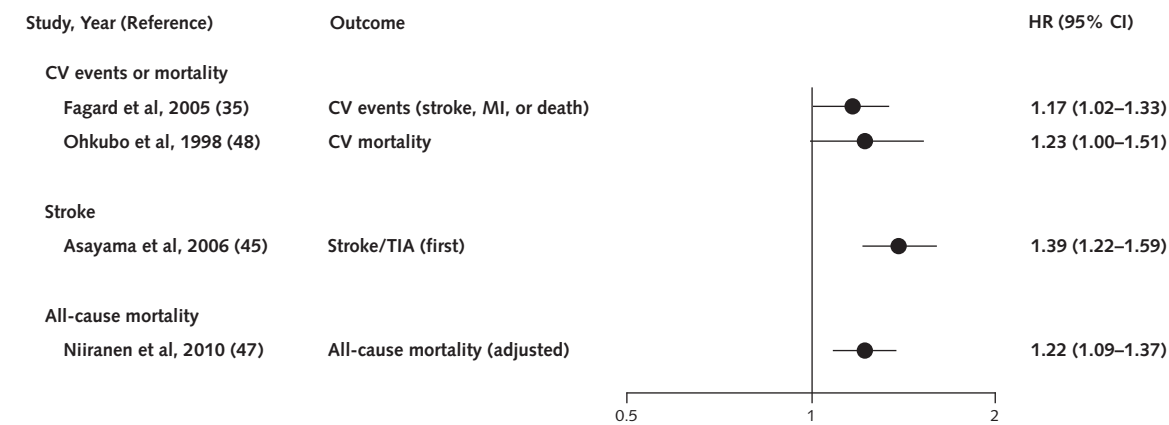
KQ = key question.
* Surveillance search results through August 2014 for trials reporting direct benefits of screening were not included; no additional trials were identified.

