

# ***Evidence Synthesis***

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# **Screening for Hypertensive Disorders of Pregnancy: An Evidence Update for the U.S. Preventive Services Task Force**

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## Structured Abstract

**Objective:** We conducted this comparative effectiveness review to support the U.S. Preventive Services Task Force in updating its recommendation on Preeclampsia Screening. The review aim was to compare different approaches to screening for hypertensive disorders of pregnancy including preeclampsia.

**Data Sources:** We performed comprehensive searches of MEDLINE, PubMed (publisher-supplied only), Embase, and the Cochrane Collaboration Registry of Controlled Trials for studies published between January 1<sup>st</sup>, 2014, and January 4<sup>th</sup>, 2022. A research librarian developed and executed the search strategy. Studies included in the prior review to support the 2015 recommendation and studies referenced in recently published reviews were also considered for inclusion.

**Study Selection:** We reviewed 6,316 abstracts and assessed 82 full-text articles against predefined inclusion and exclusion criteria. Studies considered for inclusion were randomized controlled trials and non-randomized studies of interventions (NRSI) comparing screening interventions conducted with pregnant and postpartum people, including those at increased risk for hypertensive disorders of pregnancy. Interventions and comparisons of interest included: blood pressure measurement setting (office or home), interval, frequency, or timing; proteinuria assessment setting, interval, or sequence of testing; and personalization of screening based on risk assessment.

**Data Analysis:** We conducted dual independent critical appraisal of all included studies and extracted all important study details and outcomes from fair- and good-quality studies. We narratively synthesized results by key question and type of screening intervention. We graded the overall strength of evidence as high, moderate, low, or insufficient based on criteria adapted from the Evidence-based Practice Center program.

**Results:** Five fair-quality randomized controlled trials and one fair-quality NRSI with a historical control were included. Three types of screening strategies were compared with usual screening programs: screening programs that incorporated self-measurement of blood pressure (2 studies, N= 2,521), a reduced prenatal visit schedule for people at low risk for complications of hypertensive disorders of pregnancy (3 studies, N= 5,203), and protein urine screening provided only when indicated rather than at every prenatal visit (1 study, N = 2,441). No studies were designed to test screening interventions focused on populations with the highest risks for hypertensive disorders of pregnancy and adverse pregnancy-related health outcomes.

One trial (N = 2,441) incorporated home blood pressure measurement into prenatal care and reported health outcomes. Similar proportions of maternal complications related to hypertensive disorders of pregnancy were seen in the home measurement group (15/1209; 1.2%) as in the usual care group (19/1209; 1.6%). The confidence interval for the relative risk spanned null (RR 0.79 [95% CI, 0.40 to 1.55]). Similar proportions of intrauterine growth restriction occurred in the intervention group (104/1249, 8.3%) compared with the control group (87/1235, 7.0%), and the confidence interval again spanned null (adjusted RR 1.15 [95% CI, 0.87 to 1.53]). The trial also did not report a difference in the timing of detection of high blood pressure. Increased

anxiety, a potential harm of home blood pressure measurement, was assessed in two trials and was not associated with the intervention.

Three trials published in 1996 and 1997 compared reduced prenatal visit schedules, which result in fewer antenatal blood pressure assessments, to usual care in populations at low risk for complications. Although the power to detect differences was limited for most outcomes, overall having fewer prenatal visits was not associated with better or worse pregnancy outcomes based on two trials. A large US trial (N= 2,328) including mostly White participants (81%) and a similarly sized UK trial (N= 2,794) where approximately one-third of participants belonged to an “ethnic minority” reported no evidence of differences in preeclampsia diagnoses (RR 0.94 [95% CI, 0.78 to 1.14] and RR 0.85 [95% CI, 0.35 to 2.04], respectively) or in maternal or perinatal health outcomes associated with a reduced visit schedule, although many of the outcomes were uncommon, which limited precision and the ability to rule out differences in serious outcomes. A small US trial (N = 81) was very underpowered for assessing differences between groups for serious health outcomes; few harms outcomes were reported. The UK trial and the small US trial assessed rates of anxiety or depression during and after pregnancy but did not find differences associated with the visit schedule.

A fair-quality non-randomized study with a historical control (N = 2,441) evaluated the effect of implementing indicated instead of routine urine screening in a setting predominantly serving Hispanic/Latino people with public health insurance reported. Indicated urine screening was associated with increased risk of preterm birth compared to routine screening (RR 0.64 [95% CI, 0.45 to 0.90]), and diagnoses of hypertensive disorders of pregnancy did not differ following implementation.

**Limitations:** There is very little evidence available to assess potential changes to clinical screening practices that could improve clinical outcomes related to hypertensive disorders of pregnancy. Only one fair-quality randomized study provided evidence on the effects of incorporating home-based blood pressure measurement to screen for hypertensive disorders of pregnancy on patient health outcomes. The included studies of reduced visit schedules provide potentially confounded tests of the effects of fewer office-based blood pressure measurements over the course of pregnancy, as a change in frequency of other tests and counseling received during visits could also influence the results. The evidence on an indicated urine screening strategy is very limited given the risks of bias inherent to historically controlled studies; reported findings may be due to factors other than the screening program. Black and American Indian/Alaska Native people, who experience the highest risks for adverse pregnancy-related health outcomes, were very underrepresented in the included studies.

**Conclusions:** Screening for hypertensive disorders of pregnancy with standard of care office-based blood pressure measurement can identify individuals requiring further surveillance and evidence-based clinical management to decrease risks for related adverse pregnancy outcomes. Research is needed to develop and strengthen clinical screening and management, possibly incorporating telehealth, home-based blood pressure measurement, and postpartum screening. Addressing troubling and persistent health inequities related to hypertensive disorders of pregnancy among specific populations in the US – especially Black and American Indian/Alaska

Native people – will require interventions at multiple levels, including policies, health systems, and clinical practices.

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# Chapter 1. Introduction

## Condition Definition

Hypertensive disorders of pregnancy include gestational hypertension; preeclampsia-eclampsia; and chronic hypertension with superimposed preeclampsia. Chronic (or preexisting) hypertension is diagnosed prior to pregnancy or before 20 weeks of gestation. Gestational hypertension and preeclampsia involve new-onset hypertension after the 20<sup>th</sup> week of gestation in a person with previously normal blood pressure.<sup>1,2</sup>

The diagnosis of preeclampsia requires the presence of hypertension accompanied by proteinuria or any of the following signs or symptoms: thrombocytopenia; impaired liver function as indicated by elevated blood concentrations of liver enzymes and severe persistent right upper quadrant or epigastric pain unresponsive to medication; renal insufficiency; pulmonary edema; new-onset headache unresponsive to medication; or visual disturbances.<sup>1</sup> The presence of any of these systemic signs or symptoms, or of severe hypertension (systolic blood pressure  $\geq$  160mmHg or diastolic blood pressure  $\geq$  110mmHg) are indications of preeclampsia with severe features. Eclampsia is the onset of seizures among individuals with preeclampsia and without a prior seizure disorder such as epilepsy. Gestational hypertension is defined as the new onset of hypertension after the 20<sup>th</sup> week of gestation without proteinuria or any of the additional signs and symptoms that define preeclampsia/eclampsia. HELLP syndrome is a severe form of preeclampsia that is diagnosed based on a constellation of laboratory findings (hemolysis, elevated liver enzymes, and low platelet count).<sup>1</sup>

## Prevalence and Burden

Globally, the United States stands out as having rates of maternal mortality two to ten times higher than other very-high development index countries (20.1 per 100,000 live births in the United States in 2019).<sup>3</sup> Hypertensive disorders of pregnancy are among the leading causes of pregnancy-related death (death while pregnancy or within one year of the end of pregnancy).<sup>4</sup> Data from the Center for Disease Control and Prevention indicate that the rate of hypertensive disorders of pregnancy in the United States has been steadily increasing over the last several decades, from approximately 500 cases per 10,000 deliveries in 1993 to 1021 cases per 10,000 deliveries in 2016 to 2017.<sup>5</sup> A population-based analysis of United States found that over the past four decades advancing maternal age and the increasing prevalence of chronic hypertension and higher body mass index (BMI) have contributed to these increasing trends.<sup>6</sup> From 2014-2017, hypertensive disorders of pregnancy, including preeclampsia, were responsible for 6.8 percent of pregnancy-related deaths in the United States.<sup>4</sup> A majority of deaths attributed to hypertensive disorders of pregnancy occur in the six weeks following delivery (44% and 21% during 1-6 and 7-42 days after delivery, respectively).<sup>7</sup> Severe morbidity from hypertensive disorders of pregnancy also occurs and contributes to the burden of disease.<sup>8-11</sup> Hypertensive disorders of pregnancy contribute to fetal growth restriction through impeding blood flow to the fetus.<sup>12</sup> Finally, because there is no treatment for preeclampsia and it resolves only after delivery of the placenta, the condition is a leading cause of medically induced preterm birth and low birth



weight. It has been estimated that preeclampsia contributes to 6 percent of all preterm births and 19 percent of medically indicated preterm births.<sup>13</sup>

Inequities in hypertensive disorders of pregnancy and related morbidity and mortality for Black individuals are well documented and persistent.<sup>14, 15</sup> In the United States, the maternal mortality rate (maternal deaths during and up to 42 days postpartum) is highest among Black people (44.0 per 100,000 live births in 2019, which was 2.5 times higher than among White people: 17.9 per 100,000 live births in 2019).<sup>3</sup> Other estimates based on vital statistics data have estimated that the maternal mortality rate for non-Hispanic Black people is 3.55 times that of White women. Hypertensive disorders of pregnancy account for a larger proportion of pregnancy-related mortality and serious morbidity among Black populations than White populations.<sup>16-21</sup> According to national estimates, fewer than half of White people with preeclampsia are diagnosed with cases having severe features, whereas nearly two-thirds of cases among Black people develop severe disease features.<sup>16, 19</sup> These differences in severity contribute to higher overall maternal mortality rates and greater contribution of preeclampsia/eclampsia to maternal mortality observed in Black populations.<sup>21, 22</sup> In 2016 to 2017 eclampsia and preeclampsia were the leading cause of maternal death among Black people, and the second leading cause of maternal mortality among White people. The risk of dying from eclampsia and preeclampsia was about five times greater for Black (3.93 per 100,000 live births) than White individuals (0.78 per 100,000 live births).<sup>21</sup>

While the risks for hypertensive disorders of pregnancy and related complications are clearly greatest for Black people in the United States, limited public health surveillance restricts our ability to identify the extent to which other racial or ethnic groups (particularly for American Indian/Alaska Native [AI/AN] people) are also at heightened risk.<sup>21</sup> Pregnancy-related mortality among AI/AN people is also elevated compared to White people (29.7 compared to 12.7 per 100,000 live births in 2007-2016), with hypertensive disorders of pregnancy a leading cause of pregnancy-related mortality, accounting for 12.8 percent of pregnancy-related deaths.<sup>16</sup> Among a retrospective review of cases deliveries from 2013 to 2017 at one medical center, AI/AN individuals had significantly higher severe maternal morbidity rates compared with other racial/ethnic groups (11.7% vs. 3.9% for White individuals).<sup>8</sup> Limited public health data, and lack of information about specific populations of this diverse group, have been noted. A recent scoping review highlighted factors such as hemorrhage, cardiomyopathy, and hypertensive disorders of pregnancy that may contribute to high pregnancy-related mortality among AI/AN individuals, as well as the need for further research to understand root causes.<sup>23</sup>

Data for other racial and ethnic groups are mixed, with lower incidence of hypertensive disorders of pregnancy and better pregnancy outcomes reported among Asian and Hispanic/Latino people than White people in some national estimates.<sup>16, 19, 20, 24, 25</sup> The diversity of backgrounds collapsed within these broad groupings, and sparse data for groups with smaller population numbers, likely conceal a more complex picture. Asian and Hispanic/Latino individuals usually have the lowest rates of hypertensive disorders of pregnancy in national data reports, but when data with more detailed information about race and ethnicity are disaggregated, risk for hypertensive disorders of pregnancy varies considerably among subgroups within these broad categories, defined by geography, ethnic background, and immigration status. For example,

South Asian and Filipino people have higher risks for hypertensive disorders of pregnancy than Asian people overall.<sup>26</sup>

Elevated risks of certain adverse outcomes related to hypertensive disorders of pregnancy also vary by race and ethnicity. Billing data from the Healthcare Cost and Utilization Project's National Inpatient Sample from 1998 to 2014 show that among individuals with hypertensive disorders of pregnancy, the risk of stroke in pregnancy was highest for Asian/Pacific Islander people and elevated for Hispanic/Latino and Black people compared with White people.<sup>27</sup> A separate analysis of the National Inpatient Sample for the years 2012 to 2014 found increased risk for morbidity related to preeclampsia for all other racial and ethnic groups compared with White individuals.<sup>18</sup> Eclampsia is a rare but serious complication of pregnancy that contributes to maternal mortality and also reflects underlying inequities in health. Nationwide data from US births (1989-2018) show that incidence of eclampsia is highest among Black people (4.4 per 1000 births) and lower among other racial and ethnic groups, including Hispanic/Latino people (2.1 per 1000).<sup>25</sup> A study using birth data from California, however, found that eclampsia risk was elevated for Hispanic/Latino people relative to White people.<sup>20</sup>

## Etiology and Natural History

The etiology of hypertensive disorders of pregnancy is complex and the likelihood of developing such conditions may be influenced by maternal genetic, environmental, and immunologic factors.<sup>2, 28-31</sup> Hypertensive disorders of pregnancy may have an etiology associated with the adaptation of the maternal circulatory, renal, and immune systems to pregnancy. The placenta is thought to play a primary role, as these disorders do not appear to regress until the placenta is delivered or removed.<sup>29</sup>

Individuals with gestational hypertension may eventually present with signs of preeclampsia; with progression to preeclampsia more likely if hypertension arises earlier in pregnancy (<32 weeks of gestation).<sup>1</sup> While preeclampsia can remain stable until delivery, some cases have a more serious and life-threatening course. Significant maternal morbidities associated with preeclampsia include cerebrovascular bleeding; retinal detachment; and organ damage and failure (liver and kidney).<sup>32, 33</sup> Eclamptic seizure occurs in approximately 1 to 2 percent of diagnosed preeclampsia cases and can be the first presentation of the disorder. These seizures can lead to death or serious complications including brain damage, aspiration pneumonia, pulmonary edema, placental abruption, disseminated coagulopathy, acute renal failure, cardiopulmonary arrest, and coma.<sup>34</sup>

The majority of preeclampsia cases arise after 34 weeks of gestation; however, morbidity and mortality are elevated among cases with early-onset disease.<sup>35</sup> Risk of adverse fetal, neonatal, and child health outcomes are increased with preeclampsia, including risk of intrauterine growth restriction or small for gestational age (IUGR/SGA), low birth weight, preterm birth, placental abruption, stillbirth, and neonatal death.<sup>2</sup>

In addition to adverse perinatal outcomes, there is growing evidence that having any hypertensive disorder of pregnancy, but especially preeclampsia, is associated with increased risk of maternal chronic hypertension and cardiovascular disease later in life,<sup>36-38</sup> with greater

risks among those who experience preeclampsia during more than one pregnancy and those who experienced earlier onset of HDP.<sup>39</sup> A recent US-based, prospective cohort study of 109 healthy pregnant persons with singleton gestations found that the group of individuals who developed a hypertensive disorder of pregnancy (n=58) had 4-fold increased odds of a new chronic hypertension diagnosis (adjusted odds ratio, 4.60 [95% CI, 1.65 to 12.81]) at 6-12 months postpartum and a significantly higher adjusted 30-year Framingham cardiovascular disease risk estimate compared to those without HDP (n=51) (7% vs 4%, p<.0001).<sup>40</sup> The Nulliparous Pregnancy Outcomes Study Monitoring Mothers-to-be Heart Health Study, which followed 4,484 individuals after their first pregnancy, found an increased risk of hypertension at 2-7 years postpartum among individuals who experienced any HDP (RR 2.7, [95% CI, 2.0 to 3.6]) and an even higher risk among those who experienced both an indicated preterm birth and HDP (RR 4.3 [95% CI, 2.7 to 6.7]).<sup>41</sup> A large Danish cohort of 482,972 individuals found the increased risk of incident hypertension among pregnancies complicated by HDP persisted through 20 years postpartum.<sup>42</sup> In a meta-analysis of over 13 million individuals, the relative risks of any cardiovascular disease and cardiovascular death for those with a history of hypertensive disorders of pregnancy were 1.80 (95% CI, 1.67 to 1.94) and 1.78 (95% CI, 1.58 to 2.00), respectively.<sup>43</sup> The relative risk of cardiovascular events associated with having had any hypertensive disorder of pregnancy are elevated in the year following delivery, and longer term differences in absolute risk for cardiovascular disease and related mortality are seen.<sup>37, 44</sup> As with incident hypertension, the risk of CVD appears to be highest among pregnancies in which the onset of the hypertensive disorder was preterm.<sup>45</sup>

## Risk Factors

The medical risk factors most consistently and strongly associated with preeclampsia include having an autoimmune disease (specifically antiphospholipid antibody syndrome or systemic lupus erythematosus), preexisting diabetes mellitus, chronic hypertension, chronic kidney disease, or a pregnancy conceived with assisted reproductive technology.<sup>46</sup> There is also consistent evidence that having a previous pregnancy complicated by preeclampsia or another hypertensive disorder, placental abruption, or stillbirth is associated with increased risk of preeclampsia. Most pregnant people who develop gestational hypertension or preeclampsia, however, do not have a known major risk factor. Several personal history and pregnancy characteristics have been identified as being independently associated with an increased risk for preeclampsia and gestational hypertension in observational studies. These include nulliparity, high pre-pregnancy body mass index (BMI), multifetal pregnancy, older maternal age (>35 years), and family history of preeclampsia or early-onset cardiovascular disease.<sup>19, 24, 47</sup> Maternal age is also associated with eclampsia in a J-shaped relationship – the highest incidence is seen among pregnant individuals under age 15 (7.8 per 1000) and over age 44 (5.4 per 1000). Eclampsia is also more common with multiple pregnancies (8.3 per 1000) compared with singleton (2.7 per 1000).<sup>48</sup>

The presence of multiple risk factors, whether personal characteristics or medical history risk factors, further heightens risk for preeclampsia and gestational hypertension. Several models have been developed with the aim of identifying pregnant individuals who are at risk of developing preeclampsia. Many of these models include variables for medical history, patient characteristics, blood serum biomarkers (e.g., serum placental growth factor), mean arterial pressure (MAP), and ultrasound readings (e.g., Doppler uterine artery pulsatility index). The

most extensively researched of these are various iterations of the Fetal Medicine Foundation (FMF) model.<sup>49</sup> Currently, risk assessment and risk prediction tools are being used to inform the use of aspirin for prevention of preeclampsia,<sup>50, 51</sup> however, no randomized controlled trials (RCTs) have incorporated the use of a risk prediction model to evaluate the optimal frequencies or intervals of screening for hypertensive disorders of pregnancy. In the absence of clinical implementation studies, it is not yet clear whether screening informed by risk prediction models would necessarily be superior to risk evaluations based on clinical history taking.<sup>52</sup> Moreover, it remains to be seen whether risk-based screening protocols, regardless of the risk-assessment approach used, could improve outcomes relative to usual care screening. Existing guidelines recognize the performance and practical limitations of existing risk assessment models.<sup>1, 53-55</sup>

## Sources of Health Inequities

This report focuses on the on the sources and efforts to address the inequities associated with race and ethnicity in the United States. Risk factors for HDP, such as the use of ART, chronic health conditions such as diabetes and chronic hypertension, and age at the time of giving birth are not evenly distributed in the population and contribute to maternal and infant morbidity and mortality. Socioeconomic factors, residence (region, rurality), and access to health care influence the prevalence of risk factors. These factors and other social and structural determinants of health contribute to heightened HDP risk and worse outcomes for individuals regardless of their race or ethnicity. At the same time, adjustment for these factors does not account fully for the increased rates of HDP or risk for worse outcomes for Black and AI/AN individuals.

