# Self-Measured Blood Pressure Monitoring in the Management of Hypertension

## A Systematic Review and Meta-analysis

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**Background:** Clinical guidelines recommend that adults with hypertension self-monitor their blood pressure (BP).

**Purpose:** To summarize evidence about the effectiveness of self-measured blood pressure (SMBP) monitoring in adults with hypertension.

**Data Sources:** MEDLINE (inception to 8 February 2013) and Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews (fourth quarter 2012).

**Study Selection:** 52 prospective comparative studies of SMBP monitoring with or without additional support versus usual care or an alternative SMBP monitoring intervention in persons with hypertension.

**Data Extraction:** Data on population, interventions, BP, other outcomes, and study method were extracted. Random-effects model meta-analyses were done.

**Data Synthesis:** For SMBP monitoring alone versus usual care (26 comparisons), moderate-strength evidence supports a lower BP with SMBP monitoring at 6 months (summary net difference, −3.9 mm Hg and −2.4 mm Hg for systolic BP and diastolic BP) but not at 12 months. For SMBP monitoring plus additional support versus usual care (25 comparisons), high-strength evidence supports a lower BP with use of SMBP monitoring, ranging from −3.4 to −8.9 mm Hg for systolic BP and from −1.9 to −4.4 mm Hg for diastolic BP, at 12 months in good-quality studies. For SMBP monitoring plus additional support versus SMBP monitoring alone or with less intense additional support (13 comparisons), low-strength evidence fails to support a difference. Across all comparisons, evidence for clinical outcomes is insufficient. For other surrogate or intermediate outcomes, low-strength evidence fails to show differences.

**Limitation:** Clinical heterogeneity in protocols for SMBP monitoring, additional support, BP targets, and management; follow-up of 1 year or less in most studies, with sparse clinical outcome data.

**Conclusion:** Self-measured BP monitoring with or without additional support lowers BP compared with usual care, but the BP effect beyond 12 months and long-term benefits remain uncertain. Additional support enhances the BP-lowering effect.

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Self-measured blood pressure (SMBP) monitoring refers to the measurement of BP by a patient at home or outside of a clinic setting. Clinical practice guidelines, including the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, recommend SMBP monitoring as an adjunct method in the management of hypertension (1). The American Heart Association recommends SMBP measurements for evaluation of most patients with known or suspected hypertension to assess response to treatment and possibly improve adherence (2). However, despite these recommendations, it is unclear whether SMBP monitoring confers benefit, and if so, for how long, and whether it needs to be combined with additional support (for example, education, counseling, telemedicine, or other measures) to facilitate BP measurement, transmission, interpretation, adherence to lifestyle measures and medication, or medication titration.

We conducted this systematic review to evaluate the effectiveness of SMBP monitoring at home with or without additional support in adults with hypertension. We examined the following comparisons: SMBP monitoring alone versus usual care, SMBP monitoring with additional support versus usual care, and SMBP monitoring with additional support versus SMBP monitoring with no additional support or with less intense additional support.

## Methods

This review is based on a comparative effectiveness review commissioned by the Agency for Healthcare Research and Quality (AHRQ) and published at www.effectivehealthcare.ahrq.gov (3). It followed a standard AHRQ protocol and incorporated input from stakeholders, a technical expert panel, and peer review and public comments.

### Data Sources and Search

We searched MEDLINE (inception to 8 February 2013) and the Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews (fourth quarter 2012) without language restriction (**Appendix Table 1**, available at www.annals.org). Five reviewers independently screened abstracts using the computerized screening program abstrackr (Tufts Medical Center, Boston, Massachusetts) (4) after iteratively calibrating screening on an initial batch of 200 abstracts that were screened by all reviewers.

*See also:*

**Web-Only**
Supplements

***Key Summary Points***

When compared with usual care, self-measured blood pressure (SMBP) monitoring by a patient at home improves BP at 6 mo and may continue to do so for 12 mo.

SMBP monitoring in combination with additional support shows a lower BP at 12 mo than usual care.

The evidence comparing SMBP monitoring plus additional support with SMBP monitoring alone is of low quality and does not support a difference.

Evidence beyond 12 mo and for clinical outcomes is sparse.

Evidence for other outcomes is of low quality and inconsistent, but some studies found more medication changes and greater medication adherence with SMBP monitoring.

### Study Selection

We included prospective comparative studies of SMBP monitoring with or without additional support versus usual care or versus SMBP monitoring with a different intervention and at least 8 weeks of follow-up. Self-measured BP had to be conducted in the patient's home, either by the patient or a companion. Patients had to be adults being managed for hypertension, whether treated or untreated, controlled or uncontrolled. We excluded studies in patients receiving dialysis or women with gestational hypertension, studies of SMBP monitoring as a component of disease management for heart failure or weight loss, and studies using only wrist monitors (because they are less reliable than upper arm monitors) (5). We allowed studies that used wrist monitors as a default for patients with large arm circumference. All varieties of SMBP monitors (manual, semiautomated, or automated) were included. We categorized additional support post hoc as counseling, education, Web-based support, and miscellaneous support, according to the leading component (**Appendix Table 2**, available at www.annals.org). Usual care included any protocol for clinic BP monitoring.

Clinical outcomes (including death and cardiovascular events), patient-reported outcomes (including patient satisfaction or quality of life), surrogate outcomes (including measures of left ventricular hypertrophy), intermediate outcomes (including BP; number, dose, or changes of antihypertensive medications; and adherence to antihypertensive medication), or health care utilization (including visits, calls, and e-mails) were of interest. For BP outcomes, we included systolic and diastolic BP or mean arterial pressure. These could be measured in the clinic by ambulatory BP or SMBP monitoring (if measured in both groups); BP could be reported as a continuous or categorical variable (for example, BP below a threshold).

### Data Extraction, Quality Assessment, and Strength of Evidence

Each study was extracted by 1 of 5 reviewers with systematic review experience. Data on interventions, results, and quality grades were checked by another reviewer. The extracted data included study design, methods, participant characteristics, interventions (including SMBP device and protocol), additional support, comparators, and outcomes. We used a 3-category grading system (A, B, or C) to denote the methodological quality of each study for each outcome, in accordance with AHRQ's suggested methods for systematic reviews (6).

### Data Synthesis and Analysis

For continuous and binary clinic BP outcomes, we did random-effects model meta-analyses when similar data (including interventions and follow-up duration) were available from 3 or more randomized trials or comparisons. Comparisons of SMBP monitoring plus specific additional support (for example, an education program) versus the same support alone were analyzed as comparisons of SMBP monitoring alone versus usual care. We combined net differences for continuous outcomes (systolic and diastolic BP) and relative risk (RR) for the dichotomous outcome "adequate BP control." We allowed any definition or target of adequate control reported by a study. We assessed between-study heterogeneity with the Cochran $Q$ test (significant when $P < 0.10$) and quantified its extent with the $I^2$ statistic (7).

We summarized the strength of the evidence for an outcome category following the AHRQ methods guide as high, moderate, or low (6). Ratings were assigned on the basis of our level of confidence that the evidence reflected the true effect for the comparisons of interest. Evidence was deemed insufficient if no studies existed or very few studies provided only sparse data.

### Role of Funding Source

The work was funded by AHRQ. A technical expert panel and AHRQ helped to develop and refine the scope and assisted with review of draft reports. AHRQ granted copyright assertion before the manuscript could be submitted for publication, but the authors were solely responsible for the content and the decision to submit the manuscript for publication.