Appendix Table 2. ABPM Device Characteristics*

Study, Year (Reference)	Device	Measurement Period	Time Between Measurements, *min*	Maximum Measurements, *n*	Office BP Measurements, *n*	Method of Office BP Determination
Celis et al, 2002 (40)	Spacelabs 90207 and 90239A	Day: 10:00 a.m. to 8:00 p.m.	15	40	6	Mean of 6 readings†
Clement et al, 2003 (34)	NR	24 h	30 (8:00 a.m. to 8:00 p.m.); 60 (8:00 p.m. to 8:00 a.m.)	36	3	Mean of 3 measurements
		Day: 8:00 a.m. to 8:00 p.m.	30	24	3	Mean of 3 measurements
		Night: midnight to 6:00 a.m.	60	6	3	Mean of 3 measurements
Dolan et al, 2005 (41)	Spacelabs 90202 or 90207	24 h	30	48	3	Mean of 3 measurements
		Day: 9:00 a.m. to 9:00 p.m.	30	24	3	Mean of 3 measurements
		Night: 1:00 to 6:00 a.m.	30	10	3	Mean of 3 measurements
Fagard et al, 2005 (35)	Spacelabs 90202 or 90207	Day: 10:00 a.m. to 8:00 p.m.	15	40	3	Mean of 3 measurements
		Night: midnight to 6:00 a.m.	30	12	3	Mean of 3 measurements
Gasowski et al, 2008 (43)	Spacelabs 90207	24 h	20 (8:00 a.m. to 10:00 p.m.); 45 (midnight to 6:00 a.m.)	50	5	Mean of 5 measurements
Hansen et al, 2005 (42)	Takeda TM-2421	24 h	15 (7:00 a.m. to 11:00 p.m.); 30 (11:00 p.m. to 7:00 a.m.)	80	2	Mean of 2 measurements
		Day: determined by diaries (defined as 6:00 a.m. to midnight if diaries were inadequate)	15 (7:00 a.m. to 11:00 p.m.)	64	2	Mean of 2 measurements
		Night: determined by diaries (defined as midnight to 6:00 a.m. if diaries were inadequate)	30 (11:00 p.m. to 7:00 a.m.)	16	2	Mean of 2 measurements
Hermida et al, 2011 (36)	Spacelabs 90207	48 h	20 (7:00 a.m. to 11:00 p.m.); 30 (night‡)	128	6	NR
		Day: determined by diaries and actigraphy	20 (7:00 a.m. to 11:00 p.m.)	NR	6	NR
		Night: determined by diaries and actigraphy	30 (night‡)	NR	6	NR
Ingelsson et al, 2006 (37)	Accutracker II (SunTech Medical)	24 h	20 or 30 (6:00 a.m. to 11:00 p.m.); 20 or 60 (11:00 p.m. to 6:00 a.m.)	41 or 72	2	Mean of 2 measurements§
		Day: 10:00 a.m. to 8:00 p.m.	20 or 30	20–30	2	Mean of 2 measurements§
		Night: midnight to 6:00 a.m.	20 or 60	6–18	2	Mean of 2 measurements§
Mesquita-Bastos et al, 2010 (44)	Spacelabs 90207	24 h	20 (7:00 a.m. to 11:00 p.m.); 30 (11:30 p.m. to 6:30 a.m.)	6	3	Mean of last 2 of 3 measurements‖
		Day: 7:00 a.m. to 11:00 p.m.	20	48	3	Mean of last 2 of 3 measurements‖
		Night: 11:30 p.m. to 6:30 a.m.	30	15	3	Mean of last 2 of 3 measurements‖
Ohkubo et al, 2005 (38)	ABPM-630 (Nippon Colin)	24 h	30	48	2	Mean of 2 measurements
		Day: estimated from diaries	30	NR	2	Mean of 2 measurements
		Night: estimated from diaries	30	NR	2	Mean of 2 measurements
Staessen et al, 1999 (39)	Spacelabs 90202 or 90207	24 h	≤30	48	6	Mean of 6 measurements¶
		Day: 10:00 a.m. to 8:00 p.m.	≤30	20	6	Mean of 6 measurements¶
		Night: midnight to 6:00 a.m.	≤30	12	6	Mean of 6 measurements¶

ABPM = ambulatory blood pressure monitoring; BP = blood pressure; NR = not reported.
* Results of the studies included for key question 3a.
† 3 measurements at each of 2 visits.
‡ Assumed to be 11:00 p.m. to 7:00 a.m.
§ Rounded to nearest 2 mm Hg.
‖ Clinic BP recorded at 2 visits; unclear whether reading from first, second, or both visits was used to determine BP.
¶ 2 measurements at each of 3 visits.

Appendix Figure 3. Risk for cardiovascular and mortality outcomes: systolic HBPM, adjusted for OBPM.



Results of included studies for key question 3a. CV = cardiovascular; HBPM = home blood pressure monitoring; HR = hazard ratio; MI = myocardial infarction; OBPM = office blood pressure measurement; TIA = transient ischemic attack.

Appendix Table 3. Weighted Mean Hypertension Incidence at Various Rescreening Intervals in Subgroups Identified a Priori*