Racial and ethnic categories do not reflect biologically or genetically defined differences among people, but instead are idiosyncratic groupings that have arisen from historical, economic, and cultural relationships among people and nations.<sup>56-58</sup> Efforts to understand underlying causes of race and/or ethnicity related inequities in morbidity and mortality from hypertensive disorders of pregnancy increasingly focus on the complex effects of interpersonal and structural racism on health status. Current and past policy conditions and historical events have implications for a range of exposures and conditions that contribute to HDP risk and pregnancy outcomes. These include inequities in income and wealth, housing stability and location, medical care access and quality and other factors that contribute to health status and resources for maintaining health.<sup>14, 26, 59 56-58</sup> Several frameworks have been developed to describe the factors contributing to higher incidence of hypertensive disorders of pregnancy and greater disease severity and mortality among Black and AI/AN individuals. Most broadly, the National Office of Minority Health and Health Disparities Research Framework describes important individual, interpersonal, community, and societal factors and conditions that contribute to a host of health inequities in the United States.<sup>60</sup> Other models, such as those developed for the recent Maternal Morbidity and Mortality Measurement report, focus the pregnancy care continuum (prenatal, intrapartum, postpartum). These frameworks have evolved from public health frameworks and years of scholarship documenting how structural conditions shaped by policy and history have differently impacted specific racial and ethnic populations in the United States.<sup>61-64</sup>

Contributors to racial and ethnic inequities in outcomes of hypertensive disorders of pregnancy include lower prenatal health care access and quality, greater psychosocial and work stress, and a higher prevalence of chronic health conditions (e.g., obesity, diabetes, hypertension) among

Black and AI/AN individuals than other racial/ethnic groups, as well as systemic racial biases in health care.<sup>16, 64</sup> The National Health and Nutrition Examination Survey from 2013-2016 estimated that Black populations had the highest prevalence of chronic hypertension compared with White, Asian, and Hispanic/Latino populations.<sup>65</sup> Higher prevalence of chronic health conditions associated with hypertensive disorders of pregnancy is also linked to the inequities at the societal and community level, making these factors difficult to disentangle. Environmental factors, including air and water pollution, are also associated with increased preeclampsia risk, and historical residential segregation and environmental racism make these exposures more common for Black populations than other racial/ethnic groups.<sup>66-70</sup>

Access to prenatal care and high-quality obstetric services, particularly for individuals who are at the highest risk for adverse pregnancy outcomes, has been identified as potential source of racial and ethnic inequities in birth outcomes. Having fewer than five prenatal visits increases the risk of eclampsia nearly two-fold, independent of race or ethnicity, and people who are in poverty or uninsured are less able to obtain routine prenatal care.<sup>20</sup> A study of over 300,000 pregnant individuals without a diagnosis of chronic hypertension found that a single elevated blood pressure reading before the 20<sup>th</sup> week of pregnancy was associated with increased risk of hypertensive disorders of pregnancy.<sup>71</sup> This finding demonstrates the importance of obtaining baseline blood pressure readings and conducting risk assessment as pregnancy progresses through regular prenatal care in the first half of pregnancy. National targets outlined in Healthy People 2030 set a target for 80.5 percent of pregnant individuals to receive early and adequate prenatal care by 2030 (based on the Adequacy of Prenatal Care Utilization Index). As of 2019, 76.7 percent of pregnant individuals received adequate prenatal care by this measure, with White and Asian populations close to or above the Healthy People 2030 goal (81.8% and 79.1%, respectively). However, less access to early prenatal care was seen among AI/AN (60.9%), Native Hawaiian/Pacific Islander (48.1%), Black (68.2%), and Hispanic/Latino populations (71.6%).<sup>72</sup>

## Screening and Treatment

### Screening Strategies

Screening tests are used to identify people that have a condition before it becomes symptomatic or has progressed. A positive screening test is followed by further clinical evaluation to confirm or specify the exact diagnosis. Ideally, screening tests correctly identify those who ultimately receive a diagnosis without flagging a large number of people that are not found to have the condition upon further examinations. Those with a confirmed diagnosis can then receive clinical interventions shown to reduce the health risks associated with the condition. Screening for hypertensive disorders of pregnancy has been a standard prenatal care practice for over 100 years.<sup>73</sup> Individuals who are identified as having a hypertensive disorder of pregnancy require enhanced surveillance and evidence-based clinical management to reduce the potential for maternal or infant mortality and serious complications associated with hypertensive disorders of pregnancy.<sup>53</sup> Hypertensive disorders of pregnancy comprise an array of conditions with diversity of clinical presentation and course, and screening is not based on a single stand-alone instrument or time point. In addition, blood pressure measurements before or early in pregnancy is important

for diagnosis. Without measures before 20 weeks of gestation, gestational hypertension cannot be distinguished from undiagnosed chronic hypertension until after pregnancy.

In the general population, blood pressure is traditionally measured with a sphygmomanometer by detecting sounds (auscultatory method) or by recording pulsations (oscillometric method). Factors such as patient caffeine consumption, cigarette use, and sitting position, as well as cuff size and placement, can affect the accuracy of blood pressure measurements in both in-office and out-of-office settings.<sup>74</sup> In 2017, the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines published extensive guidance for increasing accuracy of both in-office and out-of-office blood pressure measurements.<sup>74</sup> The guidance recommends use of an ambulatory blood pressure monitor (ABPM), which typically records blood pressure over 24 hours using oscillometry, as the gold standard method of measuring blood pressure, as it is able to diagnose white coat, masked, and nocturnal hypertension.<sup>75</sup> However, due to the limited availability of ambulatory blood pressure monitors, home blood pressure measurement, in which an individual measures their own blood pressure at some prespecified interval (e.g., 2 times a day for a week) with semiautomatic devices, is also recommended. Home blood pressure readings are subject to reporting bias, and the measurements are generally higher than ambulatory blood pressure readings, but lower than in-office readings.<sup>75</sup> In 2021, the US Preventive Services Task Force (USPSTF) recommended that adults should be screened for hypertension with office blood pressure measurement, and that blood pressure measurement outside of a clinical setting should be obtained for diagnostic confirmation before beginning treatment.<sup>76</sup>

Routine blood pressure measurement throughout pregnancy and the postpartum period is a key component of screening for hypertensive disorders of pregnancy, and requires both an appropriate measurement technique and a device validated for use in pregnancy to achieve the most accurate results.<sup>77</sup> It is important to validate accuracy specifically among people who are pregnant and those who have preeclampsia because there may be differences in performance due to physiologic changes associated with these states.<sup>78</sup> Various factors, including physiologic changes associated with pregnancy, may affect the accuracy of blood pressure measurements, and failure to employ the best methods of assessment may result in an over- or underestimate of blood pressure, impacting diagnosis. Because ABPM incorporates assessment during the night while an individual is sleeping, it provides the advantage of identifying nocturnal hypertension. This may be especially relevant for pregnancy given potential diurnal variation in blood pressure that has been observed in individuals with preeclampsia (blood pressure may be highest at night). A recent Cochrane review aimed to summarize the evidence examining how the techniques and settings used for blood pressure measurement to diagnose hypertensive disorders of pregnancy affected perinatal and maternal health outcomes.<sup>79</sup> The review identified only three studies and concluded there was uncertainty regarding the effects for the included comparisons (self-measurement versus office, use of Korotkoff phase IV versus Korotkoff phase V for diastolic blood pressure determination, semi-automated monitor versus usual care).

Other relevant screening assessments may include querying the pregnant patient regarding symptoms associated with preeclampsia and tests for proteinuria (typically urine dipstick). The importance of routine urine tests for screening has been questioned.<sup>80</sup> Reviews of the performance of point of care urine tests indicate substandard accuracy even in enriched clinical

populations of individuals with suspected preeclampsia.<sup>52, 81</sup> Indeed, the importance of distinguishing gestational hypertension from preeclampsia solely on basis of the presence or absence of proteinuria has been questioned, given similarities in the ongoing management of both conditions.<sup>80</sup>

## Prevention and Treatment Approaches

High-quality prenatal care aims to improve birth outcomes by identifying hypertensive disorders of pregnancy and managing them with evidence-based clinical intervention when indicated (e.g., treatment with anti-hypertensive medications, induction of labor, magnesium sulfate to prevent seizures, and administration of steroids to improve fetal outcomes in the setting of preterm delivery).<sup>1, 53, 82-85</sup> Few effective preventive interventions for hypertensive disorders of pregnancy have been identified. For individuals at increased risk for preeclampsia, daily low-dose aspirin taken during pregnancy has been shown to reduce the risk of developing preeclampsia and its serious health consequences, including perinatal mortality, preterm birth, and small for gestational age infants.<sup>50, 51</sup> There is also limited evidence that calcium supplementation may be beneficial for reducing preeclampsia and gestational hypertension risk, particularly for women with low calcium diets, but more evidence is needed.<sup>86</sup> Evidence is mixed on whether behavioral interventions related to diet and physical activity before and during pregnancy are effective at preventing hypertensive disorders of pregnancy. A 2017 systematic review of 17 trials reported reduced risk for those engaging in 30-60 minutes of aerobic exercise several times a week, but only 7 of the trials could be combined in meta-analysis.<sup>87, 88</sup> A 2018 systematic review of 23 behavioral intervention trials included fewer trials of exercise alone and more trials of interventions combining diet and exercise and did not find reductions in the risk of hypertensive disorders of pregnancy, although gestational weight gain was reduced for some participants.<sup>89</sup> In both reviews, there was no effect of exercise on the risk for preeclampsia. Another 2018 systematic review of prenatal exercise, however, showed reduced risk for HDP and noted that it required at least 600 minutes of moderate-intensity exercise each week.<sup>90</sup>

Individuals with gestational hypertension or preeclampsia without severe features arising prior to 37 weeks of gestation require close antenatal surveillance to assess for worsening disease or fetal compromise that might require more expedient delivery.<sup>1</sup> For individuals who develop a hypertensive disorder of pregnancy, preeclampsia and gestational hypertension usually resolve in the hours, days, or more uncommonly, weeks following delivery of the placenta. Current recommendations for delivery of patients with hypertensive disorders of pregnancy take into consideration the specific diagnosis and the associated risks and benefits both to the mother and the fetus. For individuals with gestational hypertension and preeclampsia without severe features, delivery is recommended when the patient reaches 37 0/7 weeks of gestation. For preeclampsia with severe features, delivery is recommended at 34 0/7 weeks of gestation, or at the time features develop if after 34 0/7 weeks. Given the serious morbidity associated with HELLP syndrome, delivery is recommended upon diagnosis regardless of the gestational age at which it arises. Similarly, individuals with eclampsia should be delivered in a timely manner once the patient is stabilized.

## Previous Recommendations of the USPSTF and Others

In 2017, the USPSTF concluded with moderate certainty that screening for preeclampsia with blood pressure measurement throughout pregnancy had a substantial net benefit (**B recommendation**).<sup>54</sup> Although the USPSTF found no recent studies on the direct effectiveness of screening for preeclampsia in improving health outcomes, trial evidence and extensive clinical experience were cited as providing evidence of effective treatments for preeclampsia. The USPSTF found inadequate evidence on the effectiveness of risk prediction tools (e.g., clinical indicators, serum markers, or uterine artery pulsatility index) that would support different screening strategies for predicting preeclampsia. Furthermore, there were no randomized implementation studies found that evaluated the health effects of using risk assessment models to replace or inform screening compared with standard screening using blood pressure measurements.<sup>51</sup>

Screening for hypertensive disorders of pregnancy has long been a central component of prenatal care. In the Guidelines to Prenatal Care (8<sup>th</sup> ed.) issued by the American College of Obstetricians and Gynecologists (ACOG) and the American Academy of Pediatrics (AAP) (2018),<sup>91</sup> the importance of regular prenatal care visits, with greater frequency in the presence of risk factors for complications, is noted. Blood pressure measurement at every visit is advised. Recent ACOG recommendations related to preeclampsia (2020) focus on the diagnostic criteria for gestational hypertension and preeclampsia, and management decisions for those diagnosed.<sup>1</sup>



## Chapter 2. Methods

### Scope and Purpose

The USPSTF will use this report to update its 2017 recommendation on screening for preeclampsia. In 2017, the USPSTF concluded with moderate certainty that screening for preeclampsia in pregnant women with blood pressure measurements throughout pregnancy had a substantial net benefit (**B recommendation**).<sup>54</sup>

The updated review broadens the topic beyond preeclampsia to screening for all hypertensive disorders of pregnancy and was designed to include screening interventions in the postpartum period (but not monitoring or surveillance of HDP). The approach to screening and clinical management of preeclampsia and other hypertensive disorders of pregnancy do not appreciably differ – gestational hypertension and preeclampsia are predicated on the identification of elevated blood pressure during pregnancy and result in heightened surveillance and ongoing testing and diagnostic evaluations to assess the disease course. Treatments for preeclampsia, gestational hypertension, and chronic hypertension include similar interventions according to disease severity, including treatment with antihypertensive medication at certain thresholds, induction of delivery in the presence of certain signs or symptoms, and treatment with magnesium sulfate to prevent seizures and stroke. Therefore, this updated review will focus on studies comparing different screening protocols for all hypertensive disorders of pregnancy, including preeclampsia. The review aims to assess the comparative effectiveness of different screening protocols that vary by gestational timing, frequency, modality, and sequencing over the course of pregnancy.

While the definition of hypertensive disorders of pregnancy includes pregnancies among individuals with existing chronic hypertension, this review is focused on screening interventions aimed at identifying hypertensive disorders of pregnancy among those without a diagnosis, in keeping with standard USPSTF procedures. Therefore, studies evaluating different approaches to *monitoring* individuals with hypertension during pregnancy or postpartum were outside of the review scope.

The primary aim of this review is to examine the comparative effectiveness of interventions to detect hypertensive disorders of pregnancy including comparisons of: blood pressure measurement setting (office or home), interval, frequency, or timing; proteinuria assessment setting, interval, or sequence of testing; and personalization of screening based on risk assessment.

Unlike the previous review, this update does not include a review of the test performance characteristics of point of care protein urine screening tests commonly used in pregnancy (e.g., urine dipstick). Since the previous review of this screening topic, the definition of preeclampsia was updated such that proteinuria is one of several clinical signs or symptoms that are used to confirm a diagnosis of preeclampsia. Routine point of care urine screening for proteinuria has modest test performance and questionable clinical value in the absence of elevated blood pressure. While this review does not address the *accuracy* of urine screening (i.e., comparison

against a gold standard), the scope does support the inclusion of studies comparing the *effectiveness* of different approaches to protein urine screening over the course of pregnancy (e.g., timing, indication, frequency, type of test).

In addition, this update review will not address the performance of risk prediction models to identify individuals at increased risk for developing preeclampsia. Evidence from clinical implementation studies is needed to inform screening recommendations, and existing reviews suggest that current models have limitations and may need further refinement prior to clinical application.<sup>50, 52</sup> While this review does not present evidence on the *performance* of risk prediction models, the scope was defined to include studies that incorporate risk assessment to personalize screening or to select patients for evaluation of new screening approaches.

## Key Questions and Analytic Framework

We followed USPSTF procedures and methods to define study inclusion and exclusion criteria (**Appendix A Table 1**) and developed an analytic framework (**Figure 1**) with three Key Questions (KQs).

### Key Questions

1. How effective are different screening programs used to identify hypertensive disorders of pregnancy for reducing maternal and perinatal morbidity and mortality?
2. How effective are different screening programs for identifying people with hypertensive disorders of pregnancy?
3. What are the harms of different screening programs used to identify hypertensive disorders of pregnancy?

In addition, we delineated four contextual questions, which were addressed using abbreviated, not fully systematic methods and are therefore not shown on our analytic framework:

1. How do racism and social inequalities contribute to existing inequities in morbidity and mortality from hypertensive disorders of pregnancy? For example, what accounts for higher mortality from hypertensive disorders of pregnancy among Black compared with White populations in the United States?
2. Are there effective interventions that could redress existing inequities in morbidity and mortality from hypertensive disorders of pregnancy?
3. What is the effectiveness of blood pressure self-monitoring and its potential utility in telehealth prenatal care delivery?
4. How are risk assessment and risk prediction tools being used in clinical practice to inform screening programs?

## Data Sources and Searches

We conducted comprehensive searches of MEDLINE and the Cochrane Collaboration Registry of Controlled Trials for relevant studies published between January 1<sup>st</sup>, 2014, and January 4<sup>th</sup>, 2022. This search was designed to partially overlap with the end search dates of the previous USPSTF-commissioned review of this topic, and to identify new studies. A research librarian developed and executed the search, which was peer-reviewed by a second research librarian (**Appendix A**). In addition, we considered for inclusion all studies from the previous review<sup>52</sup> conducted to support the 2017 USPSTF recommendation on this topic.<sup>54</sup> Additionally, supplemental and hand searching was conducted to address the identification of studies that may not have fit within the scope of the previous review (i.e., comparative effectiveness of screening, hypertensive disorders of pregnancy beyond preeclampsia). We examined the reference lists of other previously published reviews, meta-analyses, and primary studies to identify additional potential studies for inclusion. Ongoing trials were identified via ClinicalTrials.gov (<https://ClinicalTrials.gov/>) (**Appendix E**). Searches were managed using EndNote® X9 (Thomson Reuters, New York, NY).

## Study Selection

We developed specific inclusion criteria to guide study selection (**Appendix A Table 1**). Two reviewers independently reviewed the titles and abstracts of all identified articles using DistillerSR (Evidence Partners, Ottawa, Canada) and identified those that were potentially relevant. Two reviewers then independently evaluated the full text of all potentially relevant articles for inclusion in this review. Differences in judgments at the abstract and full text review stages were resolved by discussion. Excluded studies and reasons for exclusion are listed in **Appendix C**.

All key questions included studies that could address the comparative effectiveness of screening for hypertensive disorders of pregnancy using approaches that varied in their frequency, setting, or method of measurement. Included populations were pregnant or postpartum people, including those at an increased risk for hypertensive disorders of pregnancy. Studies *limited* to individuals already diagnosed with a hypertensive disorder of pregnancy (including chronic hypertension) or highly selected populations (e.g., people with renal disease) were excluded.

Studies that evaluated changes in the frequency or timing of prenatal care visits as a proxy for screening frequency were included if blood pressure measurement was described or could be inferred to be included in the visit. In addition, we included studies that addressed the use of home blood pressure measurements alongside usual clinical care. We excluded studies where other interventions occurred along with changes to the timing, frequency, or modality of screening (e.g., patient education and support, service delivery model, group model of care). Screening could occur over the course of a pregnancy or up to 8 weeks postpartum.

Key Question 1 addressed the effect of screening on maternal and perinatal health outcomes, including longer-term health consequences from complications of hypertensive disorders of pregnancy. Key Question 2 addressed the detection and time to diagnosis of a hypertensive

disorder of pregnancy. Key Question 3 addressed the potential harms of screening programs, including missed diagnoses. Nonclinical outcomes, such as length of hospital stay and neonatal intensive care unit admission, were not included. **Appendix A Table 1** lists all the outcomes considered in this review.

Study designs included in this review were RCTs, clinical controlled trials, and non-randomized studies of interventions (NRSI) comparing screening programs. The review was limited to studies conducted in countries with “very high” Human Development Index scores (as of 2020) as published by the United Nations Development Programme.<sup>92</sup>

## Quality Assessment and Data Abstraction and Synthesis

Two reviewers independently assessed the methodologic quality (risk of bias) of each included study using predefined criteria (**Appendix A Table 2**). Each study was assigned a quality rating of “good,” “fair,” or “poor” according to the USPSTF’s study-design-specific criteria. Disagreements were resolved by discussion. One investigator abstracted data on study design, patient characteristics, intervention and comparator descriptions, and outcomes into an evidence table. A second investigator checked the accuracy of the abstracted data against the article. Given the limited number and clinical heterogeneity in the included studies, we did not conduct any quantitative synthesis.

For consistency, in this report we use the following default terminology:

1. Race and/or ethnicity when referring to race/ethnicity
2. Black and White (in capitals) as descriptors for populations rather than nouns
3. Black persons as opposed to African Americans
4. Hispanic/Latino individuals to refer to both individuals from Spanish-speaking backgrounds and individuals from Latin America
5. White persons as opposed to Caucasian persons
6. In reference to persons indigenous to North America (and their descendants), American Indian or Alaska Native
7. Throughout the report when referring to different race groupings non-Hispanic/Latino ethnicity can be assumed unless otherwise stated.

There are no ideal or universally preferred terms for many of these categorizations and concepts, but we have tried to avoid inaccurate terms or those perceived as marginalizing. In select instances, when using less preferable terms referenced by the source material, we note this using quotation marks (e.g., “diverse populations”).

To recognize gender diversity in pregnant and birthing people we apply gender neutral terms when possible, but in specific cases, gendered terms are used to communicate standard health outcomes of historic importance (e.g., maternal mortality). Since this is a pregnancy topic, the literature cited is focused on people capable of becoming pregnant, who are most often people assigned female sex at birth. Gender is often inferred or assumed based on anatomy or physical presentation, however, and may not reflect self-identified gender for some people who give

birth. Additionally, binary constructions of gender fail to account for individuals that do not identify as either a men or women (e.g., people who identify as non-binary).