## RESULTS

### Study Characteristics

We identified 52 comparative studies (reported in 55 articles) (**Appendix Figure**, available at www.annals.org) (8–62). **Appendix Table 3** (available at www.annals.org) shows all studies by their comparisons, and findings are summarized in **Appendix Table 4** (available at www.annals.org).

Studies generally selected participants with uncomplicated hypertension and without acute disease (that is, without recent hospitalizations, acute cardiovascular disease

events, terminal illnesses, or advanced kidney disease). All but 2 studies were conducted in North America, Western Europe, or Australia (26, 46). Minorities were underrepresented, although 4 studies focused on African American persons (8, 9, 14, 57). In 33 studies, the device was specified to be an automated device.

## BP Outcomes

### *SMBP Monitoring Alone Versus Usual Care*

Of the 26 studies comparing SMBP monitoring alone versus usual care, 19 were included in meta-analyses for net changes in clinic systolic BP and diastolic BP (**Figure 1**). Although there was no statistically significant difference in net change between SMBP monitoring and usual care at 2 months, SMBP monitoring was associated with statistically significant net changes in both systolic BP and diastolic BP at 6 months (weighted mean difference, −3.9 mm Hg and −2.4 mm Hg, respectively). These net changes were no longer statistically significant at 12-month follow-up (weighted mean difference, −1.5 mm Hg and −0.8 mm Hg, respectively). The summary estimates were essentially unchanged in sensitivity analyses that were restricted to quality A or B studies (data not shown). Meta-analyses showed a borderline statistically significant benefit of achieving a predefined BP target with SMBP monitoring versus usual care at 6 months, which lost significance at 12 months (**Figure 1** in **Supplement 1**, available at www.annals.org). A sensitivity analysis that combined only the quality A and B studies showed a statistically significant result for adequate BP control at 6 months in favor of SMBP monitoring (data not shown). Eight studies that reported ambulatory BP outcomes were inconclusive.

Because of the consistency of findings in higher-quality studies, statistically significant findings in meta-analyses at 6 months, and a nonstatistically significant finding at 12 months, the evidence for an improvement in BP using SMBP monitoring versus usual care is rated as moderate-strength and supports an improvement in BP with SMBP monitoring.

### *SMBP Monitoring Plus Additional Support Versus Usual Care*

In the 25 studies that compared SMBP monitoring plus additional support versus usual care, additional support included educational materials, letters to patients and providers on treatment recommendations, Web resources, phone monitoring with electronic transmission of BP data, telecounseling, behavioral management, medication management with decision support, nurse or pharmacist visits, calendar pill packs, and adherence contracts (**Appendix Table 2**). Because of clinical heterogeneity, meta-analysis was not done. At 12 months, there was consistent benefit from the interventions compared with usual care, with 5 quality A studies reporting a mean net reduction in systolic BP (range, −2.1 to −8.3 mm Hg) or diastolic BP (range, 0.0 to −4.4 mm Hg) (9, 13, 29, 40, 52) (**Figures 2** and **3**). The types of additional support in these 5 trials were telemonitoring and counseling on patient adherence to antihypertensive medications (9), Web-based pharmacist counseling (29), telemonitoring with self-titration of antihypertensive medications (40), telemonitoring with nurse videoconference (52), and combined medication–behavioral management (13). Results were mixed at 18 months, with the single quality A trial finding no difference between groups. Two studies found statistically significant net reductions in systolic BP and diastolic BP at 24 to 60 months (13, 54).

Twelve studies reported categorical BP outcomes, of which 5 reported that a statistically significantly higher proportion of patients achieved the BP target for SMBP monitoring plus additional support (**Figure 1** in **Supplement 1**). Two trials provided ambulatory BP outcomes, both favoring SMBP monitoring with additional support (45, 48).

On the basis of consistent findings in quality A trials, high-strength evidence supports a reduction in BP using SMBP monitoring with some form of additional support compared with usual care.

### *SMBP Plus Additional Support Versus SMBP Monitoring Alone or SMBP Monitoring Plus Less Intense Additional Support*

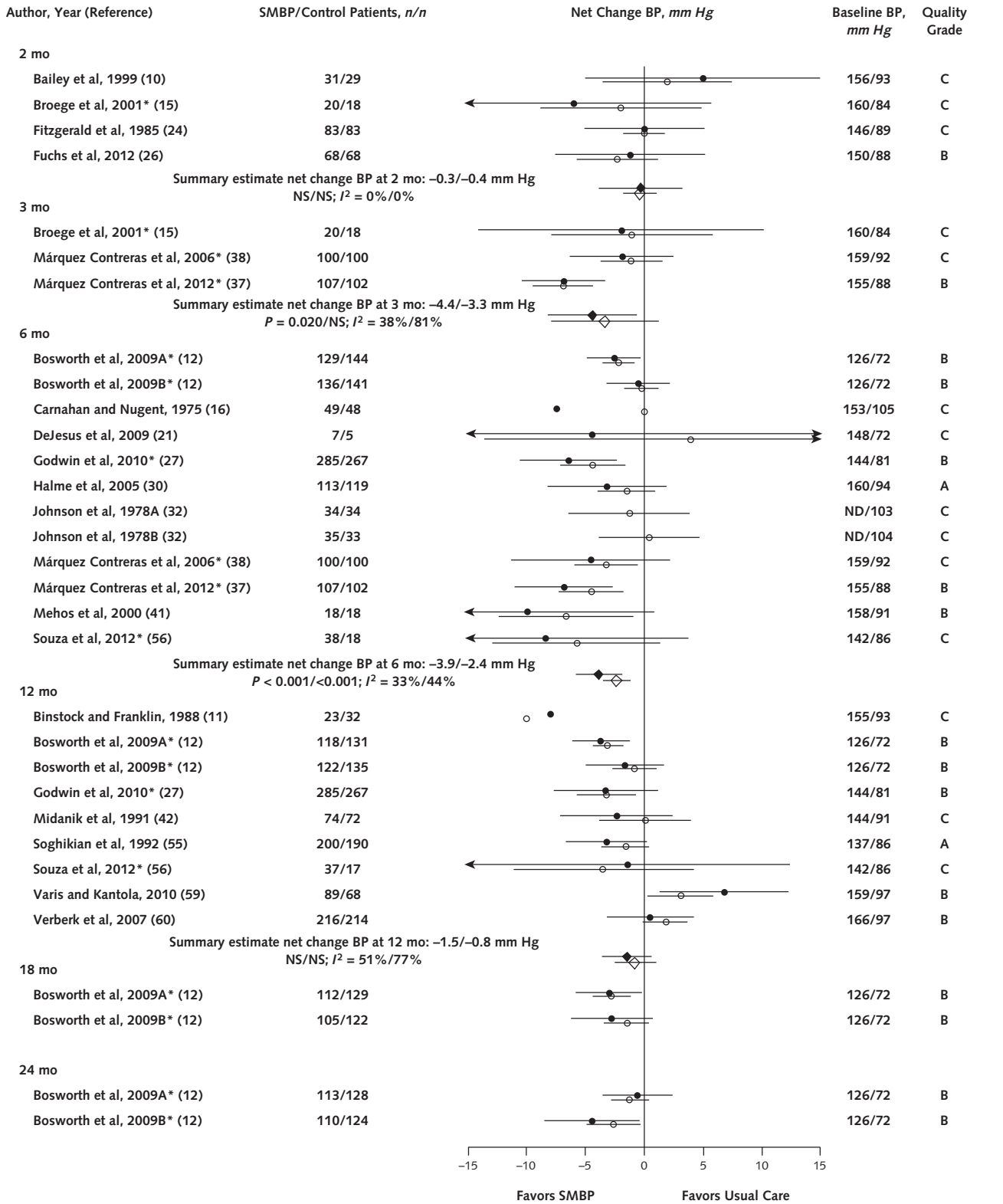
Thirteen trials studied SMBP monitoring with additional support versus SMBP monitoring without additional support (or with less intensive additional support). Groups differed in additional support, such as behavioral interventions or disease management by a nurse or pharmacist, medication management, educational interventions, electronic transmission of BP measurements, Web sites or training for patient–provider communication, telemonitoring, BP recording cards, BP and medication tracking tool, hypertension information leaflets, or home visits.