Subgroup	1 y			2 y			3 y			4 y			5 y		
	Studies, *n*	Participants, *n*	Weighted Mean Incidence, %	Studies, *n*	Participants, *n*	Weighted Mean Incidence (Range), %	Studies, *n*	Participants, *n*	Weighted Mean Incidence (Range), %	Studies, *n*	Participants, *n*	Weighted Mean Incidence (Range), %	Studies, *n*	Participants, *n*	Weighted Mean Incidence (Range), %
Age															
18 to 40 or 45 y	1†	9617	1.0	1	3436	1.2	–	–	–	1	7797	1.8	3	4568	4.1 (3.2–17.8)
40 or 45 to 60 or 65 y	1†	5805	4.0	1	1001	8.9	2	13 468	14.9 (10.4–24.9)	2	989	15.3 (6.7–20.4)	3	3052	7.1 (3.1–23.7)
≥60 or 65 y	1	275	4.4	–	–	–	–	–	–	2	2858	37.5 (35.4–40.3)	1	204	37.7
BP measurement															
High-normal	–	–	–	2	5000	27.7 (26.7–31.3)	3	3323	26.7 (21.0–30.4)	2	4736	50.3 (42.8–58.0)	2	1544	46.4 (32.7–52.2)
Normal	–	–	–	2	50 117	7.7 (7.6–7.8)	3	4318	7.0 (4.4–9.0)	1	7443	11.8	2	2970	18.6 (16.6–18.8)
Sex															
Male	1†	9691	3.4	4	40 519	10.6 (1.8–13.0)	7	19 447	15.4 (6.6–24.9)	5	49 283‡	34.6 (2.1–43.3)	14	31 153	13.0 (2.1–28.4)
Female	1†	7774	1.5	5	23 872	6.0 (0.9–11.6)	5	19 308	7.8 (1.4–19.8)	3	82 386‡	36.0 (8.7–37.3)	11	17 533	11.2 (2.5–28.8)
BMI															
18.5–<25.0 kg/m^2	1	11 751	1.5	1	3351	5.5	1	3521	13.8	–	–	–	–	–	–
≥25.0–29.9 kg/m^2	1	4674	3.9	–	–	–	1	1456	24.9	–	–	–	–	–	–
≥30.0 kg/m^2	1	1040	7.6	1	1039	3.8	1	138	32.6	–	–	–	–	–	–
Smoking status															
Current	1	5845	2.8	1	1457	5.4	1	1164	5.8	2	7194	3.4 (1.8–8.3)	6	5288	10.6 (3.0–22.0)
Nonsmoker/former smoker	1	11 620	2.4	1	3400	8.3	1	1114	7.5	2	5611	6.0 (2.6–9.3)	6	13 222	15.1 (3.4–21.0)

BMI = body mass index; BP = blood pressure.
* Results of studies included for key question 4b.
† Incidence based on 2 visits; incidence based on 1 visit also reported but not pooled (53).
‡ The study by Okubo and colleagues (119) was categorized as having a 4-y interval on the basis of an overall mean follow-up of 3.9 y; mean follow-up was 4.1 y for women and 3.4 y for men. If this study (n = 115 736) was not included in the 4-y interval category, the weighted mean incidence would be 7.3% (range, 2.1% to 35.6%) in 4 studies (n = 11 973) for men and 10.9% (range, 8.7% to 14.8%) in 2 studies (n = 3960) for women.

Appendix Table 4. Hypertension Incidence, by Age*

Study, Year (Reference)	Quality	Mean Age (Range), *y*	Country	Participants, *n*	Participants Aged 18 to 40 or 45 y, %	Diagnostic Threshold	Mean Baseline Office BP, *mm Hg*	Women, %	Rescreening Interval, *y*	Unadjusted Incidence, %		
										Aged 18 to 40 or 45 y	Aged 40 or 45 to 60 or 65 y	Aged ≥60 or 65 y
Radi et al, 2004 (53)	Fair	38.2 (15.0–69.0)	France	17 465	55.1	≥140/90 mm Hg or use of antihypertensive medications	119.5/75.3	44.5	1	1.0†	4.4†‡	NR
Lee et al, 2004 (87)	Good	38.7 (25.0–50.0)	Korea	8170	95.4	≥160/95 mm Hg	114.9/72.7	0.0	4	1.8	6.7	NA
Lee et al, 2011 (109)	Fair	56.6 (≥20)	Korea	730	15.3	≥140/90 mm Hg or use of antihypertensive medications	119.8/75.8	63.7	5	17.9	23.7	37.7
Morikawa et al, 1999 (89)	Good	34.7 (18.0–49.0)	Japan	1551	65.8	≥140/90 mm Hg	117.7/69.4	0.0	5	5.5	10.0	NA

BP = blood pressure; NA = not applicable; NR = not reported.
* Results of studies included for key question 4b, sorted by rescreening interval. Baseline characteristics are reported for the overall study population and are not further stratified by the identified subgroup.
† Includes participants aged 40 to 69 y.
‡ Based on >1 visit or involved an additional confirmation step.