## **Grading the Strength of the Body of Evidence**

The strength of the overall body of evidence for each KQ was graded using an adaptation of the Evidence-based Practice Center approach,<sup>93</sup> which is based on a system developed by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group.<sup>94</sup> This adaptation explicitly addresses four of the five Evidence-based Practice Center-required domains: consistency, precision, reporting bias, and study quality. We do not evaluate the fifth domain—directness—as it is implied in the structure of the key questions (i.e., link between the interventions to a health outcome).

Consistency (similarity of effect direction and size) was rated as reasonably consistent, inconsistent, or not applicable (e.g., single study). Precision (degree of certainty around an estimate) was rated as reasonably precise, imprecise, or not applicable (e.g., no evidence). Reporting bias was rated as suspected, undetected, or not applicable (e.g., when there was insufficient evidence for a particular outcome) to address the potential for bias related to publication, selective outcome reporting, or selective analysis reporting. Study quality summarizes the degree to which the results are likely to have adequately low risk of bias based on individual study quality. The limitations domain highlighted important constraints in answering the overall key question.

Overall grades for the strength of evidence are rated as “High,” “Moderate,” “Low,” or “Insufficient.” A rating of “High” indicates high confidence that the evidence reflects the true effect, and that further research is very unlikely to change our confidence in the estimate of effects. “Moderate” strength of evidence ratings indicates a moderate confidence that the evidence reflects the true effect, and that further research may change our confidence in the estimate of effect or may change the estimate itself. A strength of evidence rating of “Low” indicates low confidence that the evidence reflects the true effect, and that further research is likely to change our confidence in the estimate of effect and to change the estimate itself. A grade of “Insufficient” is used to indicate that evidence is either unavailable or does not permit estimation of an effect. Strength of evidence was independently assessed by at least two independent reviewers, with discrepancies resolved through consensus discussion involving more reviewers.

## **Expert Review and Public Comment**

A draft research plan was posted on the USPSTF website for public comment from May 20, 2021, through June 16, 2021. The USPSTF received comments and questions related to the scope of the review. In response, the USPSTF modified the research plan to clarify the population of interest, the wording of the contextual questions, and the focus of the review on the health effects of screening in the prenatal and postpartum periods. A final research plan was posted on the USPSTF website on September 2, 2021.

A draft version of this report was reviewed by content experts, representatives of Federal partners, USPSTF members, and AHRQ Medical Officers. Reviewer comments were presented to the USPSTF during its deliberations and addressed in subsequent revisions to the draft report. The revised draft of the report was posted for public comment on the USPSTF Website from February 7, 2023 through March 6, 2023. The draft received few public comments, leading to minor editorial changes but no updates to the included evidence or the report conclusions.

## **USPSTF and AHRQ Involvement**

The authors consulted with USPSTF members during the development of the research plan, including developing the scope of the review, the analytic framework, key questions, and inclusion criteria. After revisions in response to feedback from the public comment period, USPSTF members approved the final analytic research plan. An AHRQ Medical Officer provided project oversight, reviewed draft versions of the evidence review, and assisted in the external review of the report. The USPSTF and AHRQ had no role in the study selection, quality assessment, or writing of the evidence review.

# Chapter 3. Results

## Literature Search

We reviewed 6,316 abstracts and assessed 82 full-text articles for inclusion (**Appendix A Figure 1**). Overall, we identified six studies (reported in 10 articles)<sup>95-104</sup> that met our inclusion criteria. A list of included and excluded studies (with reasons for exclusion) are available in **Appendix B** and **Appendix C**. Of the six included studies, two were included in the previous review.<sup>95, 96</sup> We excluded 19 studies that were included in the previous review<sup>52</sup> because the current review did not include a key question on the test accuracy of urine screening for detecting proteinuria nor did it include a key question on the test performance of preeclampsia predictive models. (See explanation in Methods: Scope and Purpose).

Among the included studies, five met the criteria for KQ1 (perinatal and maternal health outcomes of screening) and KQ2 (preeclampsia or gestational hypertension diagnosis),<sup>95, 96, 98, 99, 104</sup> and all six met the criteria for KQ3 (harms of screening).<sup>95-99, 104</sup> Five of the included studies were fair-quality RCTs and one was a fair-quality NRSI with a historical control. Descriptive information on study populations, setting, design, and intervention characteristics for the included studies are provided in Table 1 and Table 2. Three included studies were conducted in the US and three in the UK. Two studies included fewer than 100 participants each, and the others included more than 2000 individuals each.

The sources of bias that were most often encountered in the RCT evidence related to group imbalances at baseline, loss to followup, and lack of accounting for these potential sources of bias with appropriate statistical analyses (e.g., adjustment for confounding, imputation). In the historical control NRSI, risk of bias from missing outcome data and loss to followup could not be ascertained due to absent reporting on reasons for missing data or loss to followup by study group, and there was no adjustment for potential confounding.<sup>95</sup> Studies with historical control designs are also inherently subject to bias from concurrent changes in the environment over time that could affect outcomes.

Three newly identified studies otherwise eligible for inclusion were excluded from the review based on poor quality ratings in risk of bias assessment.<sup>105-107</sup> One excluded study (SAFE@HOME) conducted in The Netherlands used a case-control design to evaluate home blood pressure and symptom measurement supported by a digital health platform.<sup>105</sup> It was assessed to have high risk of bias due to confounding, selection, and high attrition in the control group—adjustment for sources of confounding and differences in the characteristics of the case and control populations was not conducted. Two NRSI with historical controls of a change in prenatal care schedule were excluded for risk of bias due to considerable confounding and a lack of information on intervention fidelity—several other changes in practice occurred at the same time as the change in the prenatal visit schedule, limiting the ability to attribute outcomes to the intervention.<sup>106, 107</sup>

The interventions evaluated in the studies were of three general types: the use of screening with *home blood pressure measurement* to supplement or replace office-based blood pressure

measurement in prenatal care (2 RCTs—one included only for harms), *reduced prenatal screening visit schedules* resulting in fewer blood pressure measurements over the course of pregnancy (3 RCTs), and *indicated rather than routine urine screening* to detect proteinuria (1 NRSI with a historical control) (Table 1, Appendix D Table 1). These three intervention types will be discussed separately going forward.

## **KQ1. How Effective Are Different Screening Programs Used to Identify Hypertensive Disorders of Pregnancy for Reducing Maternal and Perinatal Morbidity and Mortality?**

### **Summary of Results**

A single trial (N = 2,411) of home blood pressure measurement as a supplement to routine prenatal care for pregnant individuals at increased risk for hypertensive disorders of pregnancy did not find differences in the risk of serious maternal or infant health outcomes. One small trial (N = 81) and two larger trials (N = 2,328, N = 2,794) evaluated the effects of having fewer prenatal care visits for low-risk pregnancies, providing limited evidence of the effects of having fewer office-based blood pressure screening tests throughout pregnancy. None of the trials reported statistically significant differences across a range of health outcomes. Estimates from these trials were not precise due to inadequate power, particularly for rare, serious health outcomes. A NRSI study using a historical control to evaluate the implementation of a new program of indicated urine screening reported fewer cases of preterm birth following implementation of the indicated testing intervention but confounding related to the study design limits the interpretation of these results. Both studies of home blood pressure measurement were conducted in the UK, the largest primarily among predominantly White (British, Irish, Other) participants (74%) at increased risk for hypertensive disorders of pregnancy. The study population in the large US trial of reduced prenatal visit schedules was described as predominantly White (81%) and Hispanic (12%). The study of indicated urine screening was predominantly Hispanic (75%) and White (19%) and was conducted in a setting with risks related to social and structural determinants of health (majority public insurance or uninsured, lower income). The available evidence precludes conclusions about the effects these interventions would have for Black and AI/AN populations, which face the greatest risk for hypertensive disorders of pregnancy and adverse outcomes in the US.

### **Included Studies**

#### **Home Blood Pressure Screening**

One fair-quality RCT conducted in the UK evaluated home blood pressure measurement three times a week to supplement routine prenatal care among individuals at increased risk for preeclampsia.<sup>104, 108</sup> The Blood Pressure Monitoring in High Risk Pregnancy to Improve the Detection and Monitoring of Hypertension (BUMP) trial enrolled 2,441 pregnant people at increased risk of a hypertensive disorder of pregnancy based on common clinical risk factors (e.g., nulliparity, age, pregnancy, family history, previous preeclampsia, BMI  $\geq$  30kg/m<sup>2</sup>, twin



pregnancy, diabetes, etc.). The trial (conducted from 2018 to 2019) evaluated an intervention of home blood pressure measurement three times a week supported by a telemonitoring mobile-phone-based application that generated automated feedback; this intervention supplemented the standard British office-based prenatal care visit schedule. Participants were randomized 1:1 to the intervention or a comparison arm that received standard prenatal care consisting entirely of the standard office-based prenatal care schedule. In addition to receiving materials and training for home blood pressure measurement, intervention participants were provided with the mobile-phone-based telemonitoring application. The application was used to record blood pressure measurements and transmit them to a central database which generated automated feedback, reminders, requests for additional readings to be submitted, or instructions to contact their health care provider in cases where persistently low (110-134/70-84mmHg) or high ( $\geq 135/85$ mmHg) readings occurred.<sup>104</sup>

Participants were enrolled between 16 and 24 weeks of gestation.<sup>104</sup> Almost two-thirds of participants were nulliparous (61%), but a substantial percentage were multiparous and also had a history of a hypertensive disorder of pregnancy (~17%). Over five percent of participants were carrying a multifetal pregnancy. This trial was also comprised mostly of White (British, Irish, Other) participants (74%); it included smaller percentages of participants identifying as Asian or Asian British (10%), Black or Black British (8%), or selecting “Other” or “Mixed” race or ethnicity (7%, not further specified in the study report). Participants were described as having on average a middle-level socioeconomic position based on UK index of multiple deprivation decile; the mean age of participants was 33 years. Adherence with blood pressure self-measurement in the intervention group was nearly 77 percent.<sup>104</sup>

### **Reduced Prenatal Screening Visit Schedules**

Three fair-quality RCTs, all conducted over 20 years ago, aimed to evaluate the effect of fewer prenatal visits for individuals considered to be at low risk for pregnancy complications. These studies provide limited evidence on the potential effect of having fewer blood pressure measurements over the course of pregnancy, since the reduced visit schedule also reduced opportunities for participants to obtain other prenatal care visit evaluations and counseling. One trial assessed pregnancy risk and study eligibility in the first trimester,<sup>96</sup> and the other two trials included eligible individuals entering prenatal care by week 24<sup>98</sup> and week 26<sup>99</sup> of gestation. A small US-based trial (N = 81) aimed to assess an eight-visit prenatal care schedule,<sup>99</sup> and a larger US-based trial (N = 2,328) evaluated the effects of a nine-visit prenatal care schedule; both were compared with a standard visit schedule that would result in approximately 14 visits (depending on the timing of delivery).<sup>96</sup> A UK trial (N = 2,794) compared a reduced visit schedule consisting of 7 visits for nullipara and 6 visits for multipara to a standard prenatal care schedule of approximately 13 visits.<sup>98</sup>

The small US-based RCT included primarily Hispanic (74%) and White (22%) participants.<sup>99</sup> Over half of the study population (56%) spoke only Spanish and most had Medicaid health insurance (82%). Study participants were assessed to be at low risk for pregnancy complications when entering prenatal care prior to 26 weeks of gestation. The larger US trial enrolled primarily White participants (81%) and smaller percentages of Hispanic (12%), Black (4%), and unspecified “Other” (2%) participants.<sup>96</sup> The included participants were assessed to be at low for risk of pregnancy complications during the “first trimester” of pregnancy. About half of study

participants were nulliparous (49%). There was limited information on measures of socioeconomic status; the population had on average 14 years of education.

The large UK trial (N = 2,794) enrolled participants at low risk for pregnancy complications that were receiving prenatal care by 24 weeks of gestation.<sup>98</sup> The study provided very little information to describe the study population. One-third of participants (32%) were described as “ethnic minority,” approximately one-third (35%) had “finished a full-time education in 16 years”, and most (81%) were living with a partner.

In all three of these trials, the difference in the overall number of visits between arms was smaller than intended by the trials design. The difference in the number of visits between groups ranged from 2.2<sup>98</sup> to 3.2.<sup>99</sup>

### **Indicated Rather Than Routine Urine Screening for Proteinuria**

One fair-quality non-randomized study (N = 2,441) conducted in the United States enrolled pregnant individuals obtaining prenatal care before and after implementation of a change in clinical practice at a hospital-based midwifery practice. From November 2000 to August 15, 2002, prenatal care included routine urine screening at every visit. Beginning on August 15, 2002 and continuing through March 2004, these same clinical sites implemented a program of indicated urine screening. During the period of indicated screening, urine tests were conducted at the first prenatal visit, and at subsequent visits for a range of indications, including patient complaint of urinary tract infection symptoms, severe vomiting or weight loss, or elevated blood pressure (see **Appendix D Table 2** for further details). Race and/or ethnicity data were self-reported by patients at the first prenatal visit. Three-quarters of the study population identified as Hispanic (75%), the remaining quarter identified as either White (19%), Black (9%), or “other” (6%, not described in further detail). Over half of the population was described as “Single” (56%) and the remainder as “Married” (41%). Most included patients had Medicaid health insurance (89%) or no health insurance (5%). The mean (SD) number of urine dipstick tests patients received was 7.8 (3.4) in the routine screening period and 1.4 (1.3) in the indicated screening period. The range of tests received was 0 to 19 for the routine screening group and 0 to 16 for the indicated screening group. The most frequently reported reasons for indicated screening were elevated blood pressure or preeclampsia related symptoms (36%) and urinary tract infection or vaginitis symptoms (32%).

## **Detailed Results by Intervention**

### **Home Blood Pressure Measurement Interventions**

Relevant outcomes for KQ1 reported in the BUMP trial (N = 2,441) were maternal mortality, maternal health complications related to hypertensive disorders of pregnancy (i.e., eclampsia, transient ischemic attack, stroke, HELLP syndrome, pulmonary edema), early neonatal mortality, stillbirth, and IUGR/SGA. The rarity of the most serious outcomes (e.g., mortality, stroke) prevented inferences regarding the absence or presence of intervention effects because of limited statistical power. (**Table 3**). There were slightly fewer maternal complications related to hypertensive disorders of pregnancy in the home measurement group (15/1209; 1.2%) than in the

usual care group (19/1209; 1.6%). However, the confidence interval for this modest estimated effect crossed null (RR 0.79 [95% CI, 0.40 to 1.55]). More cases of IUGR/SGA occurred in the intervention group (104/1249, 8.3%) than in the control group (87/1235, 7.0%), but the confidence interval again spanned null in the study-reported adjusted analysis (adjusted RR 1.15 [95% CI, 0.87 to 1.53]).

### Reduced Prenatal Screening Visit Schedules

The three included trials of reduced prenatal visits schedules did not report a consistent set of health outcomes. The large UK trial (N = 2,794) was the only trial to report maternal mortality, with one case occurring in the reduced visit schedule study arm (1/1359; 0.1%) and no cases occurring in the control arm.<sup>98</sup> The case was a multiparous woman with a postnatal cerebrovascular event who had attended 20 antenatal visits. Measures of perinatal mortality were reported in all three studies but were defined differently across studies as miscarriage or fetal loss;<sup>99</sup> stillbirth or neonatal mortality after 20 weeks of gestation;<sup>96</sup> and stillbirth or perinatal mortality.<sup>98</sup> No cases of miscarriage or fetal loss occurred in the intervention group and four cases (4/61; 6.6%) occurred in the routine care group in the small US trial (N = 81). In the large US trial (N = 2,328), five cases of stillbirth or neonatal mortality were reported in each study group (RR 1.00 [95% CI, 0.54 to 1.86]). In the large UK trial, there was a similar incidence of stillbirth/perinatal mortality in the reduced visit group (7/1361; 0.5%) and the routine visit group (10/1396; 0.7%) and the confidence interval contained null, though the study was underpowered for this rare outcome (RR 0.72 [95% CI, 0.27 to 1.88]).<sup>98</sup>

Preterm delivery was reported in the two US trials. The larger trial (N = 2,328) reported slightly more cases of preterm delivery (<37 weeks of gestation) in the reduced visit intervention (73/1165; 6.3%) than in the routine visit control group (63/1163; 5.4%) but the confidence interval for the estimated relative risk crossed null (RR 1.08 [96% CI 0.92 to 1.27]).<sup>96</sup> Due to limited power, the small US trial (N = 81) did not support effect inferences.<sup>99</sup>

In the large US trial, the risk of IUGR/SGA (<10<sup>th</sup> percentile) was not statistically different between study groups (RR 1.13 [95% CI, 0.91 to 1.41]) but there were more cases in the reduced visit intervention (36/1175; 3.1%) than the routine visit control group (28/1176; 2.4%).<sup>96</sup> The large UK trial also reported IUGR/SGA (<10<sup>th</sup> percentile) and also reported no statistically significant difference (RR 0.94 [95% CI, 0.82 to 1.09]), but with slightly fewer cases in the reduced visit intervention group (277/1355; 20.4%) than the routine visit control group (302/1393; 21.7%).<sup>98</sup> The risk for low birthweight (<2500 grams) was reported in the US trial and was similar between groups (RR 0.94 [95% CI, 0.78 to 1.12]), with a few more cases occurring in the reduced visit intervention group (64/1175; 5.4%) than the routine visit control group (72/1176; 6.1%).<sup>96</sup> Other infant health outcomes reported in the small US trial were rare, and differences in risk could not be estimated with any statistical precision.<sup>99</sup>

Placental abruption was reported in the large US trial. Similar to other rare outcomes, differences between groups were small and not statistically significant (RR 1.21 [95% CI, 0.90 to 1.64]),<sup>96</sup> with events slightly more common in the reduced visit group (17/1165; 1.5%) than the routine visit control group (11/1163; 0.9%). The risk of postpartum hemorrhage was similar in the two large trials, with estimates close to null: rates of postpartum hemorrhage were numerically lower

with the reduced visit schedule in the US study (RR 0.94 [95% CI, 0.59 to 1.50])<sup>96</sup> and nearly the same across groups in the UK study (RR 1.01 [95% CI, 0.80 to 1.26]).<sup>98</sup>

### **Indicated Rather Than Routine Urine Screening for Proteinuria**

The NRSI with a historical control (N=2,441) of indicated versus routine urine screening reported on preterm delivery rates, but not other health outcomes. Preterm delivery rates were lower for births occurring in the period with indicated urine screening (50/1019; 4.9%) than the routine urine screening period (72/933; 7.7%) and the 95 percent confidence interval for the relative risk of preterm delivery ranged from a 55 percent reduction to a 10 percent reduction in risk (RR 0.64 [95% CI, 0.45 to 0.90]). The study was designed and analyzed to test for non-inferiority between groups; the one-sided test showed that preterm birth was not equivalent between groups and was not worse with indicated screening. Given the risk of bias inherent to historically controlled studies, however, these results may be due to factors other than the change in screening approach.

## **KQ2. How Effective Are Different Screening Programs for Identifying People With Hypertensive Disorders of Pregnancy?**

### **Summary of Results**

The large trial (N = 2,441) of home blood pressure measurement in addition to usual prenatal care for individuals at increased risk for preeclampsia reported similar rates of gestational hypertension and preeclampsia in the intervention arm than the usual care only arm. More cases of preeclampsia with severe features were diagnosed in the home blood pressure measurement group than the control group, but the difference in risks was not statistically significant. The three trials that assigned participants to reduced prenatal care visit schedules did not identify differences between groups in the proportion of participants receiving a diagnosis of preeclampsia, although only one of the US trials (N = 2,328) reported adequate numbers of participants and events for estimation of effects with reasonable precision. For preeclampsia with severe features, the large US trial reported similar proportions diagnosed across arms (<1%), but confidence intervals were wide for this rare outcome. The NRSI with a historical control did not find a difference in the incidence of hypertensive disorders of pregnancy during the time periods with indicated versus routine urine screening. Overall, the different screening programs did not reduce or increase diagnoses of hypertensive disorders of pregnancy. Presumably, all cases were detected by the end of pregnancy; only one study compared the timing of diagnosis between study arms, it did not find a clinically important difference. It is unclear whether these results are discordant or concordant with the results for health outcomes, given a lack of precision for the most serious outcomes, which are rare.