Eleven studies (11–14, 17, 18, 20, 29, 32, 36, 39) showed mixed results for continuous clinic BP from the additional or more intensive support; only 1 showed statistically significant benefit for systolic and diastolic BP (29) (**Figure 4**). Findings for categorical BP were similar (**Figure 2** in **Supplement 1**). One study evaluated 24-hour ambulatory BP (44) and found benefit from SMBP monitoring with telemonitoring for systolic BP but not for diastolic BP. Overall, the evidence is rated as low-strength and fails to support a difference between SMBP monitoring plus additional support versus SMBP monitoring with no additional support or with less intensive additional support in BP.

## Other Outcomes for All Comparisons

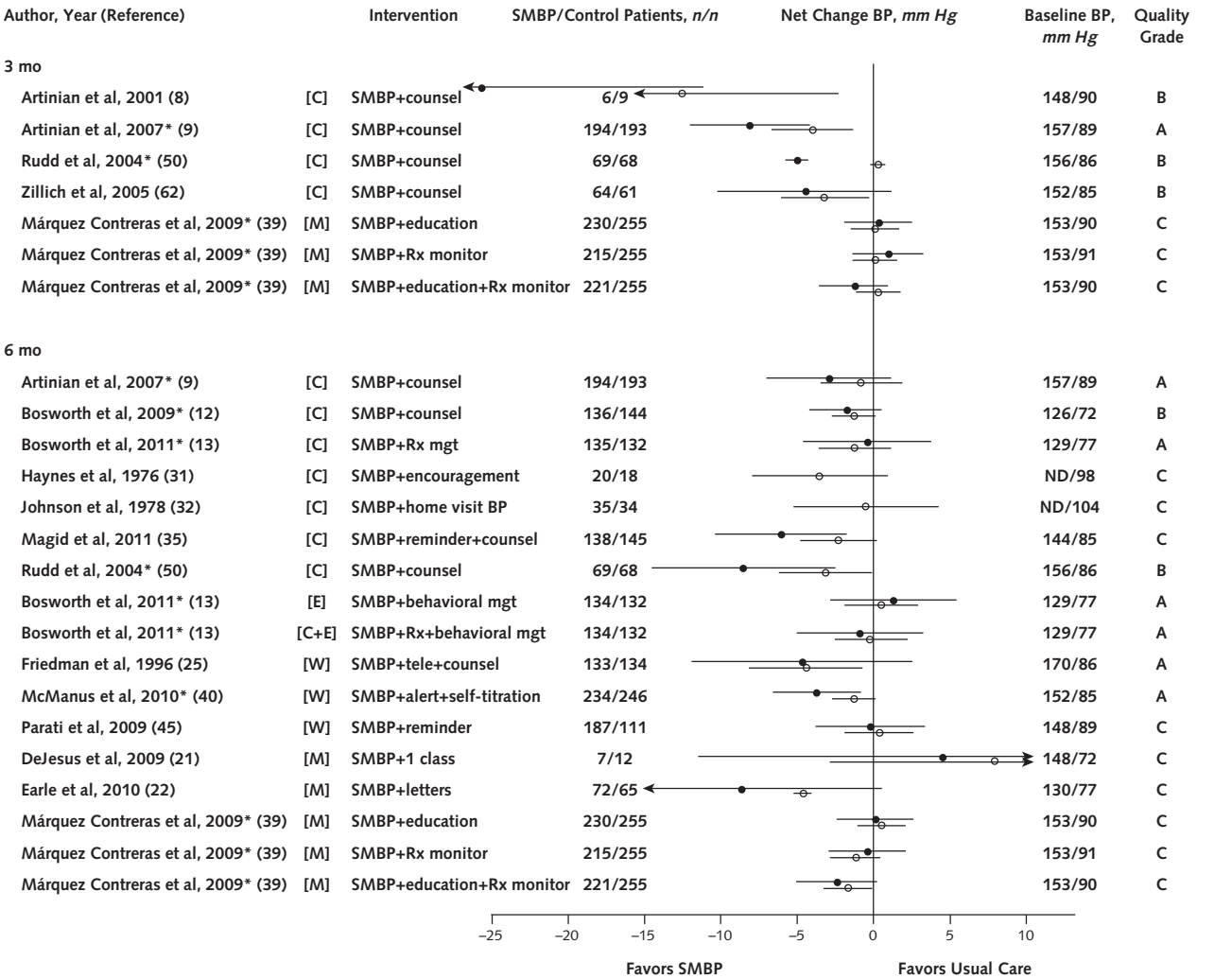
Thirty-four studies provided data for other (non-BP) outcomes across all comparisons. Only 1 provided data on clinical outcomes (51). The most commonly reported non-BP outcomes were related to medication use, quality of life, adherence, and health care encounters. These were generally not the primary study outcomes, and outcome definitions, methods for outcome assessment, and com-

*Figure 1.* **SMBP monitoring versus usual care for continuous clinic BP.**




Net change of systolic (*black circles*) and diastolic (*white circles*) BP, with separate meta-analyses and *P* values and $I^2$ estimates, at different follow-ups. BP = blood pressure; ND = no data; NS = not significant; SMBP = self-measured blood pressure.
* Study provided data at multiple time points.

*Figure 2.* **SMBP monitoring plus additional support versus usual care for continuous clinic BP at 3- and 6-month follow-up.**




Net change of systolic (*black circles*) and diastolic (*white circles*) BP at different follow-ups. See **Appendix Table 2** (available at www.annals.org) for full descriptions of letters in square brackets: C (counseling), E (education), W (Web-based), and M (miscellaneous). BP = blood pressure; counsel = counseling; mgt = management; monitor = monitoring; ND = no data; Rx = medication; SMBP = self-measured blood pressure; tele = telemedicine.
* Study provided data at multiple time points.