Appendix Table 5. Hypertension Incidence in Studies Reporting 3 BP Categories*

Study, Year (Reference)	Rescreening Interval, *y*	BP Category†	Cases, *n*	Participants, *n*	Unadjusted Incidence, %
Kim et al, 2006 (85)	2	Optimal	158	3302	4.8
		Normal	217	1485	14.6
		High-normal	345	1102	31.3
Kim et al, 2011 (107)	2	Optimal	1671	32 929	5.1
		Normal	1800	12 401	14.5
		High-normal	1040	3898	26.7
Yambe et al, 2007 (95)	3	Optimal	17	702	2.4
		Normal	40	581	6.9
		High-normal	100	475	21.0
Vasan et al, 2001 (91)	4	Optimal	286	4499	6.4
		Normal	592	2944	20.1
		High-normal	1029	2402	42.8
Nakanishi et al, 2003 (90)	5	Optimal	130	1418	9.2
		Normal	379	1281	29.6
		High-normal	567	1085	52.2

BP = blood pressure.
* Results of studies included for key question 4b.
† Optimal: <120/80 mm Hg; normal: 120 to 129/80 to 84 mm Hg; high-normal: 130 to 139/85 to 89 mm Hg.

Appendix Table 6. Hypertension Incidence at Various Rescreening Intervals, by Sex*

Study, Year (Reference)	Quality	Country	Participants, *n*	Women, %	Mean Age (Range), *y*	Diagnostic Threshold	Mean Baseline Office BP, *mm Hg*	Rescreening Interval, *y*	Unadjusted Incidence, %		Male-Female Incidence Ratio
									Men	Women	
Radi et al, 2004 (53)	Fair	France	17 465	44.50	38.2 (15.0–69.0)	≥140/90 mm Hg or use of antihypertensive medications	119.5/75.3	1.0	3.4†	1.5†	2.3
Kim et al, 2006 (85)	Good	Korea	5869	52.40	50.8 (40.0–69.0)	≥140/90 mm Hg or use of antihypertensive medications	113.1/75.3	2.0	13.0	11.6	1.1
Kim et al, 2011 (107)	Fair	Korea	49 228	32.70	37.9 (30.0–54.0)	≥140/90 mm Hg	112.4/72.8	2.0	11.0	5.4	2.0
Levine et al, 2011 (88)	Good	United States	3436	57.10	25.1 (18.0–30.0)	≥140/90 mm Hg or use of antihypertensive medications	109.5/68.1	2.0	1.8	0.9	2.0
Tozawa et al, 2002 (116)	Fair	Japan	4857	36.00	46.0 (NR)	≥140/90 mm Hg	115.0/71.0	2.0	8.0	6.3	1.3
Jung et al, 2014 (92)	Good	Korea	1553	62.40	53.9 (40.0–70.0)	≥140/90 mm Hg or use of antihypertensive medications	116.9/73.8	2.6	13.5	10.2	1.3
Apostolides et al, 1982 (97)	Fair	United States	2738	52.70	NR (30.0–69.0)	DBP >95 mm Hg or use of antihypertensive medications	NR	3.0	14.8	15.0	1.0
Juhaeri et al, 2002 (84)	Good	United States	9319	55.10	53.4 (46.0–65.0)	≥140/90 mm Hg or use of antihypertensive medications	113.6/70.0	3.0	11.6	9.4	1.2
Okubo et al, 2014 (119)	Fair	Japan	115 736	67.76	54.5 (40.0–79.0)	>140/90 mm Hg or use of antihypertensive medications	120.9/73.3	3.9‡	43.3	37.3	1.2
Dernellis and Panaretou, 2005 (103)	Fair	Greece	2512	57.30	64.6 (35.0–94.0)	≥140/90 mm Hg	119.8/77.2	4.0	35.6†	14.8†	2.4
Brantsma et al, 2006 (82)	Good	The Netherlands	4635	54.40	45.2 (28.0–75.0)	≥140/90 mm Hg or use of antihypertensive medications	119.1/69.6	4.2	9.2†	8.7†	1.1
Arima et al, 2002 (98)	Fair	Japan	1133	64.30	56.0 (40.0–79.0)	≥160/95 mm Hg or use of antihypertensive medications	124.7/74.4	5.0	16.0	16.6	1.0
Boyko et al, 2008 (100)	Fair	Australia	4306	57.00	47.6 (≥25.0–NR)	≥140/90 mm Hg or use of antihypertensive medications	120.2/67.0	5.0	15.6	12.7	1.2
Klein et al, 2006 (96)§	Good	United States	NR	56.80	57.6 (43.0–84.0)	≥140/90 mm Hg or use of antihypertensive medications	119.0/74.0	5.0	19.0	16.6	1.1
Lakoski et al, 2011 (86)	Good	United States	3543	51.20	59.0 (45.0–84.0)	≥140/90 mm Hg or history of hypertension and use of antihypertensive medications	NR	5.0	19.6	20.7	0.9
Lee et al, 2004 (110)	Fair	Japan	5840	41.30	48.6 (30.0–69.0)	≥160/95 mm Hg more than once or use of antihypertensive medications	110.5/69.8	5.0	11.7†	8.9†	1.3
Lee et al, 2011 (109)	Fair	Korea	730	63.70	56.6 (≥20.0–NR)	≥140/90 mm Hg or use of antihypertensive medications	119.8/75.8	5.0	23.0	28.8	0.8