## Included Studies

Key question 2 included the same 5 studies described in Key Question 1.<sup>95, 96, 98, 99, 104</sup>

## Detailed Results by Intervention

### Home Blood Pressure Measurement Interventions

The BUMP trial (N = 2,441) reported rates of hypertension, severe hypertension, and preeclampsia (**Table 4**). The proportion of participants developing hypertension during pregnancy was approximately the same in the intervention group (15.3%) and the control group (15.7%) and the proportion of diagnoses of preeclampsia was the same in both groups (4.2%). Confidence intervals for the estimation of no difference between groups for these outcomes contained null, and the study was not powered to detect small differences. Despite the addition of home blood pressure measurements, there was no evidence for a clinically meaningful difference in the mean days to clinical detection of a hypertensive disorder of pregnancy between the intervention (104.3 days) and control group (106.2 days; mean difference -1.58 days [95% CI, -8.10 to 4.94]). Time to diagnosis was the primary outcome of this study since a screening intervention was not expected to change the overall prevalence of hypertensive disorders of pregnancy. There was not a statistical difference in the incidence of severe hypertension in the intervention group (6.0%) and the control group (4.9%), and the estimated relative risk was imprecise with a wide confidence interval spanning null (RR 1.22 [95% CI, 0.87 to 1.70]).

### Reduced Prenatal Screening Visit Schedules

The small US RCT (N = 81) lacked statistical power to estimate group differences.<sup>99</sup> The large US RCT (N = 2,328) reported similar proportions of preeclampsia cases in the reduced visit intervention group (59/1165; 5.1%) and the usual care control group (66/1163; 5.7%).<sup>96</sup> The confidence interval for the relative risk of preeclampsia contained null and ranged from a 22 percent reduced risk to a 14 percent increased risk of detection (RR 0.94 [95% CI, 0.78 to 1.14]). Cases of preeclampsia with severe features were more uncommon overall, and a similar number occurred in the intervention (10/1165, 0.9%) and control groups (9/1163, 0.8%). The estimate of relative risk suggested a null effect, but the confidence interval was wide for this rare outcome (RR 1.05 [95% CI, 0.68 to 1.62]).<sup>96</sup> The large UK trial (N = 2,794) reported preeclampsia diagnoses, but rates were very low in the study population, with fewer than one percent of participants having the outcome, and the intervention effect was imprecisely estimated (RR 0.85 [95% CI, 0.35 to 2.04]).<sup>98</sup>

### Indicated Rather Than Routine Urine Screening for Proteinuria

There was no difference in the proportion of individuals diagnosed with a hypertensive disorder of pregnancy following the implementation of indicated urine screening (RR 1.00 [95% CI, 0.74 to 1.36]), but there was a trend toward fewer diagnoses of preeclampsia (RR 0.58 [95% CI, 0.35 to 0.98] and more diagnoses of gestational hypertension (RR 1.40 [95% CI, 0.94 to 2.08]) following implementation. Given the risk of bias inherent to historically controlled studies, however, these results may be due to factors other than the change in screening approach.

## KQ3. What Are the Harms of Different Screening Programs Used to Identify Hypertensive Disorders of Pregnancy?

### Summary of Results

The screening programs assessed for harms in this review are non-invasive, but new screening programs could result in unforeseen consequences related to the identification and management of hypertensive disorders of pregnancy or changes to the patient experience during pregnancy that could influence mental health outcomes such as anxiety or depression. Mode of delivery (Cesarean, induction) was included as a potential harm given the hypothetical risk that new screening programs could result in different medical decisions. Interpretation of these outcomes, however, is not straightforward since Cesarean delivery and induction of labor in some cases would reflect appropriate case management that would reduce risks for other adverse outcomes. Thus, these outcomes cannot be interpreted in isolation. Two home blood pressure measurement screening studies reported on harms: one trial reported emergency Cesarean delivery and both trials reported anxiety. Results were not suggestive of harms associated with the intervention. No differences in reported Cesarean delivery or anxiety and depression during or after pregnancy were reported in three trials testing interventions of reduced prenatal care visits. The NRSI historical control study of indicated urine screening also did not find different rates of Cesarean delivery following the change in practice from routine screening. Overall, there was no evidence that different strategies for screening for hypertensive disorders of pregnancy resulted in serious or significant harms. Trials included for evaluating harms, however, included few participants belonging to the populations at greatest risk for adverse consequences of hypertensive disorders of pregnancy in the US.

### Included Studies

Key question 3 included the same 5 studies described in Key Question 1<sup>95, 96, 98, 99, 104</sup> and one additional study (**Tables 5 and 6**). The additional study was a fair-quality study of home blood pressure measurement<sup>97</sup> conducted in the UK, which enrolled 80 participants at low risk for hypertensive disorders of pregnancy between 24 and 28 weeks of gestation and randomly assigned them to an intervention that reduced the number of prenatal visits in the second half of pregnancy (3 visits) but provided participants with training and instructions to conduct weekly home blood pressure screening, or a comparison group that received care according to a standard care prenatal visit schedule that involved more frequent office visits in the second half of pregnancy. The number of pregnancy-related visits to the general practitioner or midwife clinics was reduced in the intervention group (3.2 vs 5.6). Due to home measurement of blood pressure, the intervention group received blood pressure screens in more weeks overall (8.9 weeks vs 6.9 weeks).

## Detailed Results by Outcome

### Home Blood Pressure Measurement Interventions

Cesarean delivery is often cited as a potential harm in trials examining interventions to improve maternal and neonatal pregnancy outcomes. In the case of hypertensive disorders of pregnancy, however, cesarean delivery may provide benefit in terms of hastening delivery in patients whose clinical status does not allow time for induction of labor. Because it is a commonly reported outcome for antenatal intervention trials, we have also included it here, but recognize that cesarean delivery may be performed for medical necessity and therefore is considered a benefit in some circumstances.

Differences in rates of cesarian delivery could be attributed to the timing of clinical presentation and the course of the illness. In the BUMP trial (N = 2,441), the proportion of patients having emergency Cesarean delivery before and during labor was very similar between study groups, with slightly fewer cases in the home measurement group than the usual care group (RR 0.89 [95% CI, 0.76 to 1.03]).<sup>104</sup> The risk of induction or Cesarean delivery for a hypertension-related complication was also similar between groups: 7.8 percent with the addition of home blood pressure measurement and 7.1 percent with usual care (RR 1.09 [95% CI, 0.82 to 1.45]).

The BUMP trial also reported the mean difference between study groups in anxiety using the State Trait Anxiety Inventory short form (STAI-6). Anxiety was slightly lower in the home measurement group at 30 weeks of gestation (mean difference -1.45 [95% CI, -3.11 to 0.22]) and postpartum (12 months after baseline) (mean difference -1.37 [95% CI, -3.25 to 0.51]). These represent small differences on this 6-item instrument using 4-point Likert scale responses sets (scale range 6 to 24),<sup>109</sup> and the differences were not statistically significant. The smaller trial of home blood pressure measurement and a reduced office-visit schedule for low-risk pregnancies (N = 80) reported anxiety measured at four time points using the State Trait Anxiety Inventory (STAI).<sup>97</sup> The STAI includes 20 items with responses measured on a 4-point Likert scale resulting in a possible score range of 20 to 80, with higher scores reflecting higher anxiety levels.<sup>110</sup> At all of the time points reported (28, 34, 38 weeks of gestation, 6 weeks postpartum) the mean anxiety ranged from 35 to 38 in both the home measurement and usual care groups, and there were no differences between groups.

### Reduced Prenatal Screening Visit Schedules

Data on Cesarean deliveries were reported in all three trials of reduced prenatal visit schedules. The small US trial (N = 81) reported no cases in the reduced visit condition and 3 cases in the usual care control condition, and did not provide data on the reason or indication.<sup>99</sup> The large US trial (N = 2,328) reported Cesarean delivery for any indication for intervention (13.0%) and control groups (12.0%) or for fetal distress (2.0% vs 2.2%, respectively).<sup>96</sup> The relative risks between groups were small for both outcomes, with confidence intervals including the null. Similarly, the large UK trial (N = 2,794) reported overall rates of inductions (intervention group: 18.0% vs control group: 16.9%) and Cesarean deliveries (13.9% vs 15.4%).<sup>98</sup> Rates of hypertension-related induction (2.4% vs 2.7%) and hypertension-related cesarean delivery (0.8%

vs 1.0%) were also similar between intervention and control groups. Relative risks for all of these outcomes were close to or less than one, with no statistically significant differences.

The small US trial reported anxiety measured at 36 weeks of gestation with the STAI instrument (described above).<sup>99</sup> Numeric results were not presented but the authors noted in the study text that there were no statistically significant differences between the two study groups. The large UK trial measured anxiety and depression during pregnancy (34 weeks of gestation) and postpartum (2.7 years postpartum, on average).<sup>98</sup> Mean anxiety, measured using the anxiety subscale (7 items) of the Hospital Anxiety and Depression Scale (HADS), and depression, measured with the Edinburgh Postnatal Depression Scale (EPDS), were not different between groups during pregnancy or at over two years postpartum.

### **Indicated Rather Than Routine Urine Screening for Proteinuria**

The NRSI with a historical control (N = 2,441) of indicated urine screening reported similar rates of cesarean delivery (any indication) in the indicated screening group (17.8%) and the routine screening group (18.5%).<sup>95</sup>



# Chapter 4. Discussion

## Summary of Evidence

This review of the comparative effectiveness of screening strategies for hypertensive disorders of pregnancy included six studies, three conducted in the United States and three in the United Kingdom. Two RCTs tested interventions involving home blood pressure measurement as a supplement or replacement for prenatal care visits,<sup>97, 104</sup> three RCTs evaluated reduced prenatal visit schedules for individuals at low risk for complications,<sup>96, 98, 99</sup> and one NRSI with a historical control compared indicated urine screening with routine screening at all prenatal visits.<sup>95</sup> The evidence was insufficient or low for concluding that there was not a difference between the interventions studied and control conditions for a range of health outcomes (**Table 7**). All included studies were determined to have some risk of bias due to factors such as baseline group imbalances, potential confounding, or loss to followup. Additionally, the confidence intervals estimated for the most serious, but rare, pregnancy outcomes reported were too wide to rule out differences between study groups. The applicability of the evidence was limited for the RCTs of reduced visit schedules and for the study of indicated urine testing because they were conducted in settings that are not representative of the demographic composition of the US population and apply to screening only among individuals at low risk of pregnancy complications. One study, evaluating home blood pressure measurement as a supplement to usual care, enrolled a population selected based on risk factors for preeclampsia. None of the studies were conducted to evaluate interventions among the US populations with the highest rates of hypertensive disorders of pregnancy, Black and AI/AN people; these populations made up few or none of the participants in the included studies. The NRSI with historical control provided very limited evidence on the effects of indicated urine screening compared to routine screening for US pregnant populations due to risk of bias inherent to the study design and because it was narrowly focused on just one important population, mostly consisting of Hispanic individuals who had public health insurance or were uninsured.

A 2022 literature review with a broader scope included evidence on different prenatal care programs and in including qualitative studies.<sup>111</sup> The findings were similar to ours with regard to the limited evidence available for comparing different schedules and virtual care approaches for antenatal health care and their effects on health outcomes. When comparing different antenatal screening schedules and telehealth interventions evidence on health outcomes was insufficient for drawing conclusions. Additionally, the review identified themes from studies on patient and provider perspectives; potential barriers to access and reduced health care quality were seen for some prenatal schedules and telehealth interventions. Overall, the review also pointed to the limited evidence base and need for further research.<sup>111</sup>

# Current Clinical Context of Screening for Hypertensive Disorders of Pregnancy in Prenatal Care

Overall, this review highlights the limited resources that have been devoted to clinical research on antenatal screening practices that have been standard of care for decades.<sup>112</sup> Blood pressure measurement during pregnancy has long been recognized as important for screening for signs of complications that can pose serious maternal and infant health risks. Sustained high blood pressure is a key diagnostic criterion for preeclampsia, and routine measurement of blood pressure over the course of pregnancy serves to establish baseline values and to identify the emergence of new-onset hypertension. Office-based blood pressure measurement at prenatal care visits is standard practice, conducted following schedules historically established through expert consensus.<sup>112</sup> There are hints from newer research, including a trial identified in this review, that innovations in prenatal care practice are emerging. These innovations include changes to standard prenatal visit schedules, the use of virtual visits and home blood pressure measurements that should be further tested in prenatal and post-partum care for individuals with different levels of risk for developing hypertensive disorders of pregnancy. The impact of these changes on health outcomes and potential harms is unclear, as a body of high-quality research evidence is lacking.

## Home Blood Pressure Monitors and Telehealth Practices

### Home Blood Pressure Measurement

The option of having patients monitor their blood pressure at home through routine home blood pressure measurement is appealing for multiple reasons, including allowing for increased frequency of surveillance outside of the office setting (particularly for individuals at increased risk of developing a hypertensive disorder of pregnancy); to address concerns about white coat or masked hypertension; and for use in conjunction with telehealth visits or a reduced prenatal visit schedule. Potential health benefits of home blood pressure measurement include earlier detection of hypertension and less under- or over-diagnosis of hypertension. Qualitative research performed in preparation for the BUMP trial also suggests that home blood pressure monitoring may help reduce an individual's anxiety about their health during pregnancy, as well provide reassurance and a sense of empowerment, especially among those with a prior history of hypertensive disorder during pregnancy.<sup>113</sup> Potential risks include inaccurate readings, missed opportunities for intervention on severe-range blood pressure, and patient anxiety about performing the measures themselves. Existing systematic reviews have identified that studies comparing home and office measurements of blood pressure during pregnancy have significant heterogeneity,<sup>114, 115</sup> with many studies utilizing devices not clinically validated for use in pregnancy.<sup>78, 114</sup> An individual patient data meta-analysis published in 2018 included 8 studies of home blood pressure measurement during pregnancy, only 2 of which used validated blood pressure cuffs.<sup>115</sup> Pooled data for 7 studies showed no significant mean differences between home and office blood pressure readings in early or late pregnancy, but there was substantial variability among the studies, with some suggesting higher and some suggesting lower readings for home measurements compared to office measurements. Further, the mean differences between home and office readings were greater for women with a diagnosis of hypertension than

for normotensive women. A more recent systematic review published in 2021 identified a greater number of studies enlisting validated home blood pressure devices. In the 2021 review, pooled data from 7 studies that utilized validated home monitors to compare home and office blood pressure assessments indicated that home blood pressure measures were lower on average than office values (mean difference  $-4\text{mmHg}$  [95% CI,  $-7$  to  $-2$ ]) for both systolic and diastolic blood pressure.<sup>114</sup>

A trial identified in this review, the BUMP1 trial, randomized participants at increased risk for hypertensive disorders of pregnancy to home blood pressure measurements in addition to usual care or to usual care only.<sup>104</sup> The trial incorporated the use of a portable blood pressure cuff validated for use in pregnancy along with a mobile-phone-based application that provided feedback to the patient about their blood pressure readings. The study was not technically a telehealth intervention since there was no transmission of blood pressure readings to clinical care providers. Instead, participants were instructed to contact their health care provider if elevated home blood pressure readings were recorded. Based on the lack of differences in maternal and neonatal outcomes seen in this trial, including lack of earlier detection of hypertensive disorders of pregnancy in the blood pressure self-measurement in the intervention group, one could argue that there is no benefit associated with the added burden of home blood pressure checks. However, there was also no increased risk to the mother or neonate, and, like the study by Ross-McGill et al,<sup>97</sup> the authors did not find increased anxiety associated with ongoing home blood pressure measurements. These findings may support the safe use of this technique in the future for reporting blood pressures to providers in a virtual visit setting. Future research is needed to determine the value of telehealth and home blood pressure self-measurement for individuals with and without risk factors for hypertensive disorders of pregnancy.

While beyond the scope of the current review, home blood pressure monitors and self-measurement have been employed as part of ongoing monitoring for individuals diagnosed with hypertensive disorders of pregnancy. However, existing reviews have highlighted the need for more high-quality studies examining the safety and efficacy of home blood pressure monitoring in this context as well.<sup>114, 116</sup> One completed feasibility trial (OPTIMUM-BP) of 154 pregnant individuals with chronic or gestational hypertension found no differences in blood pressure or antihypertensive medication use and similar maternal and perinatal outcomes between those utilizing home blood pressure monitoring versus usual clinic monitoring.<sup>117</sup> Similarly, the BUMP2 randomized trial also examined the use of home blood pressure monitoring in individuals diagnosed with chronic or gestational hypertension and did not find a difference in blood pressure control between the study groups.<sup>104</sup> Other studies have also focused on the use of postpartum monitoring of individuals identified with hypertensive disorders of pregnancy at or prior to delivery. One randomized trial ( $N = 206$ ) of postpartum text-messaging based monitoring of home blood pressure readings found greater ascertainment of postpartum blood pressure measurements than in the office-based follow control group.<sup>118</sup> In addition, while Black participants ( $N = 141$ ) in the usual care (office-based) arm were half as likely to receive office-based blood pressure checks compared with participants of other races (33% versus 70%), this difference was not seen in the text-messaging based arm (91% versus 93%).<sup>119</sup> Other nonrandomized studies have similarly found that remote blood pressure monitoring can improve postpartum monitoring among individuals with a hypertensive disorder of pregnancy.<sup>120-122</sup>

## **Telehealth Interventions for Screening for Hypertensive Disorders of Pregnancy**

Technology-enhanced health care allows health care providers to reach patients outside the office setting using a variety of tools that leverage web and mobile phone capabilities for live audio-visual communication. These can include mobile phone applications (apps) and text messaging, and Bluetooth enabled devices. The term “telehealth” refers to health care delivery enhanced by telecommunication; telehealth and can be used to assist in remote patient assessments (e.g., blood pressure, weight, and capillary blood glucose measures) and clinical diagnosis, as well as in patient education and training.<sup>123</sup> Telehealth is increasingly recognized as a potential tool for improving maternal health outcomes, and is touted as a possible solution to problems of access to high-quality prenatal care problems experienced by individuals living in rural or medically historically and intentionally disinvested areas. Evidence on the use of telehealth for screening for hypertensive disorders of pregnancy is limited, as highlighted by our current review and others,<sup>111, 123, 124</sup> and future research could assess its value in prenatal and postpartum care.

A broadly scoped rapid literature review conducted in 2021 provided an overview of several aspects of prenatal care delivery across a range of health conditions.<sup>125</sup> The review included 53 studies evaluating different components of prenatal care delivery also found limited evidence related to the best approaches to screening for hypertensive disorders of pregnancy. This review identified no differences in health outcomes for patients without a preexisting medical conditions between those who received telehealth visits for routine prenatal care and those who received usual office-based care.<sup>125</sup> In addition, the review also assessed the accuracy, feasibility, and health effects of home blood pressure measurement in patients with chronic medical conditions, such as diabetes and hypertension. The review supported the conclusion that telemedicine in pregnancy to manage higher-risk patients is promising, but that more evidence is needed.

## **Screening for Hypertensive Disorders of Pregnancy in the Context of Racial Inequities in Pregnancy Outcomes in the United States**

As discussed, race and ethnicity are social rather than biological designations, but are powerful predictors of health risk. Many social conditions that contribute to worse general health status, including poverty, lack of health insurance, rural residence, and other social and structural determinants of health, are associated with poor birth outcomes regardless of a person’s race or ethnicity. However, Black and AI/AN individuals face particularly high risks for hypertensive disorders of pregnancy and increased risk of morbidity and mortality, even when controlling for a range of other demographic characteristics and comorbidities (see Background section on Health Inequities); accordingly, we focus on Black and AI/AN individuals in this report.<sup>26, 126</sup> Various structural conditions that contribute to the distribution of health and health care resources in society underlie observed health inequities. The concept of systemic or structural racism refers to the policies and practices that lead to racial inequities in the conditions of living, including housing options,<sup>69</sup> safety, education, nutrition, and stress levels<sup>63, 126, 127</sup> and ultimately to inequities in health and well-being.<sup>128</sup> There is also emerging evidence that exposure to certain contaminants in drinking water,<sup>68</sup> poor air quality (often due to traffic),<sup>66</sup> and other historical and persistent features of the built environment<sup>129</sup> may contribute to the risk of developing

hypertensive disorders of pregnancy and related health complications. In addition to structural factors that shape the conditions of life, overt interpersonal racism and implicit bias can lead to mistreatment in health care settings.<sup>57, 58, 130</sup>

## **Multilevel and Structural Interventions to Address Inequities in Incidence of Hypertensive Disorders of Pregnancy and Related Morbidity and Mortality**

Given the racial and ethnic inequities in the incidence and severity of hypertensive disorders of pregnancy, and the resulting inequal outcomes of pregnancy, there is a need for health care programs to better support Black people in pregnancy and birth, as well as other at-risk populations, including AI/AN people and specific subpopulations within the broader Asian and Hispanic/Latino race/ethnicity categories. Several important projects have been undertaken in recent years to highlight inequities and point toward interventions to address profound inequities in maternal health outcomes for Black and AI/AN people in the United States. First, the National Academies of Sciences, Engineering, and Medicine (NASEM) convened a workshop on advancing maternal health equity and published a report on the proceedings (2021).<sup>130</sup> Second, the National Quality Forum, funded by the Centers for Medicare and Medicaid Services, published a report on maternal morbidity and mortality measurement (2021).<sup>131</sup> Finally, and perhaps most comprehensively, the Surgeon General's Call to Action to Improve Maternal Health (2020) outlines a range of actions that health care professionals, public health institutions, health systems, hospitals, birthing facilities, employers, payors, researchers, states, tribes, and communities should undertake to improve and address inequities in maternal health in the United States.<sup>132</sup> These reports, and several additional publications providing additional context, were used to define the scope of the problem of racial inequities in hypertensive disorders of pregnancy and related complications.