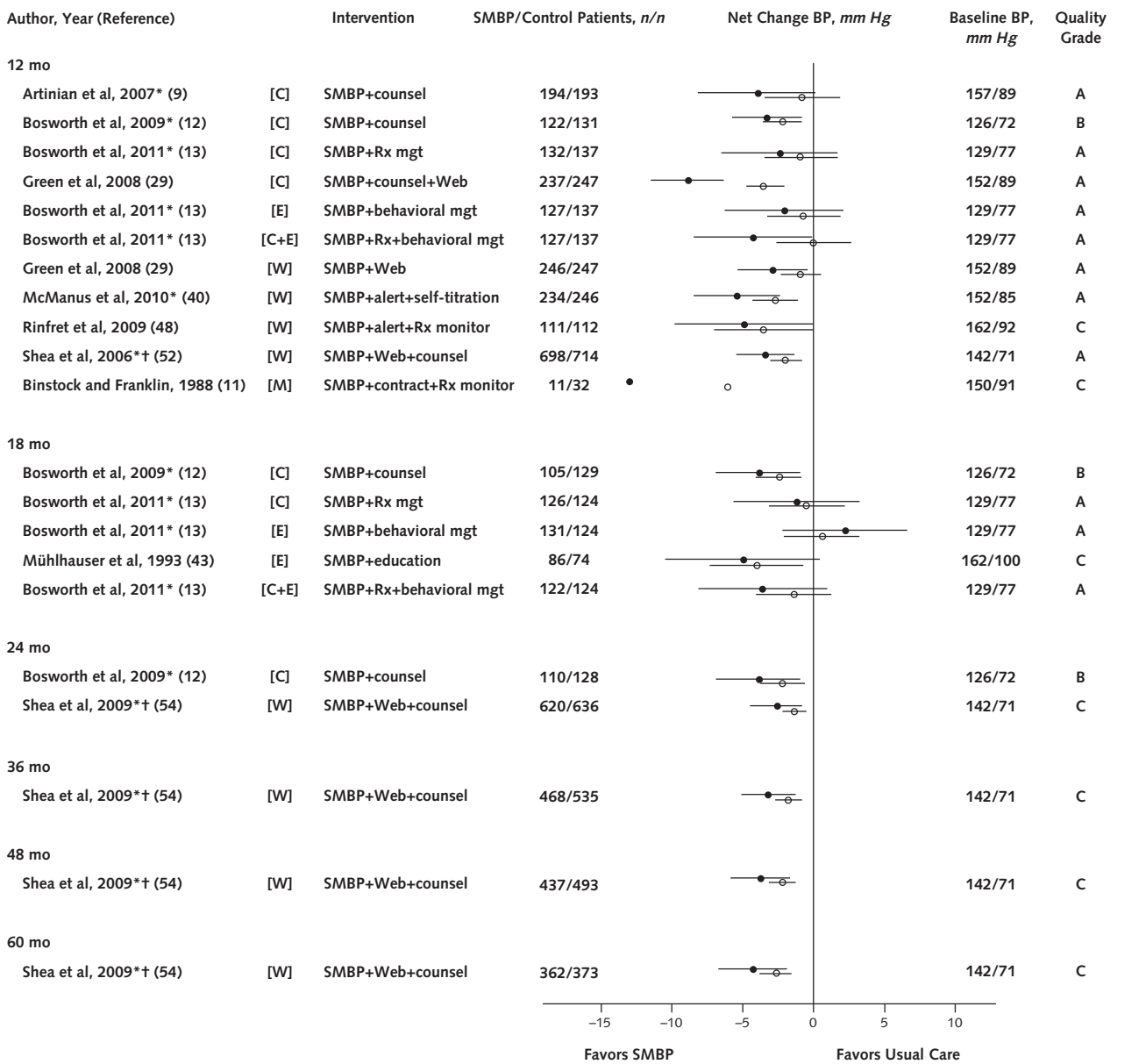
pleteness of ascertainment varied. Therefore, strength of evidence for these surrogate outcomes was low. Findings were inconsistent, although a few studies showed more medication changes and better adherence with SMBP monitoring. For quality of life, no difference was found. For health care encounters, findings were inconsistent.

## DISCUSSION

This review of 52 comparative studies on use of SMBP monitoring in adults with hypertension shows that for SMBP monitoring alone versus usual care, moderate-strength evidence supports a lower BP with SMBP monitoring at 6 months and possibly at 12 months. For SMBP monitoring plus additional support versus usual care, high-strength evidence supports a lower BP for up to 12 months. For SMBP monitoring plus additional support versus SMBP monitoring alone or with less intense additional support, low-strength evidence fails to support a difference for BP. The effect of SMBP monitoring on BP beyond 12 months and on clinical outcomes is uncertain. Evidence for other surrogate outcomes or health care encounters was low-strength and not conclusive. The findings of the review are applicable to adults with uncomplicated hypertension without recent acute illnesses who are willing and able to participate in SMBP monitoring at home.

Despite the ostensible similarity in research questions across studies, there was a large degree of variability in

*Figure 3.* **SMBP monitoring plus additional support versus usual care for continuous clinic BP at 12- to 60-month follow-up.**




Net change of systolic (*black circles*) and diastolic (*white circles*) BP at different follow-ups. See **Appendix Table 2** (available at www.annals.org) for full descriptions of letters in square brackets: C (counseling), E (education), W (Web-based), and M (miscellaneous). BP = blood pressure; counsel = counseling; mgt = management; monitor = monitoring; Rx = medication; SMBP = self-measured blood pressure.

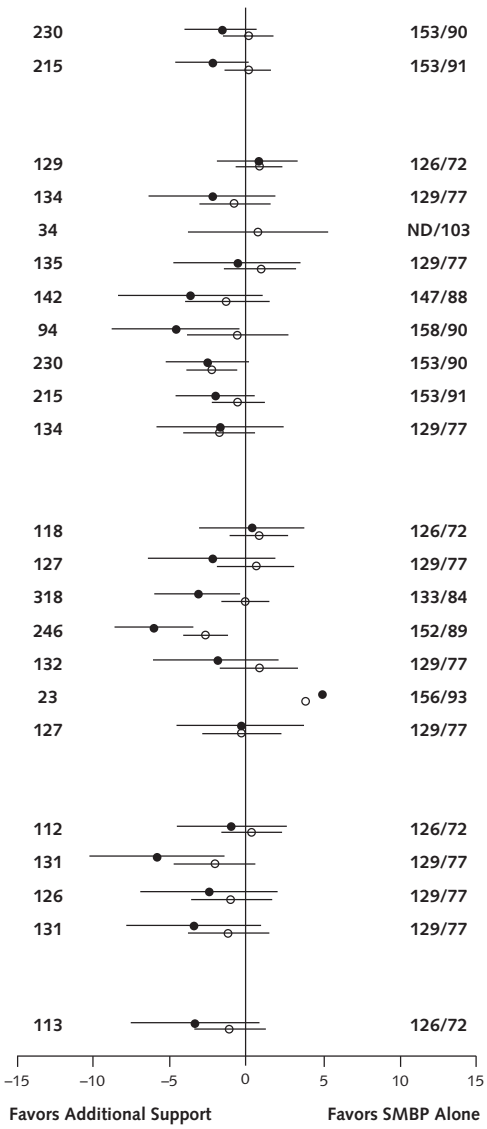
* Study provided data at multiple time points.

† References 52 and 54 are the same trial at different time points.