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Appendix Table 6–Continued

Study, Year (Reference)	Quality	Country	Participants, *n*	Women, %	Mean Age (Range), *y*	Diagnostic Threshold	Mean Baseline Office BP, *mm Hg*	Rescreening Interval, *y*	Unadjusted Incidence, %		Male–Female Incidence Ratio
									Men	Women	
Levine et al, 2011 (88)	Good	United States	3436	57.10	25.1 (18.0–30.0)	≥140/90 mm Hg or use of antihypertensive medications	109.5/68.1	5.0	4.2	2.5	1.7
Sung et al, 2014 (117)	Fair	Korea	11 448	30.64	40.6 (NR)	≥140/90 mm Hg or use of antihypertensive medications	111.4/72.0	5.0	9.7	4.0	2.4
Cheung et al, 2012 (102)	Fair	China (Hong Kong)	1115	56.60	48.3 (25.0–74.0)	≥140/90 mm Hg or use of antihypertensive medications	113.9/72.2	5.3	22.5	20.1	1.1
Völzke et al, 2013 (93)	Good	Germany	1605	63.05	42.9 (20.0–79.0)	≥140/90 mm Hg or use of antihypertensive medications	120.5/76.8	5.3	23.9	17.9	1.3
Kivimäki et al, 2009 (108)	Fair	United Kingdom	6055	31.10	44.6 (35.0–55.0)	≥140/90 mm Hg or use of antihypertensive medications	118.9/74.6	5.6	12.6	10.2	1.2

BP = blood pressure; DBP = diastolic blood pressure; NR = not reported.
* Results of studies included for key question 4b, sorted by rescreening interval. Baseline characteristics are reported for the overall study population and are not further stratified by the identified subgroup.
† Measure based on >1 visit or involved an additional confirmation step.
‡ 3.4 y for men and 4.1 y for women.
§ Not included in **Figure 3** because estimated from published figures; number of participants at specified interval not reported.