Given the complex factors that contribute to health inequities,<sup>14, 130, 132</sup> multilevel interventions are needed to address them. Inequities in chronic conditions that increase the risk for hypertensive disorders of pregnancy for those entering pregnancy must be addressed through interventions that change health trajectories in childhood and early adulthood.<sup>126</sup> For example, changes to school nutritional programs and development of open spaces for recreation are likely essential to improving health in communities experiencing food insecurity and unsafe neighborhoods, but cannot be addressed at the level of clinical care. The availability of prenatal care services that are accessible and affordable is also likely critical to addressing these inequities but cannot be wholly addressed by individual clinicians or health systems.

## **Clinical Interventions to Address Inequities in Incidence of Hypertensive Disorders of Pregnancy and Related Morbidity and Mortality**

Screening for hypertensive disorders of pregnancy is a necessary but not sufficient intervention to improve inequities in health outcomes given existing barriers to accessing early and adequate prenatal care. In the absence of interventions to improve preconception health and remove barriers to prenatal care, interventions to change clinical practice will have only partial potential

to reduce inequities. Clinicians are at a disadvantage in serving their patients if they are not able to screen for hypertensive disorders of pregnancy until late in pregnancy; this results in missed opportunities to take a clinical history, address patient concerns, and partner with other organizations to offer service supports when needed. In some communities, health care resources are not robust, and healthcare is unaffordable or difficult to access. This makes it difficult to establish ongoing, culturally humble and competent relationships that precede pregnancy and continue across the life course.<sup>126</sup> Studies of new models of care hold promise for providing patients with better links to clinicians, other pregnant people, and community resources.<sup>133, 134</sup> Where health care and other community resources are limited, particularly in rural areas, the Surgeon General's Call to Action to Improve Maternal Health has recommended increases in the number of health care providers and expansion of public insurance eligibility.<sup>132</sup> Beyond strengthening access to health care, additional interventions applicable to clinical care could be consequential for reducing adverse outcomes.<sup>132, 135</sup>

### **Awareness of HDP Risk**

One possible intervention would be to increase clinician awareness of groups with elevated risk of hypertensive disorders of pregnancy and adverse outcomes, such as preeclampsia risks in Black and AI/AN populations, in order to improve dissemination of preventive measures. The USPSTF has recommended that all pregnant Black individuals should be considered for low-dose aspirin to prevent preeclampsia, with aspirin use recommended in those with at least one other moderate risk factor.<sup>51</sup> Clinicians should also be aware of increased adverse outcome risks of hypertensive disorders of pregnancy for specific populations, such as a two times higher risk of stroke with hypertensive disorders of pregnancy among Black and Hispanic/Latino people compared with White people;<sup>27</sup> this could encourage clinicians to focus clinical energy and resources to those most likely to suffer morbidity or mortality. Newer initiatives, such as the Maternal Vulnerability Index (<https://mvi.surgoventures.org/>), may help clinicians access and interpret data on inequities in risk. Local and regional data could also help clinicians focus on the risks to their birthing populations and develop appropriate interventions addressing the local issues driving inequities.<sup>135</sup>

### **Improved Surveillance and Disease Management**

Once a hypertensive disorder of pregnancy is detected through screening, ongoing monitoring and evidence-based management of severe hypertension and preeclampsia reduces the risk of adverse pregnancy outcomes.<sup>1</sup> Race and ethnicity have been found to be associated the likelihood of receiving some recommended treatments.<sup>64, 136</sup> This likely contributes to the risks for adverse outcomes cited above. Best practices for managing hypertensive disorders of pregnancy can be implemented with clear and standardized clinical bundles, which can help ensure that individuals receive appropriate anti-hypertensive medication, ongoing clinical evaluation of the safety of expectant management or induction of labor, and magnesium sulfate to prevent eclampsia and stroke when indicated.<sup>137, 138, 139, 140</sup> Studies of different programs for monitoring people with chronic hypertension or diagnosed with HDP are also important for ensuring the timely delivery of interventions that reduce complication risks. Programs focused on the populations at greatest risk for morbidity and mortality from HDP are particularly important for reducing the burden of disease.

## **Enhanced Attention to Health Risks Emerging Postpartum**

Black people and (in fewer studies) Hispanic/Latino people are seen to have increased risk of a hypertension-related hospital readmissions after delivery, due to new-onset or worsening existing hypertension and other complications.<sup>141-143</sup> Patient presentation is more likely to be symptomatic (e.g., headache, shortness of breath, swelling) and emergent among Black and Hispanic/Latino patients than White patients.<sup>141, 144</sup> The observed increased risk of postpartum preeclampsia and admissions for hypertensive disorders of pregnancy for Black and Hispanic/Latino individuals warrant consideration of screening and blood pressure monitoring protocols that extend into the postpartum period.<sup>145, 146</sup> A 2019 systematic review that included 9 observational studies on postpartum monitoring screening for hypertensive disorders of pregnancy and gestational diabetes reported a pattern of lower rates of followup for Black and Hispanic people than White people in the 6 weeks after delivery.<sup>147</sup> Screening, monitoring, and risk assessment during the postpartum period could be important for reducing health inequities. There is evidence that Black individuals experience a less rapid decrease in blood pressure during the postpartum period than White individuals,<sup>148</sup> contributing to their risk for readmission.<sup>147</sup> Despite the evidence that hypertensive disorders of pregnancy can worsen or newly present in the weeks following birth, opportunities to be screened may be diminished due to health provider and insurance transitions, a focus on the neonate, and reduced continuity of support, particularly for populations at greater risk for complications.<sup>147, 149, 150</sup>

Screening for hypertensive disorders of pregnancy has historically been viewed as a focus of prenatal health since delivery usually resolves the condition. The emerging conceptualization of a “fourth trimester” of pregnancy is important for reducing health inequities,<sup>149</sup> given inequities in postpartum complications and risks of cardiovascular disease following pregnancy that are associated with hypertensive disorders of pregnancy.<sup>130, 151</sup> Screening and monitoring by a range of providers (nurse midwives, nurses, pediatricians, and lactation consultants), could help prevent serious adverse events and emergencies in the postpartum period.<sup>59</sup> Policy and practice innovations aimed at improving access to high-quality postpartum care have been identified as important for addressing inequities in maternal morbidity and mortality related to hypertensive disorders of pregnancy.<sup>148, 149</sup> An ongoing systematic review will address the healthcare strategies for postpartum individuals. Specifically, the review will address the (comparative) benefits and harms of alternative strategies for postpartum healthcare delivery and the extension of postpartum healthcare or health insurance coverage.<sup>152</sup>

## **Attention to Future Cardiovascular Health Risks Associated With HDP**

The risk of mortality from cardiovascular disease is also higher among non-Hispanic Black women. As noted in the Background, HDP is a risk factor for the development of cardiovascular disease. To address long term risks associated with hypertensive disorders of pregnancy it is important to educate clinicians who provide primary care about the increased risk of hypertension and cardiovascular disease associated with a history of hypertensive disorder of pregnancy. According to the 2019 American College of Cardiology (ACC)/American Heart Association (AHA) Guideline for primary prevention of cardiovascular disease, history of HDP is now a recognized female-specific risk enhancing factor that should be assessed and utilized to modify the 10-year atherosclerotic cardiovascular disease (ASCVD) clinical risk estimate for

adults at borderline (5% to <7.5%) and intermediate ( $\geq 7.5\%$  to <20%) ASCVD risk.<sup>153, 154</sup> Preterm birth is also recognized as an independent predictor of CVD,<sup>154</sup> and as previously noted, the risk of CVD after HDP is higher among individuals who also experienced a preterm birth. The ACC/AHA emphasizes the importance of lifelong monitoring of cardiovascular risk factors, such as blood pressure and diabetes, among individuals with a history of HDP; early identification of individuals at high risk for cardiovascular events; and the prioritization of patient education about lifestyle modification to reduce risk.<sup>154</sup> To accurately assess CVD risk, clinicians should incorporate questions regarding their patients' reproductive history into their preventive health care, including questions about history of hypertensive disorders and preterm birth.

## Limitations of Our Approach

The review scope was developed following USPSTF procedures for evaluating the effectiveness of screening, and thus focused somewhat narrowly on evidence that could isolate the contribution of different screening strategies to the detection of hypertensive disorders of pregnancy, the prevention of adverse health outcomes associated with hypertensive disorders of pregnancy, and potential screening harms. The primary screening test for hypertensive disorders of pregnancy is office-based blood pressure measurement provided at every prenatal care visit, amidst a bundle of other services that can influence health outcomes for hypertensive disorders of pregnancy and other obstetric complications. It is therefore challenging to disentangle the effects of blood pressure screening from other prenatal care co-interventions. We excluded several studies testing prenatal care model interventions that incorporated changes to approaches to screening for hypertensive disorders of pregnancy alongside other care delivery alterations intended to improve pregnancy outcomes (**Appendix C**). For example, we excluded an RCT evaluating the OB Nest model of care involving a reduced prenatal visit schedule, remote blood pressure measurements, telehealth, nurse support, and an online prenatal community.<sup>133</sup> Experiments aimed at improving the patient experience of prenatal care, and to ensure ongoing support and recommended screening during pregnancy, may lead to improved outcomes across a range of health conditions that can occur in pregnancy. The condition-specific focus of this clinical evidence review does not allow for more comprehensive consideration of studies examining the effectiveness of different ways of delivering comprehensive prenatal care services which include changes in screening for hypertensive disorders of pregnancy. The literature on monitoring for pregnant individuals with chronic hypertension or those diagnosed with a hypertensive disorder of pregnancy was also outside the scope of this review. The implementation of these interventions may result in a larger impact on maternal and child health than interventions related to initial screening.

## Limitations of the Evidence

There is a mismatch between the small amount of available evidence and the need for improved approaches to screening for hypertensive disorders of pregnancy. We identified very few studies evaluating different strategies for screening. The included evidence was mostly from nearly 20 years ago, some in settings that may not be applicable to the full range of US clinical settings



providing primary care in pregnancy and the postpartum period. As presented in the background section of this report, there are stark differences in the risk of hypertensive disorders of pregnancy, and morbidity and mortality related to severe manifestations of these disorders, between Black and AI/AN people and White people, and the available evidence did not provide insight into reducing these inequities. None of the include evidence focused on US Black and AI/AN US populations. In addition, limited public health surveillance data on specific subpopulations within broadly defined racial and ethnic groups (e.g., South Asian and Filipino populations) limits the development of research including or focusing on other groups that may also be at increased risk of hypertensive disorders of pregnancy.

A considerable body of research on hypertensive disorders of pregnancy addresses the clinical pathway after a diagnosis has been made, including the work highlighting the importance of evaluating and monitoring individuals diagnosed with HDP during pregnancy and in the postpartum period.<sup>155, 156</sup> A much smaller body of evidence has examined different approaches to screening, and no studies have focused on screening in the postpartum period.

The literature we searched included a large body of evidence focused on markers and multivariable models that could be used in early pregnancy to identify people likely to develop preeclampsia.<sup>157</sup> Many of these studies are referred to in the literature as “screening” investigations, but, strictly speaking, screening tools are used to identify individuals that have a condition, whereas prediction and risk assessment tools are generally used to identify a group of individuals with a greater chance of developing a condition who might benefit from prophylaxis or enhanced screening. To date, there is no good evidence that existing validated prediction models have strong performance across the full range of clinical populations in the United States,<sup>158, 159</sup> and the potential role of these models in screening for hypertensive disorders of pregnancy has not been established.

## **Future Research Needs and Emerging Issues**

The bulk of clinical research on hypertensive disorders of pregnancy has focused on prevention and treatment interventions to reduce morbidity and mortality. These efforts are critically important given only a few interventions are available to reduce, but not eliminate, the risk for adverse outcomes from preeclampsia and gestational hypertension. Considerable research has also been devoted to developing and testing risk prediction algorithms, with the aim of determining early in pregnancy who might be most at risk for poor outcomes related to preeclampsia. These algorithms could help to focus clinical attention on patients at high risk. Research on prevention, treatment and risk prediction is more developed, but screening for HDP is remains a key step in the clinical pathway to interventions needed to reduce risks for poor health outcomes. Research and interventions to address health inequities were addressed above. The broader research needs outlined below should be subject to priority setting that would identify areas from above, and from the following list that would be most important for addressing health inequities. Any studies taken to further the science on HDP would be most beneficial to population health if studies enrolled enough participants to be statistically powered to assess important health outcomes and to comparisons among groups with different risk levels, and especially Black and AI/AN individuals who face the highest mortality risk from HDP.

**Research on barriers to health care before and during pregnancy** is important for increasing the proportion of people entering pregnancy with baseline blood pressure measurements, preeclampsia risk assessment, and low dose aspirin prophylaxis if indicated. Since screening can only improve outcomes if it is used to identify HDP early in its course, before progression to severe features, patients that enter prenatal care at the time of delivery or late in pregnancy are at increased risk for complications.

**The development and evaluation of complex interventions** for individuals at greatest risk of morbidity and mortality from HDP is needed. Many people enter pregnancy care late and with existing clinical and demographic risk factors/markers of risk for hypertensive disorders. We identified one ongoing trial (**Appendix E**), informed by a social and structural determinants of health framework, that aims to prevent complications from hypertensive disorders of pregnancy by providing access to resources and supports to reduce social risks and stress (Social Risks-Focused Lifestyle Intervention to Reduce Preeclampsia [SAIL]) in pregnancy. Most behavioral interventions in pregnancy to reduce risks for hypertensive disorders of pregnancy focus on lifestyle factors related to diet and physical activity, and as discussed in the background have not yielded consistent evidence of effectiveness. More broadly framed intervention studies are needed, especially to address health inequities, that incorporate access to health care and preconception health, early prenatal care and community supports during pregnancy, as well as blood pressure screening as part of comprehensive antenatal care.

**Studies are needed to help identify optimal, adaptive screening schedules**, such that pregnant individuals are not under constant surveillance but are brought into a higher level of care when complications emerge. Hypertensive disorders of pregnancy can emerge unexpectedly and either remain stable or quickly lead to serious health risks. Many clinical practices in obstetrics and prenatal care are based on longstanding historical precedent, founded in clinical observation and trial and error but not necessarily evaluated or updated.<sup>112</sup> Pregnancy poses unique challenges and opportunities in preventive care and screening since it is time limited and evolves constantly. New experiments like the BUMP study that integrated home blood pressure measurement into prenatal care are needed to identify whether virtual health approaches could strengthen connections between patients and clinical care.

**Telehealth interventions** have the potential to improve access to care and the opportunity for more ongoing contact over the course of pregnancy, but there is very little evidence available to assess whether specific innovations involving telehealth might improve outcomes or lead to adverse or unintended consequences. Whether telehealth can help to address inequities in health, or will further exacerbate these inequities, also remains to be seen. Natural experiments in telehealth-delivered prenatal care visits during the COVID-19 pandemic may stimulate further research and innovation. Indeed, some ongoing studies may inform the use of telehealth or additional measurements to screen for hypertensive disorders of pregnancy.<sup>160, 161</sup> We did not include these studies given the number of other changes to health and health care occurring during the pandemic that would introduce confounding.

**Research on the basic science of HDP** and potential multigenerational effects is ongoing and important to better understand the placenta, signaling pathways, and inflammatory processes remain important in the search for risk markers and treatments.<sup>126</sup> The complex factors

contributing to higher risks for disease among Black and AI/AN people are also important to investigate to inform intervention development. Investigations into the effects of multilevel interventions to improve child and adolescent health on future pregnancy are also needed, given the roles of type II diabetes mellitus, obesity, and chronic hypertension in increasing risk for hypertensive disorders of pregnancy.

**Further research on recent changes to the diagnostic criteria of hypertension and preeclampsia** is needed to determine whether health outcomes have been improved as a result. Changes to the diagnostic criteria for preeclampsia such that proteinuria is no longer a necessary indicator will change the incidence of preeclampsia. Initial research suggests that while the total number of diagnoses will rise, the increase will be in mild cases,<sup>162</sup> potentially leading to modest improvements in neonatal outcomes<sup>163</sup> and improved identification of women with adverse outcomes from the condition that would not have been previously recognized.<sup>164</sup> Ongoing efforts to evaluate how trends in blood pressure and other measures differ in normal and hypertensive pregnancies are important for establishing meaningful diagnostic thresholds.<sup>165</sup>

**Research is needed to evaluate postpartum screening for new onset HDP** to ascertain whether this practice could prevent serious complications and mortality from rare but dangerous cases that manifest late. Currently screening for new onset HDP is not usually conducted in the postpartum period, nevertheless the scope of this review was defined such that studies of screening during pregnancy and extending into the postpartum period would have been included. However, while we identified several studies of postpartum monitoring among individuals diagnosed with a hypertensive disorder of pregnancy,<sup>118, 166, 167</sup> we did not identify any studies of screening among individuals without a diagnosis.<sup>168</sup> Postpartum preeclampsia cases have been identified as contributing to maternal morbidity and mortality, and the racial inequities discussed above. Research to evaluate screening programs designed to extend beyond the delivery hospitalization would be informative to clinical practice. Innovative approaches to postpartum blood pressure measurement, including home health visits that could include other services or the use of home blood pressure monitoring devices, deserve study.

**Studies to further clarify the value and role of proteinuria assessment** in prenatal care would potentially contribute to improvements in evidence-based practices. Routine urinalysis using point of care dipstick testing is a common prenatal care practice that has traditionally been used to screen for proteinuria and bacteriuria. The clinical benefits of this practice have not been supported, in part because previous reviews have shown that test accuracy is modest (below 80%).<sup>52, 80, 169</sup> A urine culture test is recommended to screen for asymptomatic bacteriuria in pregnancy (B recommendation)<sup>170</sup> and the test performance of routine proteinuria screening has been previously reviewed<sup>52</sup> and its value in clinical practice questioned.<sup>80</sup> Only one included study compared routine screening to indicated screening using a non-randomized study with a historical control design.<sup>95</sup> The study highlights important questions that deserve further study using lower risk of bias study designs, reporting more relevant outcomes, and enrolling a range of diverse patient populations, including large representative samples. Given that the clinical management of gestational hypertension and preeclampsia is similar, leading to heightened surveillance, treatment of severe high blood pressure, induced delivery when indicated, and administration of magnesium sulfate, further research is needed into the screening protocols and diagnostic pathways that are most important for improving clinical outcomes.

**Research on the best approaches for blood pressure monitoring** for people with chronic hypertension or diagnosed with HDP during pregnancy and postpartum would contribute to the literature on managing the condition and could identify areas for improving outcomes among those at greatest risk for complications. Although beyond the scope of this review, the next step in the clinical pathway from detection and diagnosis of HDP involves monitoring, and actions taken during that phase of disease management affect the health outcomes of screening.

## Conclusions

Screening using blood pressure during pregnancy at every prenatal encounter is a long-standing standard clinical practice that identifies hypertensive disorders of pregnancy; however, morbidity and mortality related to these conditions persists. There is limited evidence available to evaluate different strategies for screening that might ensure more timely identification of hypertensive disorders of pregnancy. Once hypertension is diagnosed, additional surveillance and testing inform the provision of interventions that can reduce the risk of adverse outcomes related to severe hypertension and preeclampsia. None of the studies included in this review identified clear differences in the benefits or harms of different screening strategies or schedules involving home blood pressure measurement, or the approach to urine screening for proteinuria. Large studies are needed to ascertain whether different screening approaches have detectable effects on rare but serious pregnancy outcomes that can develop in people with hypertensive disorders of pregnancy. Individuals with limited access to health care or poor-quality health care, with comorbid health conditions, exposed to toxic environmental or working conditions, and affected by structural racism are at increased risk for complications related to hypertensive disorders of pregnancy, and are also at risk of not being diagnosed, monitored, and intervened upon. Most pregnant people have their blood pressure taken at some point during pregnancy, and for many, a hypertensive disorder of pregnancy is first diagnosed at the time of delivery. Diagnoses made late offer less time for evaluation and stabilization and may limit intervention options. Future implementation research is needed to improve access to regular blood pressure measurement earlier in pregnancy and possibly continuing in the weeks following delivery.