SMBP monitoring protocols, transmission of and response to BP data, and types of additional support. Additional support varied in the primary intents, ancillary equipments, educational materials and encounters, qualification and effort of personnel, and algorithms for medication adjustments. Despite overlap, we categorized the additional support interventions as being based predominantly on education, counseling, Web support, or other support. However, no 2 studies used the same method of additional support, and even the studies that used SMBP monitoring without additional support varied in their methods. This makes it impossible to draw firm conclusions about the potential effects of specific methods or particular components of additional support or their interactions with SMBP monitoring. Nevertheless, with the caveat that evidence from indirect comparisons is inferior to that from

*Figure 4.* **SMBP monitoring plus additional support versus a less intense SMBP monitoring intervention for continuous clinic BP.**

| Author, Year (Reference) | | Additional Support | SMBP + AS Patients, *n* | SMBP Alone Patients, *n* | Baseline BP, *mm Hg* | Quality Grade |
|---|---|---|---|---|---|---|
| **3 mo** | | | | | | |
| Márquez Contreras et al, 2009A* (39) | [M] | Rx monitor | 221 | 230 | 153/90 | C |
| Márquez Contreras et al, 2009B* (39) | [M] | Education | 221 | 215 | 153/91 | C |
| **6 mo** | | | | | | |
| Bosworth et al, 2009* (12) | [C] | Counsel | 136 | 129 | 126/72 | B |
| Bosworth et al, 2011A* (13) | [C] | Rx mgt | 134 | 134 | 129/77 | A |
| Johnson et al, 1978 (32) | [C] | Home visit BP | 35 | 34 | ND/103 | C |
| Bosworth et al, 2011B* (13) | [E] | Behavioral mgt | 134 | 135 | 129/77 | A |
| Carrasco et al, 2008 (17) | [W] | Web+counsel | 131 | 142 | 147/88 | B |
| Margolius et al, 2012 (36) | [M] | Home titration | 110 | 94 | 158/90 | A |
| Márquez Contreras et al, 2009A* (39) | [M] | Rx monitor | 221 | 230 | 153/90 | C |
| Márquez Contreras et al, 2009B* (39) | [M] | Education | 221 | 215 | 153/91 | C |
| Bosworth et al, 2011C* (13) | [C vs. E]† | Rx vs. behavioral mgt† | 135 | 134 | 129/77 | A† |
| **12 mo** | | | | | | |
| Bosworth et al, 2009* (12) | [C] | Counsel | 122 | 118 | 126/72 | B |
| Bosworth et al, 2011A* (13) | [C] | Rx mgt | 127 | 127 | 129/77 | A |
| Brennan et al, 2010 (14) | [C] | Counsel | 320 | 318 | 133/84 | B |
| Green et al, 2008 (29) | [C] | Counsel | 237 | 246 | 152/89 | A |
| Bosworth et al, 2011B* (13) | [E] | Behavioral mgt | 127 | 132 | 129/77 | A |
| Binstock and Franklin, 1988 (11) | [M] | Contract+Rx monitor | 11 | 23 | 156/93 | C |
| Bosworth et al, 2011C* (13) | [C vs. E]† | Rx vs. behavioral mgt† | 132 | 127 | 129/77 | A† |
| **18 mo** | | | | | | |
| Bosworth et al, 2009* (12) | [C] | Counsel | 105 | 112 | 126/72 | B |
| Bosworth et al, 2011A* (13) | [C] | Rx mgt | 122 | 131 | 129/77 | A |
| Bosworth et al, 2011B* (13) | [E] | Behavioral mgt | 122 | 126 | 129/77 | A |
| Bosworth et al, 2011C* (13) | [C vs. E]† | Rx vs. behavioral mgt† | 126 | 131 | 129/77 | A† |
| **24 mo** | | | | | | |
| Bosworth et al, 2009* (12) | [C] | Counsel | 110 | 113 | 126/72 | B |




Net change of systolic (*black circles*) and diastolic (*white circles*) BP. See **Appendix Table 2** (available at www.annals.org) for full descriptions of letters in square brackets: C (counseling), E (education), W (Web-based), and M (miscellaneous). AS = additional support; BP = blood pressure; counsel = counseling; mgt = management; monitor = monitoring; ND = no data; Rx = medication; SMBP = self-measured blood pressure.
* Study provided data at multiple time points.
† Comparison is SMBP monitoring plus medication management vs. SMBP monitoring plus behavioral management.

direct comparisons within trials, overall there is a suggestion that additional support is synergistic with SMBP monitoring to achieve BP control.

The observed magnitude of BP reduction by SMBP monitoring with or without additional support would be clinically relevant on a population level if it was sustained over time. For example, a decrease of 2 or 5 mm Hg in systolic BP in the population has been estimated to result in mortality reductions of 6% or 14% due to stroke, 4% or 9% due to chronic heart disease, and 3% or 7% due to all causes (1, 63). Beyond its effect on clinic BP, SMBP monitoring may be beneficial by allowing physicians to tailor treatment to a person's BP abnormality, thus avoiding overtreatment as well as undertreatment. Included studies recruited patients with controlled or uncontrolled hypertension but did not evaluate patients regarding their patterns of home and clinic BPs before inclusion. Further, studies differed in protocols for medication adjustment and

whether they were based on home or clinic BP levels and in the actual BP treatment target. Depending on the particular pattern between home and clinic BP in a given patient, the mix of patients in a study, and whether BP management was guided by home or clinic BP readings, SMBP monitoring may have resulted in opposing effects on medication management and clinic BP within and across studies. This is supported by the findings from Staessen and colleagues (64, 65) and Verberk and associates (60), which compared adjustments in BP medication to achieve the same BP target for either home or clinic BP and found less intensive drug treatment but also less clinic BP control in the groups managed on the basis of home BP. Other possible benefits of SMBP monitoring are to engage patients and facilitate adherence to lifestyle modification. Estimates for cost-effectiveness of SMBP monitoring depend on the time horizon and assumptions for long-term benefit. In the short term, there may be greater resource utilization to respond to and treat BP, as well as costs for additional support (66, 67).

The evidence base has several limitations. Many studies were quality C and were likely underpowered, even for BP outcomes. Duration of follow-up in most instances was less than 12 months. Data on clinical outcomes were lacking. Given the clinical heterogeneity stemming from the variation in the populations, interventions, outcomes, and time points examined, often only 1 or 2 studies were available for specific comparisons.

To put our findings in the context of the current literature, we searched MEDLINE in February 2013 for reviews on this topic published since 2010. Three systematic reviews were published, each including between 14 and 37 trials (68–70). In contrast to our review, these other reviews did not require a minimum follow-up of 2 months, and 2 also included studies in patients receiving long-term hemodialysis. All reviews excluded nonrandomized studies, which we allowed. All found a statistically significant reduction in BP with SMBP monitoring, with net differences ranging from −2.5 to −3.8 mm Hg for systolic BP and −1.5 to −1.9 mm Hg for diastolic BP. Two additional reviews focused on the trials that used telemonitoring with SMBP monitoring and found that this led to a greater reduction in office BP (−4.71 mm Hg and −5.2 mm Hg for systolic BP; −2.45 and −2.1 mm Hg for diastolic BP) (67, 71). One other review examined the effect of SMBP monitoring on medication adherence and found mixed results depending on the complexity of the additional support and the setting of primary care or hospital-based clinics (72). To our knowledge, ours is the most comprehensive review to date. It involves the most studies, including a large, recently published trial (13). It reviews BP effects over time, suggesting waning of the effect. Our comprehensive review of pertinent non-BP outcomes yielded only low-strength evidence. Our separation of comparisons into SMBP monitoring with or without additional support suggests that additional support and SMBP monitoring are synergistic.

In conclusion, SMBP monitoring lowers BP, but its sustainability and long-term clinical effectiveness remain uncertain. Future research is needed to determine the effect of SMBP monitoring on BP control beyond 12 months and long-term benefits of SMBP monitoring. Effects should be explored in persons stratified by patterns of home and clinic BPs and in subgroups (for example, older persons and those with cardiovascular and cerebrovascular disease, diabetes mellitus, and chronic kidney disease).

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## *Appendix Table 1.* Literature Search Strategy*

| Search Number | Searches |
|---|---|
| **SMBP monitoring** | |
| 1 | exp Blood Pressure Monitoring, Ambulatory/ |
| 2 | exp Blood Pressure Monitors/ |
| 3 | exp Blood Pressure/ |
| 4 | exp hypertension/ |
| 5 | exp Self Care/ |
| 6 | (3 or 4) and 5 |
| 7 | ((blood pressure or hypertens$) and self and (measure$ or monitor$ or care or manage$)).mp. |
| 8 | 1 or 2 or 6 or 7 |
| **Comparative studies** | |
| 9 | randomized controlled trial.pt. |
| 10 | controlled clinical trial.pt. |
| 11 | randomized controlled trials/ |
| 12 | Random Allocation/ |
| 13 | Double-blind Method/ |
| 14 | Single-Blind Method/ |
| 15 | clinical trial.pt. |
| 16 | Clinical Trials.mp. or exp Clinical Trials/ |
| 17 | (clinic$ adj25 trial$).tw. |
| 18 | ((singl$ or doubl$ or trebl$ or tripl$) adj (mask$ or blind$)).tw. |
| 19 | Placebos/ |
| 20 | placebo$.tw. |
| 21 | random$.tw. |
| 22 | trial$.tw. |
| 23 | (randomized control trial or clinical control trial).sd. |
| 24 | (latin adj square).tw. |
| 25 | Comparative Study.tw. or Comparative Study.pt. |
| 26 | exp Evaluation studies/ |
| 27 | Follow-Up Studies/ |
| 28 | Prospective Studies/ |
| 29 | (control$ or prospectiv$ or volunteer$).tw. |
| 30 | Cross-Over Studies/ |
| 31 | or/9-30 |
| **Cohorts** | |
| 32 | exp cohort studies/ or exp prospective studies/ or exp retrospective studies/ or exp epidemiologic studies/ or exp case-control studies/ |
| 33 | (cohort or retrospective or prospective or longitudinal or observational or follow-up or followup or registry).af. |
| 34 | case-control.af. or (case adj10 control).tw. |
| 35 | ep.fs. |
| 36 | 32 or 33 or 34 or 35 |
| **Limits** | |
| 37 | 8 and (31 or 36) |
| 38 | limit 37 to humans [Limit not valid in CDSR,CCTR; records were retained] |
| 39 | limit 38 to yr="1888 - 2000" |
| 40 | remove duplicates from 39 |
| 41 | limit 37 to yr="2001-2008" |
| 42 | remove duplicates from 41 |
| 43 | limit 37 to yr="2009-current" |
| 44 | remove duplicates from 43 |
| **Final** | |
| 45 | or/40, 42, 44 |
| **Added terms** | |
| 46 | (home adj20 blood pressure).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] |
| 47 | or/9-45 |
| 48 | 46 and 47 |
| 49 | (exp telemedicine/ or exp self-examination/) and (exp Blood pressure/ or exp Hypertension/) |
| 50 | 47 and 49 |
| 51 | 45 or 48 or 50 |

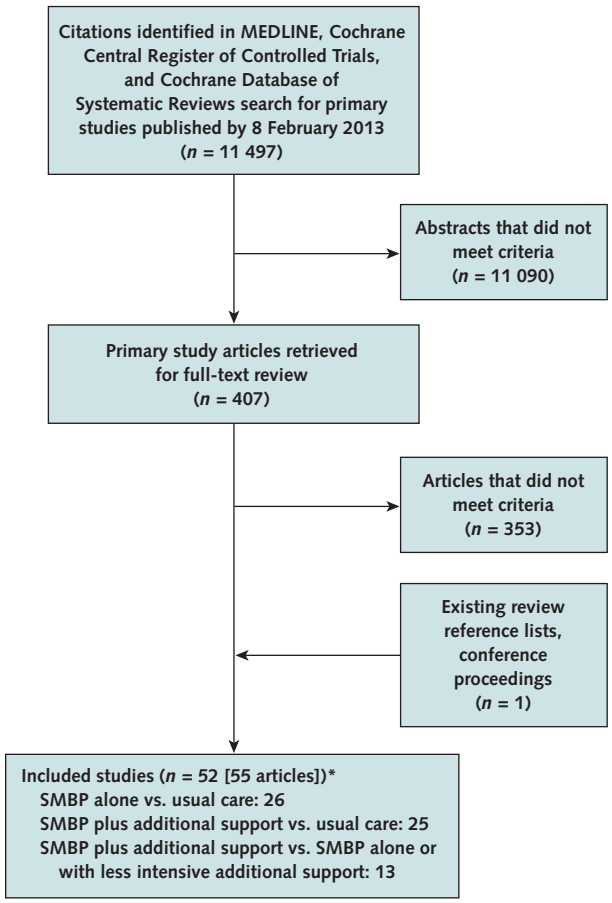
SMBP = self-measured blood pressure.
* Databases: Ovid MEDLINE, MEDLINE In-Process, Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews.

*Appendix Table 2.* **Post Hoc Categorization of Comparisons by Leading Type of Additional Support**

| Category | Definition of Additional Support | SMBP Monitoring Plus Additional Support vs. Usual Care | SMBP Monitoring Plus Additional Support vs. SMBP Monitoring Alone or SMBP Monitoring Plus Less Intense Additional Support |
|---|---|---|---|
| C | Face-to-face counseling or telecounseling with regular 1-on-1 encounters with study personnel (nurse, pharmacist, or others) on a regular basis during the intervention. During these encounters, there may be opportunities for education and disease management, or these encounters could simply be for checking BP alone. | Artinian et al, 2001 (8)<br>Artinian et al, 2007 (9)<br>Bosworth et al, 2009 (12)<br>Bosworth et al, 2011 (13)*<br>Earp et al, 1982 (23)<br>Green et al, 2008 (29)†<br>Haynes et al, 1976 (31)<br>Johnson et al, 1978 (32)<br>Magid et al, 2011 (35)<br>Rudd et al, 2004 (50)<br>Zillich et al, 2005 (62) | Bosworth et al, 2009 (12)<br>Bosworth et al, 2011 (13)*<br>Brennan et al, 2010 (14)<br>Cheltsova et al, 2010 (18)<br>Green et al, 2008 (29)†<br>Johnson et al, 1978 (32)<br>Margolius et al, 2012 (36) |
| E | Education offered in regular classes on hypertension during the study. No regular 1-on-1 contact with a professional was reported. The classes covered various topics, such as self-management and nondrug therapies (including behavioral and lifestyle modifications to nutrition and weight loss). | Bosworth et al, 2011 (13)*<br>Pierce et al, 1984 (47)<br>Gran, 1991 (28)<br>Mühlhauser et al, 1993 (43)<br>Sawicki et al, 1995 (51) | Bosworth et al, 2011 (13)*<br>Pierce et al, 1984 (47) |
| W | Web-based or telephonic tools with or without counseling support by a professional or preprogrammed computer. No regular 1-on-1 encounters or regular educational classes. | Friedman et al, 1996 (25)<br>Green et al, 2008 (29)†<br>McManus et al, 2010 (40)<br>Parati et al, 2009 (45)<br>Park et al, 2009 (46)<br>Rinfret et al, 2009 (48)<br>Shea et al, 2006 (52) | Carrasco et al, 2008 (17)<br>Neumann et al, 2011 (44) |
| M | Miscellaneous types of additional support: A single class offered by a diabetes educator and instruction by a nurse on SMBP monitoring; a leaflet with educational materials on hypertension or a card for recording BP and pill counts; a contract on a behavior related to hypertension and calendar pill packs; or letter to patients and providers on treatment recommendations | Binstock and Franklin, 1988 (11)‡<br>DeJesus et al, 2009 (21)<br>Earle et al, 2010 (22)<br>Márquez Contreras et al, 2009 (39) | Binstock and Franklin, 1988 (11)‡<br>Dawes et al, 2010 (20)<br>Márquez Contreras et al, 2009 (39) |

BP = blood pressure; SMBP = self-measured blood pressure.
* Provides both category C and E comparisons.
† Provides both category C and W comparisons.
‡ All groups, including the control group, also participated in an educational program.