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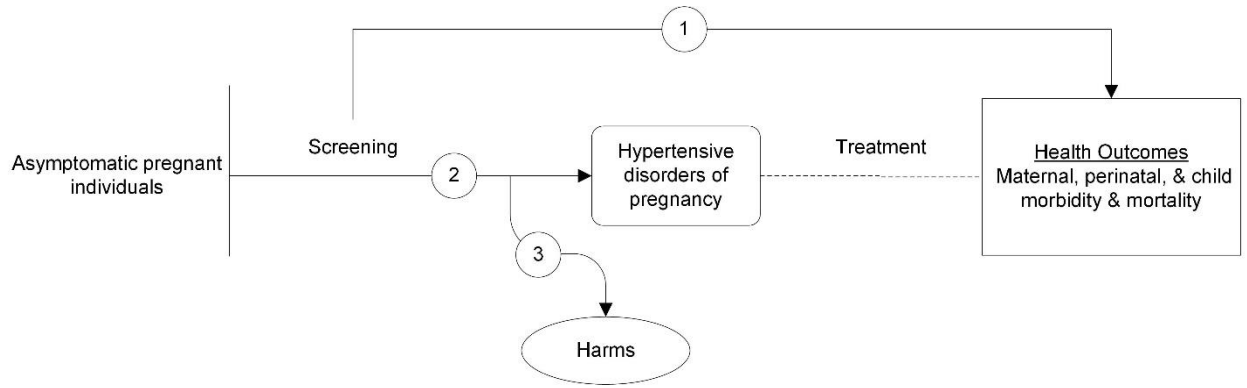
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**Figure 1. Analytic Framework**



**Table 1. Characteristics of Included Studies, by Intervention Category and Year**

Intervention Category	Author, Year Quality	Country	Design	N	Brief Population Description	Study Years	Screening Intervention	Screening Control
Home blood pressure measurement	Tucker, 2022 <sup>104</sup> Fair	UK	RCT	2,441	Pregnant individuals at higher risk of preeclampsia*, enrolled at 16 to 24 weeks of gestation	2018 to 2019	Standard prenatal visit schedule plus home blood pressure measurement 3 times a week with automated feedback via a mobile-phone application	Standard prenatal visit schedule with blood pressure measurement by usual antenatal care team
	Ross-McGill, 2000 <sup>97</sup> Fair	UK	RCT	80	Low-risk pregnant individuals, enrolled at 24 to 28 weeks of gestation	1996 to 1997 <sup>†</sup>	Reduced prenatal visit schedule in second half of pregnancy (3 visits) with home blood pressure measurement	Standard visit schedule in the second half of pregnancy (every 2 weeks from 28 to 36 weeks of gestation and weekly thereafter until delivery)
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup> Fair	US	RCT	81	Low-risk pregnant individuals, entered prenatal care before 26 weeks of gestation	1993 to 1994	Reduced prenatal visit schedule (8 visits)	Standard prenatal visit schedule (every four weeks until 28 weeks of gestation, every two weeks from 28 to 36 weeks of gestation, weekly thereafter until delivery)
	McDuffie, 1996 <sup>96</sup> Fair	US	RCT	2,328	Low-risk pregnant individuals assessed in first trimester	1992 to 1994	Reduced prenatal visit schedule (9 visits)	Standard prenatal visit schedule (14 visits)
	Sikorski, 1996 <sup>98</sup> Fair	UK	RCT	2,794	Low-risk pregnant individuals attending prenatal care by 24 weeks of gestation	1993 to 1994	Reduced prenatal visit schedule (7 visits for nullipara, 6 visits for multipara)	Standard prenatal visit schedule (13 visits)
Indicated vs. routine urinary screening	Rhode, 2007 <sup>95</sup> Fair	US	NRSI, historical control	2,441	General population accessing prenatal care	2000 to 2004	Urinary screening only if preestablished criteria were present <sup>‡</sup>	Routine urine screening at every prenatal visit

\*Age 40 years or older, nulliparity, pregnancy interval of more than 10 years, family history of preeclampsia, previous history of preeclampsia or gestational hypertension, body mass index 30 kg/m<sup>2</sup> or above at booking for pregnancy care, chronic kidney disease, twin pregnancy, pre-pregnancy diabetes (type 1 or 2), or autoimmune disease (e.g., systemic lupus erythematosus or anti-phospholipid disease).

<sup>†</sup><https://www.isrctn.com/ISRCTN20643323>

<sup>‡</sup> First prenatal visit; symptoms of urinary tract infection (dysuria, frequency, pain, fever, etc.); vaginitis symptoms; severe vomiting; weight loss of ≥0.9 kg since previous visit; systolic blood pressure elevated (≥140 mm Hg); diastolic blood pressure elevated (≥90 mm Hg); or any pregnancy requiring periodic urine testing (e.g., chronic hypertension, renal disease).

**Abbreviations:** NRSI = Non-randomized study of an intervention; RCT = Randomized controlled trial; UK = United Kingdom; US = United States.

**Table 2. Population Characteristics, by Intervention Category and Year**

Intervention Category	Author, Year	Mean Age	Study-Described Race/Ethnicity	SES Descriptors	History of Hypertensive Disorders of Pregnancy	Pre-Pregnancy Hypertension	Nulliparous	Multi-fetal Gestation
Home blood pressure measurement	Tucker, 2022 <sup>104</sup>	32.9	White (British, Irish, Other): 74% Asian or Asian British: 10% Black or Black British: 8% Other/Mixed: 7%	UK index of multiple deprivation decile: 6.1*	17%	0%	61%	6% <sup>†</sup>
	Ross-McGill, 2000 <sup>97</sup>	28.5	"Member of an ethnic minority": 7.5% <sup>‡</sup>	Employed: 84% Married: 68%	0%	0%	33%	0%
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup>	25.3	White: 22% Hispanic: 74% Asian American: 1.2%	Born outside United States: 76% Speak only Spanish: 56% Employed: 31% Married: 58% Insurance: Medicaid (82%), private (10%), uninsured (3%)	0%	0%	NR	0%
	McDuffie, 1996 <sup>96</sup>	28.5	White: 81% Hispanic: 12% Black: 4% Other: 2% <sup>¶</sup>	Mean years of education: 14.0	0% <sup>§</sup>	0% <sup>  </sup>	49%	1%
	Sikorski, 1996 <sup>98</sup>	28.0	"Member of an ethnic minority": 32%	Finished full time education in 16 years: 35% Living with partner: 81%	0%	0%	NR <sup>**</sup>	0%
Indicated vs. routine urinary screening	Rhode, 2007 <sup>95</sup>	24.7	Hispanic: 75% White: 19% Black: 9% Other: 6% <sup>¶</sup>	Married: 41% Single: 56% Insurance: Medicaid (89%), Uninsured (5%), private (6%)	NR	NR	NR	NR

\*Deprivation deciles are the official measure of relative deprivation, with decile 1 representing the most deprived and decile 10 representing the least deprived.

<sup>†</sup>Twins.

<sup>‡</sup>12.5% in intervention group and 2.5% in control group.

<sup>§</sup>History of severe preeclampsia.

<sup>||</sup>Chronic hypertension at baseline.

<sup>¶</sup>No other details reported.

<sup>\*\*</sup>Mean parity intervention group: 0.9, control group: 0.8.

**Abbreviations:** NR = Not reported; SES = socioeconomic status; US = United States.

**Table 3. KQ1: Health Outcomes, by Intervention Category**

Intervention Category	Author, Year	Outcome	IG Events (%)	CG Events (%)	IG vs. CG
Home blood pressure measurement	Tucker, 2022 <sup>104</sup>	Maternal mortality	0/1171 (0%)	0/1175 (0%)	NA
		One or more serious maternal health complications related to HDP*	15/1209 (1.2%)	19/1209 (1.6%)	RR: 0.79 (95% CI, 0.40 to 1.55) <sup>†</sup>
		Neonatal mortality	2/1248 (0.2%)	0/1240 (0%)	NA
		Stillbirth	5/1260 (0.4%)	3/1248 (0.2%)	RR: 1.65 (95% CI, 0.40 to 6.89) <sup>†</sup>
		IUGR/SGA (<10 <sup>th</sup> percentile)	104/1249 (8.3%)	87/1235 (7.0%)	Adj RR: 1.15 (95% CI, 0.87 to 1.53) <sup>‡</sup>
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup>	Miscarriage/fetal loss (<20 weeks of gestation)	0/61(0.0%)	4/61 (6.6%)	NA
		Preterm delivery (<37 weeks of gestation)	5/43 (11.6%)	2/38 (5.3%)	RR: 2.21 (95% CI, 0.45 to 10.7) <sup>†</sup>
		Neonatal sepsis	1/43 (2.3%)	0/38 (0.0%)	NA
		Neonatal respiratory distress	3/43 (7.0%)	0/38 (0.0%)	NA
		IUGR/SGA (<10 <sup>th</sup> percentile)	0/43 (0.0%)	1/38 (2.6%)	NA
	McDuffie, 1996 <sup>96</sup>	Postpartum hemorrhage <sup>§</sup>	34/1165 (2.9%)	36/1163 (3.1%)	RR: 0.94 (95% CI, 0.59 to 1.50) <sup>†</sup>
		Placental abruption	17/1165 (1.5%)	11/1163 (0.9%)	RR: 1.21 (95% CI, 0.90 to 1.64)
		Stillbirth/neonatal mortality	5/1175 (0.4%)	5/1176 (0.4%)	RR: 1.00 (95% CI, 0.54 to 1.86)
		Early preterm delivery (<32 weeks)	10/1165 (0.9%)	8/1163 (0.7%)	RR: 1.11 (95% CI, 0.73 to 1.68)
		Preterm delivery (<37 weeks)	73/1165 (6.3%)	63/1163 (5.4%)	RR: 1.08 (95% CI, 0.92 to 1.27)
		Very low birth weight (<1500g)	7/1175 (0.3%)	6/1176 (0.3%)	RR: 1.08 (95% CI, 0.65 to 1.79)
		Low birth weight (<2500g)	64/1175 (5.4%)	72/1176 (6.1%)	RR: 0.94 (95% CI, 0.78 to 1.12)
		IUGR/SGA (<10 <sup>th</sup> percentile)	36/1175 (3.1%)	28/1176 (2.4%)	RR: 1.13 (95% CI, 0.91 to 1.41)
	Sikorski, 1996 <sup>98</sup>	Maternal mortality	1/1359 (0.1%)	0/1396 (0.0%)	NA
		Postpartum hemorrhage	135/1358 (9.9%)	137/1390 (9.9%)	RR: 1.01 (95% CI, 0.80 to 1.26) <sup>†</sup>
		Antepartum hemorrhage	70/1360 (5.1%)	74/1391 (5.3%)	RR: 0.97 (95% CI, 0.70 to 1.33) <sup>†</sup>
		Stillbirth/neonatal mortality	7/1361 (0.5%)	10/1396 (0.7%)	RR: 0.72 (95% CI, 0.27 to 1.88) <sup>†</sup>
		IUGR/SGA (<3 <sup>rd</sup> percentile)	94/1355 (6.9%)	113/1393 (8.1%)	RR: 0.86 (95% CI, 0.66 to 1.11) <sup>†</sup>
			IUGR/SGA (<10 <sup>th</sup> percentile)	277/1355 (20.4%)	302/1393 (21.7%)
Indicated vs. routine urinary screening	Rhode, 2007 <sup>95</sup>	Preterm delivery <sup>  </sup>	50/1019 (4.9%)	72/933 (7.7%)	RR: 0.64 (95% CI, 0.45 to 0.90) <sup>†</sup>

\*Eclampsia, transient ischemic attack, or stroke, HELLP syndrome, liver involvement (ALT or AST >70 U/L), pulmonary edema, renal involvement (creatinine ≥90 mmol), or hematological involvement (platelets <x100<sup>9</sup>/L).

<sup>†</sup>Calculated.

<sup>‡</sup>Adjusted for group, parity, and site.

<sup>§</sup>Defined as >750 mL for vaginal birth and >1500 mL for cesarean birth.

<sup>||</sup>p-value for equivalence = 0.14 (A p-value <0.05 indicates that rates are equivalent at a statistically significant level.)

**Abbreviations:** CG = Control group; CI = Confidence interval; HDP = Hypertensive disorders of pregnancy; IG = Intervention group; IUGR/SGA = Intrauterine growth restriction/small for gestational age; NA = Not applicable; RR = Relative risk.

**Table 4. KQ2: Intermediate Outcomes, by Intervention Category**

Intervention Category	Author, Year	Outcome	IG Events (%) or Mean (SD)	CG Events (%) or Mean (SD)	IG vs. CG
Home blood pressure measurement	Tucker, 2022 <sup>104</sup>	HDP*	179/1171 (15.3%)	184/1175 (15.7%)	RR 0.98 (95% CI, 0.81 to 1.18) <sup>†</sup>
		Days to detection of HDP	104.3 (32.6)	106.2 (32.0)	Mean difference: -1.58 (95% CI, -8.10 to 4.94), p=0.64 <sup>‡</sup>
		Preeclampsia	51/1209 (4.2%)	51/1209 (4.2%)	RR 1.00 (95% CI, 0.66 to 1.51)
		Severe hypertension <sup>§</sup> (professionally measured)	69/1171 (6.0%)	57/1175 (4.9%)	RR 1.22 (95% CI, 0.87 to 1.70)
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup>	Preeclampsia	NR	NR	NS
		Gestational hypertension	2/43 (4.7%)	1/38 (2.6%)	RR 1.77 (95% CI, 0.17 to 18.7) <sup>  </sup>
	McDuffie, 1996 <sup>96</sup>	Preeclampsia <sup>¶</sup>	59/1165 (5.1%)	66/1163 (5.7%)	RR 0.94 (95% CI, 0.78 to 1.14)
		Preeclampsia with severe features <sup>**</sup>	10/1165 (0.9%)	9/1163 (0.8%)	RR 1.05 (95% CI, 0.68 to 1.62)
	Sikorski, 1996 <sup>98</sup>	Preeclampsia <sup>††</sup>	9/1240 (0.7%)	11/1286 (0.9%)	RR 0.85 (95% CI, 0.35 to 2.04) <sup>  </sup>
Indicated vs. routine urinary screening	Rhode, 2007 <sup>95</sup>	HDP	81/1019 (7.9%)	74/933 (7.9%)	RR 1.00 (95% CI, 0.74 to 1.36) <sup>  </sup>
		Preeclampsia <sup>‡‡</sup>	23/1019 (2.3%)	36/933 (3.8%)	RR 0.58 (95% CI, 0.35 to 0.98) <sup>§§</sup>
		Gestational hypertension <sup>   </sup>	58/1019 (5.7%)	38/933 (4.1%)	RR 1.40 (95% CI, 0.94 to 2.08) <sup>¶¶¶</sup>

\*Defined as sustained high blood pressure (2+ readings within 1 week) recorded in the clinical record, a recorded diagnosis of hypertension (including preeclampsia or gestational hypertension), or prescription of antihypertensive medication for raised blood pressure.

<sup>†</sup>Calculated RR. Study-reported adjusted (site, parity) hurdle effect: -0.02 (95% CI, -0.15 to 0.10). Difference in probability: 0.00 (95% CI, -0.03 to 0.02); p=0.751.

<sup>‡</sup>Adjusted for group, parity (0 or ≥1), and site as fixed effects.

<sup>§</sup>Systolic blood pressure ≥160 mm Hg and/or diastolic blood pressure ≥110 mm Hg.

<sup>||</sup>Calculated.

<sup>¶</sup>Mild preeclampsia was defined as a blood pressure measurement of 140/90 mm Hg or a blood pressure rise of 30/15 mm Hg over first-trimester levels accompanied by significant proteinuria (>300 mg/24 h) or edema (weight gain, >2.25 kg in 1 week).

<sup>\*\*</sup>Blood pressure measurement of 160/110 mm Hg, more than 5 g of urinary protein in 24 hours, oliguria, thrombocytopenia, or elevated liver function test findings.

<sup>††</sup>Defined according to the criteria of the International Society for the Study of Hypertension in Pregnancy.

<sup>‡‡</sup>Defined by at least 1 elevated blood pressure (>140/90 mm Hg) and proteinuria of any type, a discharge diagnosis of preeclampsia, or received magnesium sulfate during labor for preeclampsia-related signs or symptoms.

<sup>§§</sup>Study-reported test for group equivalence: p = 0.0011. A p-value <0.05 indicates that rates are equivalent at a statistically significant level.

<sup>|||</sup>Gestational hypertension was defined by only 1 elevated blood pressure (>140/90 mm Hg). Confirmation of return to normal blood pressure by 12 weeks postpartum was not possible within the study.

<sup>¶¶¶</sup>Study-reported test for group equivalence: p < 0.0001. A p-value <0.05 indicates that rates are equivalent at a statistically significant level.

**Abbreviations:** CI = Confidence interval; CG = Control group; HDP = Hypertensive disorders of pregnancy; IG = Intervention group; RR = Relative risk; SD = Standard deviation.

**Table 5. KQ3: Delivery Outcomes, by Intervention Type**

Intervention Category	Author, Year	Outcome	IG	CG	IG vs. CG
Home blood pressure measurement	Tucker, 2022 <sup>104</sup>	Induction or cesarean delivery for hypertension-related complication	92/1187 (7.8%)	84/1181 (7.1%)	RR 1.09 (95% CI, 0.82 to 1.45)*
		Emergency cesarean delivery	250/1259 (19.9%)	278/1244 (22.3%)	RR 0.89 (95% CI, 0.76 to 1.03)*
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup>	Cesarean delivery	0/43 (0%)	3/38 (7.9%)	NA
	McDuffie, 1996 <sup>96</sup>	Cesarean delivery	151/1165 (13.0%)	140/1163 (12.0%)	RR 1.04 (95% CI, 0.93 to 1.17)
		Cesarean delivery for fetal distress	23/1165 (2.0%)	26/1163 (2.2%)	RR 0.94 (95%: 0.69 to 1.27)
	Sikorski, 1996 <sup>98</sup>	Induction related to pregnancy-related hypertension	33/1358 (2.4%)	37/1395 (2.7%)	RR 0.92 (95% CI, 0.58 to 1.46)*
		Cesarean delivery for pregnancy-related hypertension	11/1359 (0.8%)	14/1396 (1.0%)	RR 0.81 to (95% CI, 0.37 to 1.77)*
		Induction of labor for any reason	244/1359 (18.0%)	236/1395 (16.9%)	RR 1.06 (95% CI, 0.90 to 1.25)*
		Cesarean delivery for any reason	189/1360 (13.9%)	215/1396 (15.4%)	RR 0.90 (95% CI, 0.75 to 1.08)*
Indicated vs. routine urinary screening	Rhode, 2007 <sup>95</sup>	Cesarean delivery	181/1019 (17.8%)	173/933 (18.5%)	RR 0.96 (95% CI, 0.79 to 1.16)*†

\*Calculated.

†Study-reported test for group equivalence:  $p = 0.029$ . A  $p$ -value  $< 0.05$  indicates that rates are equivalent at a statistically significant level.

**Abbreviations:** CI = Confidence interval; CG = Control group; HDP = Hypertensive disorders of pregnancy; IG = Intervention group; NA = Not applicable; RR = Relative risk.