*Appendix Figure.* **Summary of evidence search and selection.**




SMBP = self-measured blood pressure.
* Several studies include multiple comparisons of interest.

## *Appendix Table 3.* Description of Included Studies*

| Author, Year (Reference) | SMBP Monitoring vs. Usual Care | SMBP Monitoring + AS vs. Usual Care | SMBP Monitoring + AS vs. SMBP Monitoring ± AS | Total Patients, *n* | Intervention | Duration† | Quality Grade |
|---|---|---|---|---|---|---|---|
| Artinian et al, 2001 (8) | | X | | 15 | SMBP monitoring + counseling<br>Usual care | 3 mo | B |
| Artinian et al, 2007 (9) | | X | | 336 | SMBP monitoring + telecounseling<br>Enhanced usual care | 12 mo | A |
| Bailey et al, 1999 (10) | X | | | 60 | SMBP monitoring<br>Usual care | 8 wk | C |
| Binstock and Franklin, 1988 (11) | X | X | X | 55 | SMBP monitoring + contract + prescription monitoring + education<br>SMBP monitoring + education<br>Education | 12 mo | C |
| Bosworth et al, 2009 (12) | X | X | X | 506 | SMBP monitoring + counseling<br>SMBP monitoring<br>Counseling<br>Usual care | 12 mo | B |
| Bosworth et al, 2011 (13) | | X | X | 503 | SMBP monitoring + medication management + behavioral management<br>SMBP monitoring + medication management<br>SMBP monitoring + behavioral management<br>Usual care | 18 mo | A |
| Brennan et al, 2010 (14) | | | X | 638 | SMBP monitoring + counseling<br>SMBP monitoring | 13 mo (mean) | B |
| Broege et al, 2001 (15) | X | | | 38 | SMBP monitoring<br>Nurse BP | 3 mo | C |
| Carnahan and Nugent, 1975 (16) | X | | | 97 | SMBP monitoring<br>Usual care | 6 mo | C |
| Carrasco et al, 2008 (17) | | | X | 273 | SMBP monitoring + telemedicine + counseling<br>SMBP monitoring | 6 mo | B |
| Cheltsova et al, 2010 (18) | | | X | 86 | SMBP monitoring + counsel<br>SMBP monitoring | 6 mo | Abstract |
| Dalfó i Baqué et al, 2005 (19) | X | | | 1325 | SMBP monitoring<br>Usual care | 6 mo | C |
| Dawes et al, 2010 (20) | | | X | 109 | SMBP monitoring + education + prescription monitoring<br>SMBP monitoring + education | 12 wk | C |
| DeJesus et al, 2009 (21) | X | X | | 36 | SMBP monitoring + 1 class<br>1 class<br>Usual care | 6 mo | C |
| Earle et al, 2010 (22) | | X | | 137 | SMBP monitoring + letters<br>Usual care | 6 mo | C |
| Earp et al, 1982 (23) | | X | | 93 | SMBP monitoring + counseling<br>Counseling<br>Usual care | 24 mo | C |
| Fitzgerald et al, 1985 (24) | X | | | 166 | SMBP monitoring<br>Clinic BP | 9 wk | C |
| Friedman et al, 1996 (25) | | X | | 267 | SMBP monitoring + telecounseling<br>Usual care | 6 mo | A |
| Fuchs et al, 2012 (26) | X | | | | SMBP monitoring<br>Usual care | 8 wk | B |
| Godwin et al, 2010 (27) | X | | | 552 | SMBP monitoring<br>Usual care | 12 mo | B |
| Gran, 1991 (28) | | X | | 204 | SMBP monitoring + lifestyle interventions<br>Usual care | 24 mo | C |
| Green et al, 2008 (29) | | X | X | 730 | SMBP monitoring + counseling + Web training<br>SMBP monitoring + Web training<br>Usual care | 12 mo | A |
| Halme et al, 2005 (30) | X | | | 232 | SMBP monitoring<br>Usual care | 6 mo | A |
| Haynes et al, 1976 (31) | | X | | 38 | SMBP monitoring + encouragement<br>Usual care | 6 mo | C |
| Johnson et al, 1978 (32) | X | X | X | 103 | SMBP monitoring + home visit BP<br>SMBP monitoring<br>Home visit BP<br>Usual care | 6 mo | C |

*Continued on following page*

*Appendix Table 3*—**Continued**

| Author, Year (Reference) | SMBP Monitoring vs. Usual Care | SMBP Monitoring + AS vs. Usual Care | SMBP Monitoring + AS vs. SMBP Monitoring ± AS | Total Patients, *n* | Intervention | Duration† | Quality Grade |
|---|---|---|---|---|---|---|---|
| Madsen et al, 2008 (34)‡ | X | | | 236 | SMBP monitoring<br>Usual care | 6 mo | A |
| Magid et al, 2011 (35) | | X | | 283 | SMBP monitoring + telecounseling<br>Usual care | 6 mo | C |
| Margolius et al, 2012 (36) | | | X | 237 | SMBP monitoring + counseling + home titration<br>SMBP monitoring + counseling | 6 mo | B |
| Márquez Contreras et al, 2006 (38) | X | | | 200 | SMBP monitoring<br>Usual care | 6 mo | C |
| Márquez Contreras et al, 2009 (39) | | X | X | 921 | SMBP monitoring + education + prescription monitoring<br>SMBP monitoring + prescription monitoring<br>SMBP monitoring + education<br>Usual care | 6 mo | C |
| Márquez Contreras et al, 2012 (37) | X | | | 209 | SMBP monitoring<br>Usual care | 6 mo | B |
| McManus et al, 2010 (40) | | X | | 480 | SMBP monitoring + alert + self-titration<br>Usual care | 12 mo | A |
| Mehos et al, 2000 (41) | X | | | 36 | SMBP monitoring<br>Usual care | 6 mo | C |
| Midanik et al, 1991 (42) | X | | | 146 | SMBP monitoring<br>Usual care | 12 mo | C |
| Mühlhauser et al, 1993 (43) | | X | | 160 | SMBP + education<br>Usual care | 18 mo | C |
| Neumann et al, 2011 (44) | | | X | 57 | SMBP monitoring + telemonitoring<br>SMBP monitoring | 3 mo | C |
| Parati et al, 2009 (45) | | X | | 298 | SMBP monitoring + reminder<br>Usual care | 6 mo | C |
| Park et al, 2009 (46) | | X | | 49 | SMBP monitoring + Web + counseling<br>Usual care | 2 mo | B |
| Pierce et al, 1984 (47) | X | X | X | 55 | SMBP monitoring + education<br>SMBP monitoring<br>Education | 6 mo | C |
| Rinfret et al, 2009 (48) | | X | | 223 | SMBP monitoring + alert + prescription monitoring<br>Usual care | 12 mo | C |
| Rogers et al, 2001 (49) | X | | | 121 | SMBP monitoring<br>Usual care | 11 wk (median) | A |
| Rudd et al, 2004 (50) | | X | | 137 | SMBP monitoring + counseling<br>Usual care | 6 mo | B |
| Sawicki et al, 1995 (51) | | X | | 59 | SMBP monitoring + education + self-titration<br>Usual care | 60 mo | C |
| Shea et al, 2006 (52)§ | | X | | 1406 | SMBP monitoring + Web + counseling<br>Usual care | 12 mo | A |
| Soghikian et al, 1992 (55) | X | | | 390 | SMBP monitoring<br>Usual care | 12 mo | A |
| Souza et al, 2012 (56) | X | | | 57 | SMBP monitoring<br>Usual care | 12 mo | C |
| Stahl et al, 1984 (57) | X | | | 274 | SMBP monitoring<br>Usual care | 7–12 mo | C |
| van Onzenoort et al, 2010 (58) | X | | | 228 | SMBP monitoring<br>Usual care | 12 mo | B |
| Varis and Kantola, 2010 (59) | X | | | 157 | SMBP monitoring<br>Usual care | 12 mo | B |
| Verberk et al, 2007 (60) | X | | | 430 | SMBP monitoring<br>Usual care | 12 mo | B |
| Zarnke et al, 1997 (61) | X | | | 30 | SMBP monitoring<br>Usual care | 8 wk | B |
| Zillich et al, 2005 (62) | | X | | 125 | SMBP monitoring + counseling<br>Pharmacist BP | 3 mo | B |