**Table 6. KQ3: Mental Health and Quality-of-Life-Related Screening Harms, by Intervention Type**

Inter-vention category	Author, Year	Outcome	Time Point	IG N	IG Mean (SD or 95% CI)	CG N	CG Mean (SD or 95% CI)	IG vs. CG
Home blood pressure measurement	Tucker, 2022 <sup>104</sup>	Anxiety (STAI-6 short form)*	Baseline	1,203	23.4 (18.18)	1,191	23.2 (18.00)	NA
			30 weeks of gestation	884	25.5 (18.49)	881	27.0 (20.11)	Adjusted Mean Difference: -1.45 (95% CI, -3.11 to 0.22) <sup>†</sup>
			Postpartum (12 months after baseline)	672	23.3 (19.93)	688	24.6 (20.96)	Adjusted Mean Difference: -1.37 (95% CI, -3.25 to 0.51) <sup>‡</sup>
		HRQoL measured by EQ-5D-5L <sup>§</sup>	Baseline	1,202	0.870 (0.148)	1,194	0.862 (0.148)	NA
			30 weeks of gestation	875	0.783 (0.166)	897	0.767 (0.184)	Adjusted Mean Difference: 0.012 (95% CI, -0.002 to 0.026) <sup>¶</sup>
			Postpartum (12 months after baseline)	660	0.859 (0.158)	669	0.853 (0.160)	Adjusted Mean Difference: 0.004 (95% CI, -0.011 to 0.019) <sup>**</sup>
	Ross-McGill, 2000 <sup>97</sup>	Anxiety (STAI) <sup>††</sup>	28 weeks of gestation	40	37 (95% CI, 34 to 40)	39	37 (95% CI, 34 to 40)	Mean Difference: 0 (95% CI, -4.31 to 4.31) <sup>‡‡</sup>
			34 weeks of gestation	32	36 (95% CI, 32 to 40)	28	37 (95% CI, 33 to 41)	Mean Difference: -1 (95% CI, -6.5 to 4.5) <sup>‡‡</sup>
			38 weeks of gestation	24	38 (95% CI, 34 to 42)	23	38 (95% CI, 33 to 43)	Mean Difference: 0 (95% CI, -5.8 to 5.8) <sup>‡‡</sup>
			6 weeks postpartum	40	35 (95% CI, 32 to 38)	38	35 (95% CI, 32 to 38)	Mean Difference: 0 (95% CI, -3.9 to 3.9) <sup>‡‡</sup>
Reduced prenatal visit schedule	Walker, 1997 <sup>99</sup>	Anxiety (STAI) <sup>§§</sup>	36 weeks of gestation	43	NR	38	NR	NS <sup>  </sup>
	Sikorski, 1996 <sup>98</sup>	Antenatal/postnatal depression (EPDS) <sup>¶¶</sup>	34 weeks of gestation	901	8.8 (SD: 5.63)	933	8.6 (SD: 5.51)	P=0.712 <sup>***</sup>
			6 weeks postpartum	843	6.9 (SD: 4.96)	830	6.8 (SD: 5.06)	P=0.759 <sup>***</sup>
			2.7 years postpartum	548	5.7 (SD: 4.6)	554	6.1 (SD: 5.24)	P=0.965 <sup>***</sup>
		Anxiety (anxiety subscale of HADS) <sup>†††</sup>	2.7 years postpartum	541	5.2 (SD: 3.41)	549	5.3 (SD: 3.79)	P=0.781 <sup>***</sup>

\*The six-item short-form of the Spielberger State-Trait Anxiety Inventory. Scores scaled to 100 with higher scores indicating greater anxiety.

†There is high risk of bias for this outcome due to attrition and missing data.

‡Linear mixed-effects model of STAI-6 at 30 weeks and postnatal followup modelled against randomized arm, time point, the interaction between randomized arm and time point, parity, and baseline STAI-6 as fixed effects; site as a random effect, and a random intercept for each participant.

§There is high risk of bias for this outcome due to attrition and missing data.

¶EuroQol instrument 5 Dimensions 5 levels, converted to a single index score (on a scale where a score of 0 is equivalent to death and 1 to perfect health).

¶¶Multiple imputation analysis, adjusted for center, parity, and potential EQ-5D-5L index baseline imbalances. Completers adjusted mean difference: 0.012 (95% CI, -0.002 to 0.026), p-value NR.

**Table 6. KQ3: Mental Health and Quality-of-Life-Related Screening Harms, by Intervention Type**

\*\*Multiple imputation analysis, adjusted for center, parity, and potential EQ-5D-5L index baseline imbalances. Completers adjusted mean difference: 0.001 (95% CI, -0.015 to 0.017), p-value NR.

††State component of the State-Trait Anxiety Inventory. Includes 20 questions, scores range from 20 to 80 with higher scores indicating higher reported anxiety.

##Calculated.

§§State-Trait Anxiety Inventory. Both subscales include 20 questions with scores ranging from 20 to 80 with higher scores indicating higher reported anxiety.

|||Anxiety scores on both state and trait scales did not differ significantly between the two study groups at baseline or followup, nor was the change in state anxiety scores significantly different.

¶¶Edinburgh Perinatal/Postnatal Depression Scale, scores range from 0 to 30 with higher scores indicating higher likelihood of depression.

\*\*\*P-value from study-reported log-rank test.

†††Anxiety subscale of the Hospital Anxiety and Depression Scale, scores range from 0 to 21 with higher scores indicating higher symptoms of anxiety.

**Abbreviations:** CI = Confidence interval; CG = Control group; EPDS = Edinburgh Perinatal/Postnatal Depression Scale; EuroQoL-5D-5L = EuroQoL instrument 5 Dimensions 5 Levels; HDP = Hypertensive disorders of pregnancy; HADS = Hospital Anxiety and Depression Scale; HRQoL = Health related quality of life; IG = Intervention group; NA = Not applicable; NR = Not reported; NS = Not significant; SD = Standard deviation; STAI = State component of the State-Trait Anxiety Inventory.

**Table 7. Summary of the Evidence**

Intervention	Studies (K), Design Number of Observations (N) Country	Summary of Findings	Outcome(s)	Consistency and Precision	Overall Strength of Evidence	Body of Evidence Limitations	Applicability
KQ1							
Home blood pressure measurement	K = 1 fair-quality RCT N = 2,441 UK	Fewer than 2% of participants experienced serious HDP complications. The difference between groups was not statistically significant (RR 0.79 [95% CI, 0.40 to 1.55]).  Estimated risk of SGA/IUGR (RR 1.15 [95% CI 0.87 to 1.53]) was not statistically significant, with slightly more cases in the home measurement group (8.3% vs 7.0%)	Maternal morbidity and mortality	NA, imprecise	Insufficient	Underpowered for precise estimation of small differences and rare outcomes  Single study in one setting, lack of replication  Slight imbalance in baseline characteristics not accounted for in analysis	Individuals attending prenatal care by 16 to 24 weeks of gestation (in the UK) at increased risk for preeclampsia based on established clinical risk factors
			Neonatal morbidity and mortality	NA, imprecise	Insufficient		
			SGA/IUGR	NA, imprecise	Insufficient		
Reduced prenatal screening visit schedule	K = 3 fair-quality RCTs (N = 5,203) US, UK	Few cases of perinatal mortality, risk lower or the same in large trials (RR 0.72 and 1.00) with wide 95% confidence intervals.  Similar proportions with preterm delivery, SGA/IUGR, and low birthweight in two large trials (RRs ranged from 0.94 to 1.13); 95% confidence intervals contained null.  Placental abruption rarely occurred and was similar between groups in one large trial; confidence intervals contained null. The risk for postpartum hemorrhage was the same	Postpartum hemorrhage	Reasonably consistent, reasonably precise	Low for no difference	Heterogeneous outcomes reported  Modest risk of bias mostly related to absent information on long-term followup, but attrition low  Two larger trials underpowered to detect small differences in rare, serious outcomes; one small trial had too few events to estimate effects with any precision	US and UK populations of people at low risk for pregnancy complications  Change to number of blood pressure measurements resulted from a change in number of prenatal visits.  Confounding of blood pressure measurement with other clinical interventions that occur during prenatal visits limits conclusions
			Placental abruption	NA, reasonably precise	Insufficient		
			Perinatal mortality	Reasonably consistent, imprecise	Insufficient		
			Miscarriage, fetal loss	NA, imprecise	Insufficient		
			Neonatal sepsis, respiratory distress	NA, imprecise	Insufficient		
			Preterm delivery	Reasonably consistent, imprecise	Insufficient		
			Low birth weight	NA, reasonably precise	Insufficient		
			SGA/IUGR	Inconsistent, reasonably precise	Insufficient		

**Table 7. Summary of the Evidence**

Intervention	Studies (K), Design Number of Observations (N) Country	Summary of Findings	Outcome(s)	Consistency and Precision	Overall Strength of Evidence	Body of Evidence Limitations	Applicability
		or reduced with fewer visits (RR 1.01 and RR 0.94).					
Indicated rather than routine urine screening	K = 1 fair-quality NRSI, historical control (N = 2,441) US	Risk of preterm delivery was reduced with indicated urine screening (4.9%) compared with routine urine screening (7.7%); RR 0.64 (95% CI, 0.45 to 0.90)	Preterm delivery	NA, reasonably precise	Insufficient	Only one health outcome reported, possible selective reporting  Analysis unadjusted; increase in Medicaid health insurance eligibility and decrease in self-pay in indicated screening period compared with routine  Observational study design with inherent risk of concurrent changes (history)	U.S. population obtaining prenatal care in safety-net settings serving Medicaid-eligible populations, especially pregnant people reporting Hispanic ethnicity
<b>KQ2</b>							
Home blood pressure measurement	K = 1 fair-quality RCT (N = 2,441)	No statistical difference in days to detection of HDP (mean days -1.58 [95% CI, -8.10 to 4.94]).  No difference in HDP diagnoses (RR 0.98 [95% CI, 0.81 to 1.18]).  Slightly higher incidence of severe hypertension in home measurement group	HDP detection	NA, reasonably precise	Insufficient	Low risk of bias for health outcomes collected from medical record, minor group imbalance at baseline could bias toward null  Single study in one setting	Individuals attending prenatal care by 16 to 24 weeks of gestation (in the UK) at increased risk for preeclampsia based on established clinical risk factors

**Table 7. Summary of the Evidence**

Intervention	Studies (K), Design Number of Observations (N) Country	Summary of Findings	Outcome(s)	Consistency and Precision	Overall Strength of Evidence	Body of Evidence Limitations	Applicability
		(6.0% vs. 4.8%), but not statistically different (RR 1.22 [95% CI, 0.87 to 1.70])				Underpowered for precise estimation of small differences and rare outcomes	
Reduced prenatal screening visit schedule	K = 3 fair-quality RCTS (N = 5,203)	No differences in diagnoses of HDP.  A large US trial showed a trend toward fewer individuals diagnosed with preeclampsia and more with gestational hypertension, but equal diagnoses of preeclampsia with severe features (RR 1.01 [95% CI, 0.68 to 1.62])	HDP detection	Reasonably consistent, reasonably precise	Low for no difference	Differences between the intervention and control schedules were smaller than planned (difference between arms ranged from 2.2 to 3.2 visits)	US and UK populations at low risk for pregnancy complications of people attending prenatal care  Change to number of blood pressure measurements resulted from a change in number of prenatal visits.  Confounding of blood pressure measurement with other clinical interventions that occur during prenatal visits limits conclusions
Indicated rather than routine urine screening	K = 1 fair-quality NRSI, historical control (N = 2,441)	Fewer diagnoses of preeclampsia (RR 0.58 [95% CI, 0.35 to 0.98]) and a trend toward more with gestational hypertension; no difference in diagnoses of HDP overall (RR 1.00 [95% CI, 0.74 to 1.36])	HDP detection	NA, reasonably precise	Insufficient	Analyses unadjusted; increase in Medicaid health insurance eligibility and decrease in self-pay in indicated screening period compared with routine	U.S. populations obtaining prenatal care in safety-net settings serving Medicaid eligible populations, especially pregnant people reporting Hispanic ethnicity

**Table 7. Summary of the Evidence**

Intervention	Studies (K), Design Number of Observations (N) Country	Summary of Findings	Outcome(s)	Consistency and Precision	Overall Strength of Evidence	Body of Evidence Limitations	Applicability
KQ3							
Home blood pressure measurement	K = 2 fair-quality RCTs (N = 2,521)	<p>One large trial reported similar rates of induction of labor and cesarean delivery for hypertension related complications (RR 1.09 [95% CI, 0.82 to 1.44]) and similar rates of emergency cesarean delivery (RR 0.89 [95% CI, 0.76 to 1.03])</p> <p>Two trials reported no difference in anxiety (STAI) during pregnancy or postpartum</p>	Delivery outcomes	NA, reasonably precise	Insufficient	<p>Risk of bias higher for anxiety outcome measures due to high loss to followup and missing data</p> <p>Single study in one setting, lack of replication</p>	<p>Individuals attending prenatal care by 16 to 24 weeks of gestation (in the UK) at increased risk for preeclampsia based on established clinical risk factors</p>
			Mental health/HRQoL	Reasonably consistent, reasonably precise	Insufficient		
Reduced prenatal screening visit schedule	K = 3 fair-quality RCTS (N = 5,203)	<p>Two large trials reported similar levels of Cesarean delivery or induction of labor for any reason and for reasons related to hypertension or fetal distress (between-group differences <math>\leq</math>1.5%, RRs 0.81 to 1.06). A small trial had too few cases to test differences in Cesarean delivery.</p> <p>None of the trials found differences in anxiety or postnatal depression between study groups; different measures and time points reported.</p>	Delivery outcomes	Inconsistent, reasonably precise	Insufficient	<p>Risk of bias higher for anxiety outcomes due to higher loss to followup and incomplete data</p>	<p>US and UK populations at low risk for pregnancy complications of people attending prenatal care</p> <p>Change to number of blood pressure measurements resulted from a change in number of prenatal visits.</p> <p>Confounding of blood pressure measurement with other clinical interventions that occur during prenatal visits limits conclusions</p>
			Mental health/HRQoL	NA, reasonably precise	Insufficient		

**Table 7. Summary of the Evidence**

Intervention	Studies (K), Design Number of Observations (N) Country	Summary of Findings	Outcome(s)	Consistency and Precision	Overall Strength of Evidence	Body of Evidence Limitations	Applicability
Indicated rather than routine urine screening	K = 1 fair-quality NRSI, historical control (N = 2,441)	Similar risk for cesarean delivery (RR 0.96 [95% CI, 0.79 to 1.16])	Delivery outcomes	NA, reasonably precise	Insufficient	Analyses unadjusted; increase in Medicaid health insurance eligibility and decrease in self-pay in indicated screening period compared with routine  Reason for cesarean delivery not provided	U.S. populations obtaining prenatal care in safety-net settings serving Medicaid-eligible populations, especially pregnant people reporting Hispanic ethnicity

**Abbreviations:** CI = Confidence interval; HDP = Hypertensive disorders of pregnancy; HRQoL = Health-related quality of life; NA = Not applicable; NRSI = Non-randomized study of an intervention; RCT = Randomized controlled trial; RR = Relative risk; SGA/IUGR = Small for gestational age/intrauterine growth restriction; STAI = State component of the State-Trait Anxiety Inventory; UK = United Kingdom; US = United States.

## Search Strategy

Key:

/ = MeSH subject heading

\$ = truncation

ti = word in title

ab = word in abstract

pt = publication type

\* = truncation

kw = keyword

adj = adjacent

### MEDLINE

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily <1946 to May 28, 2021>

Search Strategy:

- 
- 1 Pre-Eclampsia/
  - 2 Hypertension, Pregnancy-Induced/
  - 3 Eclampsia/
  - 4 HELLP Syndrome/
  - 5 Pregnancy/
  - 6 Pregnancy Trimester, First/
  - 7 Pregnancy Trimester, Second/
  - 8 Pregnancy Trimester, Third/
  - 9 Postpartum Period/
  - 10 Hypertension/
  - 11 (5 or 6 or 7 or 8 or 9) and 10
  - 12 (preeclamp\$ or pre eclamp\$).ti.
  - 13 eclamp\$.ti. (8692)
  - 14 gestosis.ti. (776)
  - 15 HELLP.ti. (1269)
  - 16 ((gestational or pregnan\$ or postpartum or antepartum or puerper\$ or prenatal or antenatal or perinatal or peripartum) and (tox?emi\$ or hypertens\$ or blood pressure)).ti.
  - 17 1 or 2 or 3 or 4 or 11 or 12 or 13 or 14 or 15 or 16
  - 18 Blood pressure/
  - 19 Blood pressure determination/
  - 20 Blood pressure monitoring, Ambulatory/
  - 21 Blood pressure monitors/
  - 22 Urinalysis/
  - 23 Proteinuria/
  - 24 ((blood or systolic or diastolic) adj pressure).ti,ab.
  - 25 urinalys\$.ti,ab.
  - 26 (urine adj (measur\$ or analy\$ or test\$ or collect\$)).ti,ab.
  - 27 (proteinuria or albuminuria or urine albumin).ti,ab.
  - 28 or/18-27
  - 29 Mass screening/



## Appendix A. Detailed Methods

- 30 screen\$.ti,ab.
- 31 (detect\$ or predict\$ or identif\$).ti.
- 32 29 or 30 or 31
- 33 17 and (28 or 32)
- 34 33 not (animals/ not humans/)
- 35 limit 34 to (english language and yr="2014 -Current")

## Cochrane Central Register of Controlled Clinical Trials (CENTRAL)

- | ID  | Search Hits  |
|-----|--|
| #1  | preeclamp*:ti,ab,kw  |
| #2  | (pre-eclampsia or pre-eclamptic):ti,ab,kw                                |
| #3  | eclamp*:ti,ab,kw   |
| #4  | gestosis:ti,ab,kw  |
| #5  | HELLP:ti,ab,kw   |
| #6  | #1 or #2 or #3 or #4 or #5   |
| #7  | hypertension:ti,ab,kw  |
| #8  | hypertensive:ti,ab,kw  |
| #9  | (toxemi*:ti,ab,kw or toxaemi*:ti,ab,kw)                                  |
| #10 | "blood pressure":ti,ab,kw near/5 (high or elevated or abnormal):ti,ab,kw |
| #11 | #7 or #8 or #9 or #10  |
| #12 | (pregnancy or pregnant):ti,ab,kw   |
| #13 | (prenatal or antenatal or perinatal or peripartum):ti,ab,kw              |
| #14 | gestational:ti,ab,kw   |
| #15 | (postpartum or antepartum):ti,ab,kw                                      |
| #16 | peurper*:ti,ab,kw  |
| #17 | #12 or #13 or #14 or #15 or #16  |
| #18 | #11 and #17  |
| #19 | #6 or #18  |
| #20 | screen*:ti,ab,kw   |
| #21 | (detect* or predict* or identif*):ti                                     |
| #22 | (blood or systolic or diastolic):ti,ab,kw next pressure:ti,ab,kw         |
| #23 | urinalys*:ti,ab,kw   |
| #24 | urine:ti,ab,kw next (measur* or analy* or test* or collect*):ti,ab,kw    |
| #25 | (proteinuria or albuminuria or "urine albumin"):ti,ab,kw                 |
| #26 | risk*:ti,ab,kw   |
| #27 | "multivariable prediction":ti,ab,kw                                      |
| #28 | #20 or #21 or #22 or #23 or #24 or #25 #26 or #27                        |
| #29 | #19 and #28 with Publication Year from 2014 to present, in Trials        |

**Appendix A Table 1. Inclusion and Exclusion Criteria**

Category	Inclusion Criteria	Exclusion Criteria
Populations	Studies among pregnant persons without a diagnosis of hypertensive disorders of pregnancy, including pregnant persons with common chronic conditions managed in usual primary/prenatal care (i.e., chronic hypertension, diabetes mellitus)	Studies that exclusively include: <ul style="list-style-type: none"> <li>• Inpatients or hospitalized persons</li> <li>• Other selected nongeneralizable populations or populations with other preexisting health conditions requiring specialized prenatal care (e.g., HIV, hepatitis, renal disease, organ transplant recipients, sickle cell trait)</li> </ul>
Interventions	Screening programs used to identify preeclampsia and other hypertensive disorders of pregnancy over the course of pregnancy and in the postpartum period (up to 8 weeks after delivery), including studies comparing screening with different protocols in terms of: <ul style="list-style-type: none"> <li>• Blood pressure measurement, setting (office or home), interval, frequency, or timing</li> <li>• Proteinuria assessment setting, interval, or sequence of testing</li> <li>• Personalization of screening based on risk assessment</li> </ul>	Secondary evaluations and tests used to confirm diagnosis or assess preeclampsia severity  Prognostic evaluation used to inform disease management
Comparisons	Usual care screening programs, as defined by the study	

**Appendix A Table 1. Inclusion and Exclusion Criteria**

Category	Inclusion Criteria	Exclusion Criteria
Outcomes	<p><b>KQ1 (maternal and perinatal health outcomes):</b></p> <p>Maternal</p> <ul style="list-style-type: none"> <li>• Eclamptic seizure</li> <li>• Stroke</li> <li>• Cardiomyopathy, myocardial infarction</li> <li>• Renal or hepatic injury/failure</li> <li>• Pulmonary edema, adult respiratory distress syndrome</li> <li>• Venous thromboembolism (deep vein thrombosis/pulmonary embolism)</li> <li>• Disseminated intravascular coagulation</li> <li>• Longer-term health consequences from complications of pregnancy</li> <li>• Maternal mortality</li> </ul> <p>Fetal/infant</p> <ul style="list-style-type: none"> <li>• Preterm birth (&lt;37 weeks): late preterm birth (34–36 weeks), moderate preterm birth, (32–34 weeks), very preterm birth (&lt;32 weeks), extremely preterm birth (&lt;28 weeks)</li> <li>• Gestational age at birth</li> <li>• Low birth weight (weight &lt;2,500 g)</li> <li>• Intrauterine growth restriction/small for gestational age (&lt;10th percentile weight for gestational age)</li> <li>• Stillbirth or neonatal mortality</li> <li>• Longer-term health consequences from exposure to maternal hypertensive disorders</li> </ul> <p><b>KQ 2 (hypertensive disorders of pregnancy):</b></p> <ul style="list-style-type: none"> <li>• Gestational hypertension</li> <li>• Preeclampsia, preeclampsia with severe features</li> <li>• Hemolysis, elevated liver enzymes, and low platelet count (HELLP) syndrome</li> <li>• Chronic hypertension with superimposed preeclampsia</li> <li>• Timing of diagnosis</li> </ul> <p><b>KQ 3 (harms):</b></p> <ul style="list-style-type: none"> <li>• Missed diagnosis (e.g., diagnosis timing, severity at time of diagnosis)</li> <li>• Overdiagnosis and overtreatment (e.g., increased labor induction, cesarean delivery, induced preterm birth, hypermagnesemia)</li> <li>• Mental health diagnoses or symptoms</li> <li>• Reduced quality of life</li> </ul>	<p>Nonclinical health outcomes, such as length of hospital stay (without indication), intensive care unit admission, or neonatal intensive care unit admission</p>