AS = additional support; BP = blood pressure; SMBP = self-measured blood pressure.
* For additional information on included studies, see **Supplement 2**.
† Duration is for the longest BP outcome with <20% loss of follow-up.
‡ Also includes Madsen and colleagues (33).
§ Also includes Shea and colleagues (53, 54).

## *Appendix Table 4.* Summary of Findings of Comparative Studies on SMBP Monitoring

| Comparison | Strength of Evidence | Summary |
|---|---|---|
| **SMBP monitoring alone vs. usual care** | – | 26 studies with 5651 patients (4 quality A, 8 quality B, 14 quality C). |
| Clinical outcomes | Insufficient | No study reported clinical outcomes. |
| BP | Moderate | 24 studies (4 quality A, 6 quality B, 14 quality C).<br>13 studies reported BP control, 19 reported clinic BP, 6 reported 24-h ambulatory BP, 6 reported awake (day) ambulatory BP, and 5 reported asleep (night) ambulatory BP.<br>Consistent findings from the higher-quality studies show an improvement in BP using SMBP monitoring vs. usual care at 6 mo, which is no longer statistically significant at 12 mo. |
| Other surrogate outcomes | Low | 3 studies reported quality-of-life outcomes (2 quality B, 1 quality C). Studies found no difference in quality of life.<br>8 studies reported outcomes related to number of medications and dosage (1 quality A, 3 quality B, 4 quality C): 6 found no statistically significant difference in medication outcomes, 1 found more patients adhering to medications with SMBP monitoring, and 1 found fewer prescribed daily medication doses with SMBP monitoring.<br>8 studies reported medication adherence (3 quality B, 5 quality C): 3 reported statistically significantly better adherence with SMBP monitoring, and 5 found no difference.<br>A single study each reported patient satisfaction (quality C) and left ventricular mass index (quality B). No differences were found.<br>The evidence is weak or insufficient for all other surrogate outcomes. |
| Health care encounters | Low | 5 studies reported health care encounters, such as office visits, other encounters, or medical procedures received for hypertension (1 quality A, 4 quality C). The studies reported no difference or conflicting findings. |
| **SMBP monitoring + additional support vs. usual care** | – | 25 studies with 6187 patients (6 quality A, 5 quality B, 14 quality C).<br>Additional support varied across studies in the primary intents, technical equipment and interface, educational materials, personnel, and algorithms for medication adjustments. |
| Clinical outcomes | Insufficient | 1 trial (quality C) found lower mortality and lower composite mortality and ESRD with SMBP monitoring plus additional support. ESRD alone was not statistically significantly different. |
| BP | High | 25 studies (6 quality A, 5 quality B, 14 quality C); 13 studies reported BP control, 23 reported clinic BP, 2 reported ambulatory BP.<br>Consistent findings from the high-quality studies show an improvement in BP at 12 mo.<br>Beyond 12 mo, there was variability about statistical significance of findings. |
| Other surrogate outcomes | Low | 3 studies (2 quality A, 1 quality C) reported quality-of-life outcomes or anxiety. These studies found no difference.<br>12 studies reported outcomes related to medication number and dosage (3 quality A, 2 quality B, 7 quality C). Studies were divided between finding no difference in medication outcomes and finding either an increase or a decrease in medications in patients using SMBP monitoring with additional support.<br>7 studies reported on medication adherence (1 quality A, 2 quality B, 4 quality C). One half of the studies found no difference in medication adherence and one half found greater adherence with SMBP monitoring plus additional support; 1 study (quality C) found no difference in adverse drug reactions across 3 groups with different forms of additional support.<br>The evidence is weak or insufficient for all other surrogate outcomes. |
| Health care encounters | Low | 8 studies reported health care encounters, including number of physician (or physician and nurse) visits and phone or Web encounters (8 quality C).<br>6 studies found no difference in number of visits, 1 found fewer visits, and 1 found more visits with SMBP monitoring plus additional support.<br>1 study found mixed results with respect to phone and Web encounters. |
| **SMBP monitoring + additional support vs. SMBP monitoring alone or SMBP monitoring with less intense additional support** | – | 13 studies with 3548 patients (4 quality A, 2 quality B, and 6 quality C; 1 ungraded conference abstract). |
| Clinical outcomes | Insufficient | No study reported clinical outcomes. |
| BP | Low | 13 studies reported BP outcomes (4 quality A, 2 quality B, 6 quality C, 1 ungraded abstract). 9 studies reported BP control, 11 studies reported clinic BP, 1 study reported 24-h ambulatory BP. Findings were mixed, and most studies did not find a statistically significant difference. |
| Other surrogate outcomes | Low | 2 trials reported quality of life or anxiety (1 quality A, 1 quality B). Neither trial found differences.<br>6 trials reported outcomes related to medication number and dosage (2 quality A, 1 quality B, 3 quality C); 4 trials found no difference; 1 trial found somewhat greater mean number of medication drug classes with SMBP monitoring plus additional support.<br>3 trials (quality C) reported medication adherence. No trial found a statistically significant difference in medication adherence.<br>1 trial (quality C) found no difference in adverse drug reactions; 1 trial (quality A) found no difference for consumer satisfaction.<br>The evidence is weak or insufficient for all other surrogate outcomes. |
| Health care encounters | Low | 6 studies reported health care encounters, such as outpatient primary care visits, hospital admissions, inpatient or urgent care/emergency use, and cardiac or other specialist visits (1 quality A, 5 quality C). No study found a difference in the numbers of outpatient visits or hospital admissions; 1 found more electronic and telephonic communication with more intense additional support. |

BP = blood pressure; ESRD = end-stage renal disease; SMBP = self-measured blood pressure.