**Appendix A Table 1. Inclusion and Exclusion Criteria**

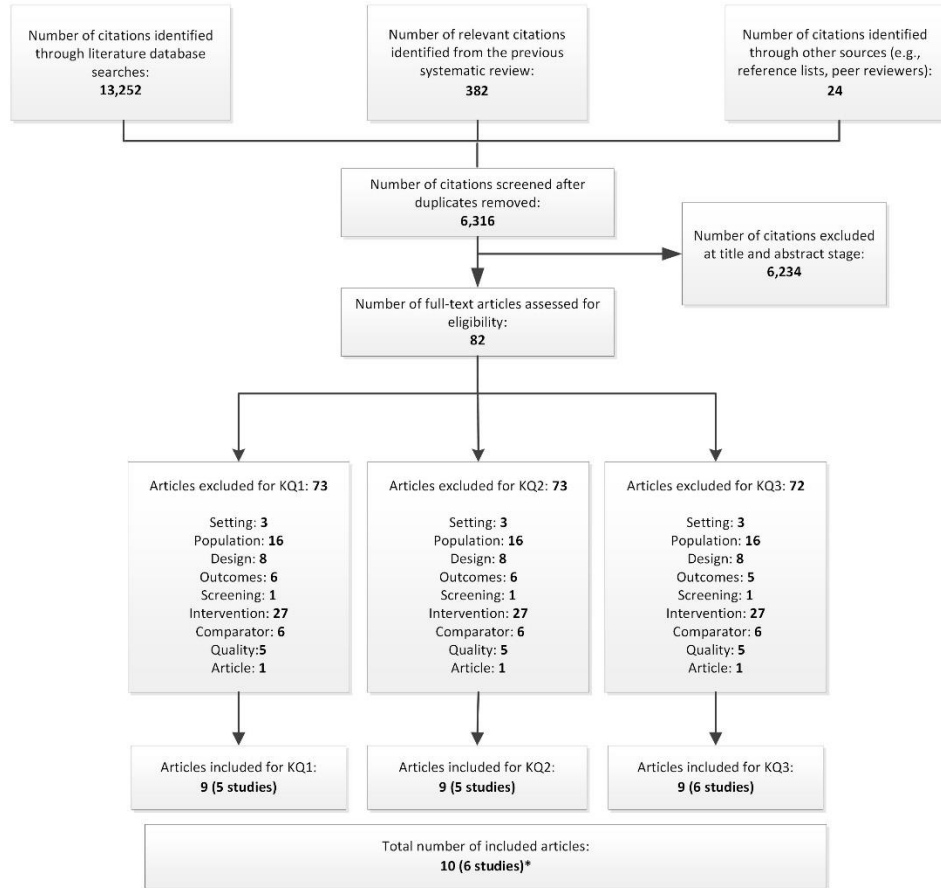
<b>Category</b>	<b>Inclusion Criteria</b>	<b>Exclusion Criteria</b>
Setting	Primary care outpatient settings for obstetric care (e.g., obstetrician-gynecologists, family physicians, certified nurse midwives)  Countries categorized as “Very High” or equivalent on the Human Development Index (as defined by the United Nations Development Programme)	Clinics and study sites treating only high-risk maternity patients
Study Designs	Randomized, controlled trials, controlled clinical trials, and nonrandomized studies comparing screening programs (e.g., comparisons over time or between settings, population cohort studies, nested case-control studies)	Studies that do not represent the spectrum of disease (e.g., case-control study, editorial, narrative review, commentary, postmarketing surveillance, and case report)
Publication Dates	References from the previous USPSTF review, and eligible studies identified through a bridge search	
Study Quality	Good and fair quality according to USPSTF design-specific criteria	Poor quality according to USPSTF design-specific criteria
Language	English	Non-English language studies

**Appendix A Table 2. Study Design-Specific Quality Rating Criteria**

Study Design	Adapted Quality Criteria*
Randomized and controlled trials, adapted from the U.S. Preventive Services Task Force methods <sup>144</sup>	<p><b>Bias arising in the randomization process or due to confounding</b></p> <ul style="list-style-type: none"> <li>• Valid random assignment/random sequence generation method used</li> <li>• Allocation concealed</li> <li>• Balance in baseline characteristics</li> </ul> <p><b>Bias in selecting participants into the study</b></p> <ul style="list-style-type: none"> <li>• CCT only: No evidence of biased selection of sample</li> </ul> <p><b>Bias due to departures from intended interventions</b></p> <ul style="list-style-type: none"> <li>• Fidelity to the intervention protocol</li> <li>• Low risk of contamination between groups</li> <li>• Participants were analyzed as originally allocated</li> </ul> <p><b>Bias from missing data</b></p> <ul style="list-style-type: none"> <li>• No, or minimal, post-randomization exclusions</li> <li>• Outcome data are reasonably complete and comparable between groups</li> <li>• Reasons for missing data are similar across groups</li> <li>• Missing data are unlikely to bias results</li> </ul> <p><b>Bias in measurement of outcomes</b></p> <ul style="list-style-type: none"> <li>• Blinding of outcome assessors</li> <li>• Outcomes are measured using consistent and appropriate procedures and instruments across treatment groups</li> <li>• No evidence of inferential statistics</li> </ul> <p><b>Bias in reporting results selectively</b></p> <ul style="list-style-type: none"> <li>• No evidence that the measures, analyses, or subgroup analyses are selectively reported</li> </ul>
Cohort studies, adapted from Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) <sup>145</sup>	<p><b>Bias arising in randomization process or due to confounding</b></p> <ul style="list-style-type: none"> <li>• Balance in baseline characteristics</li> <li>• No baseline confounding</li> <li>• No time-varying confounding</li> </ul> <p><b>Bias in selecting participants into the study</b></p> <ul style="list-style-type: none"> <li>• No evidence of biased selection of sample</li> <li>• Start of followup and start of intervention coincide</li> </ul> <p><b>Bias due to departures form intended interventions</b></p> <ul style="list-style-type: none"> <li>• Participant intervention status is clearly and explicitly defined and measured</li> <li>• Classification of intervention status is unaffected by knowledge of the outcome or risk of the outcome</li> </ul> <p><b>Bias in classifying interventions</b></p> <ul style="list-style-type: none"> <li>• Fidelity to intervention protocol</li> <li>• Participants were analyzed as originally allocated</li> </ul> <p><b>Bias from missing data</b></p> <ul style="list-style-type: none"> <li>• Outcome data are reasonably complete and comparable between groups</li> <li>• Confounding variables that are controlled for in analysis are reasonably complete</li> <li>• Reasons for missing data are similar across groups</li> <li>• Missing data are unlikely to bias results</li> </ul> <p><b>Bias in measurement of outcomes</b></p> <ul style="list-style-type: none"> <li>• Blinding of outcome assessors</li> <li>• Outcomes are measured using consistent and appropriate procedures and instruments across treatment groups</li> <li>• No evidence of biased use of inferential statistics</li> </ul> <p><b>Bias in reporting results selectively</b></p> <ul style="list-style-type: none"> <li>• No evidence that the measures, analyses, or subgroup analyses are selectively reported</li> </ul>

\*Good-quality studies generally meet all quality criteria. Fair-quality studies do not meet all the criteria but do not have critical limitations that could invalidate study findings. Poor-quality studies have a single fatal flaw or multiple important limitations that could invalidate study findings. Critical appraisal of studies using *a priori* quality criteria are conducted independently by at least two reviewers. Disagreements in final quality assessment are resolved by consensus, and, if needed, consultation with a third independent reviewer

## Appendix A Figure 1. Literature Flow Diagram



\*Studies may appear in more than one Key Question.

## Appendix B. Included Studies

**Below is a list of included studies and their ancillary publications (indented below main results publication):**

McDuffie RS Jr, Beck A, Bischoff K, Cross J, Orleans M. Effect of frequency of prenatal care visits on perinatal outcome among low-risk women. A randomized controlled trial. *JAMA*. 275(11): 847-851. 1996. PMID: 8596222.

McDuffie R, Bischoff K, et al. An evaluation of risk-based prenatal care: a randomized controlled trial. *Am J Obstet Gynecol*. 172: 270. 1995.

McDuffie R, Bischoff, K, Beck A, Orleans M. Does reducing the number of prenatal office visits for low-risk women result in increased use of other medical services? *Obstet Gynecol*. 90(1): 68-70. 1997.

Rhode MA, Shapiro H, Jones OH 3rd. Indicated vs. routine prenatal urine chemical reagent strip testing. *J Reprod Med*. 52(3): 214-219. 2007. PMID: 17465289.

Ross-McGill H, Hewison J, Hirst J, et al. Antenatal home blood pressure monitoring: a pilot randomised controlled trial. *BJOG*. 107(2): 217-221. 2000. PMID: 10688505.

Sikorski J, Wilson J, Clement S, Das S, Smeeton N. A randomised controlled trial comparing two schedules of antenatal visits: the antenatal care project. *BMJ*. 312(7030): 546-553. 1996. PMID: 8595286.

Clement S, Candy B, Sikorski J, Wilson J, Smeeton N. Does reducing the frequency of routine antenatal visits have long term effects? Follow up of participants in a randomised controlled trial. *BJOG*. 106(4): 367-370. 1999.

Henderson J, Roberts T, Sikorski J, Wilson J, Clement S. An economic evaluation comparing two schedules of antenatal visits. *J Health Serv Res Policy*. 5(2): 69-75. 2000.

Tucker K, Mort S, et al. A randomised controlled trial of self-monitoring of blood pressure during higher risk pregnancy: The BUMP1 trial. 2021.

Walker DS, Koniak-Griffin D. Evaluation of a reduced-frequency prenatal visit schedule for low-risk women at a free-standing birthing center. *J Nurse Midwifery*. 42(4): 295-303. 1997.

## Appendix C. Excluded Studies

Reason for Exclusion*
<b>E1. Setting</b>
<b>E1a.</b> Clinics and study sites treating only high-risk maternity patients
<b>E1b.</b> Study country not a “very high” HDI
<b>E2. Population</b>
<b>E2a.</b> Patients seeking high risk obstetric care or those with known chronic conditions (other than HTN or DM)
<b>E2b.</b> Hospitalized patients
<b>E2c.</b> Population selected for high-risk monitoring (e.g. already diagnosed with HDP)
<b>E3. Study design</b>
<b>E3a.</b> Editorial, narrative review, commentary, post-marketing surveillance, case reports
<b>E3b.</b> Case-control study, not nested
<b>E4. No relevant outcomes</b>
<b>E4a.</b> Non-clinical health outcomes, such as length of hospital stay (without indication), ICU admission, or NICU admission
<b>E5. No screening for a hypertensive disorder or pregnancy</b>
<b>E6. Intervention</b>
<b>E6a.</b> Secondary evaluations and tests used to confirm diagnosis or assess preeclampsia severity
<b>E6b.</b> Prognostic evaluation used to inform disease management
<b>E6c.</b> Intervention includes health care delivery or behavioral interventions alongside changes to screening
<b>E7. Comparator</b>
<b>E8. Non-English language</b>
<b>E9. Publication date before 1990</b>
<b>E10. Poor study quality</b>
<b>E11. Unable to locate article</b>
<b>E12. Study aim</b>

- Aguilar R, Gorgonio N. A randomized controlled trial to evaluate the effectiveness of the new who model of antenatal care versus the standard model of antenatal care in a tertiary government hospital. *Int J Gynaecol Obstet.* 131. E362. 2015. **KQ1E1b, KQ2E1b, KQ3E1b**
- Bailit JL, Grobman WA, et al. Does the presence of a condition-specific obstetric protocol lead to detectable improvements in pregnancy outcomes? *Am J Obstet Gynecol.* 213(1): 86.e1-86.e6. 2015. PMID: 25659468. <https://dx.doi.org/10.1016/j.ajog.2015.01.055> **KQ1E6, KQ2E6, KQ3E6**
- Banke-Thomas A, Rosser C, et al. Patient costs and outcomes before and after the institution of a pre-eclampsia quality improvement initiative in a southwestern tertiary facility. *J Obstet Gynaecol (Lahore).* 39(6): 748-752. 2019. PMID: 31008661. <https://dx.doi.org/10.1080/01443615.2019.1575343> **KQ1E2c, KQ2E2c, KQ3E2c**
- Berglund AC, Lindmark GC. Health services effects of a reduced routine programme for antenatal care: an area-based study. *Eur J Obstet Gynecol Reprod Biol.* 77(2): 193-199. 1998. [https://dx.doi.org/10.1016/S0301-2115\(97\)00270-4](https://dx.doi.org/10.1016/S0301-2115(97)00270-4) **KQ1E10, KQ2E10, KQ3E10**
- Binstock MA, Wolde-Tsadik G. Alternative prenatal care. Impact of reduced visit frequency, focused visits and continuity of care. *J Reprod Med.* 40(7): 507-512. 1995. PMID: 7473439. **KQ1E6c, KQ2E6c, KQ3E6c**
- Black MH, Zhou H, et al. Prehypertension prior to or during early pregnancy is associated with increased risk for hypertensive disorders in pregnancy and gestational diabetes. *J Hypertens.* 33(9): 1860-7; discussion 1867. 2015. PMID: 26147387.



- <https://dx.doi.org/10.1097/HJH.0000000000000646> **KQ1E7, KQ2E7, KQ3E7**
7. Boehm FH, Glass CA, et al. Prevention of preterm birth. Role of daily telephone contact. *J Reprod Med.* 41(8): 595-601. 1996. **KQ1E6c, KQ2E6c, KQ3E6c**
  8. Bronstein JM, Ounpraseuth S, et al. Use of specialty OB consults during high-risk pregnancies in a Medicaid-covered population: initial impact of the Arkansas ANGELS intervention. *Med Care Res Rev.* 69(6): 699-720. 2012. <https://dx.doi.org/10.1177/1077558712458157> **KQ1E6, KQ2E6, KQ3E6**
  9. Butler Tobah YS, LeBlanc A, et al. Randomized comparison of a reduced-visit prenatal care model enhanced with remote monitoring. *Am J Obstet Gynecol.* 221(6): 638.e1-638.e8. 2019. <https://dx.doi.org/10.1016/j.ajog.2019.06.034> **KQ1E6c, KQ2E6c, KQ3E6c**
  10. Chappell LC, McManus RJ. P-077. Self-monitoring of blood pressure in women with higher risk pregnancies: the BUMP1 multicentre randomised controlled trial. *Pregnancy Hypertens.* 25. 2021. <https://dx.doi.org/10.1016/j.preghy.2021.07.112> **KQ1E11, KQ2E11, KQ3E11**
  11. Chappell L, Tucker K, et al. Self-monitoring of blood pressure in women with pregnancy hypertension: the BUMP2 multicentre randomised controlled trial. *J Hypertens.* 39(Suppl 1): e9. 2021. <https://dx.doi.org/10.1097/01.hjh.0000744452.18575.74> **KQ1E2c, KQ2E2c, KQ3E2c**
  12. Chappell LC, Tucker K, et al. P-094. Self-monitoring of blood pressure in women with pregnancy hypertension: the BUMP2 multicentre randomised controlled trial. *Pregnancy Hypertens.* 25. e59-e60. 2021. <https://dx.doi.org/10.1016/j.preghy.2021.07.129> **KQ1E2c, KQ2E2c, KQ3E2c**
  13. Chappell, LC, Tucker, KL, et al. Blood pressure monitoring in pregnant women with hypertension for improving blood pressure control: the BUMP2 randomised controlled trial. 2021. **KQ1E2c, KQ2E2c, KQ3E2c**
  14. Cluver C, Tong S. Revisiting blood pressure thresholds to define hypertension during pregnancy: is 140/90 mmHg too high? *Lancet Global Health.* 9(8): e1041-e1042. 2021. [https://dx.doi.org/10.1016/S2214-109X\(21\)00285-0](https://dx.doi.org/10.1016/S2214-109X(21)00285-0) **KQ1E3a, KQ2E3a, KQ3E3a**
  15. Cordisco A, Periti E, et al. Clinical implementation of pre-eclampsia screening in the first trimester of pregnancy. *Pregnancy Hypertens.* 25. 34-38. 2021. <https://dx.doi.org/10.1016/j.preghy.2021.05.010> **KQ1E6b, KQ2E6b, KQ3E6b**
  16. Dalfo Pibernat A, Garcia Millan R, et al. Approach of pre-eclampsia: importance of home blood pressure monitoring and ambulatory blood pressure monitoring in the early detection. *Int Nurs Rev.* 68(1): 138. 2021. PMID: 33891769. <https://dx.doi.org/10.1111/inr.12664> **KQ1E3a, KQ2E3a, KQ3E3a**
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**Appendix D Table 1. Detailed Inclusion and Exclusion Criteria**

Author, Year	Inclusion criteria	Exclusion criteria
Tucker, 2021 <sup>88</sup>	Pregnant individuals at higher risk of pre-eclampsia were recruited by research midwives through antenatal clinics in 15 secondary care maternity units between 16- and 24-weeks' gestation. Higher risk was defined by the relevant National Institute of Health and Care Excellence guidance at the time and included one or more of the following risk factors for pregnancy hypertension: age 40 years or older, nulliparity, pregnancy interval of more than 10 years, family history of pre-eclampsia, previous history of pre-eclampsia or gestational hypertension, body mass index 30 kg/m <sup>2</sup> or above at booking for pregnancy care, chronic kidney disease, twin pregnancy, pre-pregnancy diabetes (type 1 or 2), autoimmune disease (e.g., systemic lupus erythematosus or anti-phospholipid disease)	Pre-existing diagnosis of hypertension (i.e., diagnosed before randomization)
Ross-McGill, 2000 <sup>81</sup>	Individuals undergoing either shared general practitioner and hospital antenatal care, or entirely general practitioner care, were eligible whatever their parity	Multiple pregnancy, established hypertension ≥140/90 mmHg, or with previous early onset (before 34 weeks) pre-eclampsia, serious medical disease, or previous pregnancy loss after 24 weeks
Walker, 1997 <sup>83</sup>	Low-risk pregnancy, beginning prenatal care before 26 weeks' gestation, older than 18 years of age, and ability to speak or read Spanish or English. Pre-pregnancy weight less than 250 pounds.	Evidence of diabetes, hypertension, cardiac conditions, seizures, lupus, asthma requiring medication, chronic infections, multiple gestation, previous stillbirth, previous preterm birth, previous cesarean section.
McDuffie, 1996 <sup>80</sup>	Pregnant individuals in the first trimester classified as having a low risk of adverse events	Age younger than 18 years or older than 39 years, completed 13 weeks of gestation, past or current high risk obstetrical condition, current medical condition, non-English speaking, planning to change insurance during the pregnancy. Past high risk obstetrical conditions were defined as preterm delivery, preterm labor, abruptio placentae, severe preeclampsia, classical cesarean delivery (vertical uterine incision), gestational diabetes, incompetent cervix, uterine anomaly, diethylstilbestrol exposure, isoimmunization, fetal anomaly, or small for gestational age neonate. Current high-risk obstetrical conditions included multiple gestation (if known at intake), pregnancy conceived through assisted reproductive technology, and large (> 4cm) leiomyomata). Current medical conditions included diabetes, chronic hypertension, drug or alcohol abuse, or any ongoing medical or psychiatric illness requiring treatment or monitoring.

**Appendix D Table 1. Detailed Inclusion and Exclusion Criteria**

Author, Year	Inclusion criteria	Exclusion criteria
Sikorski, 1996 <sup>82</sup>	Pregnant individuals aged 16 to 39 years at low antenatal risk; at least 24 weeks gestation; registered with general practitioner; understanding or literacy in English, Turkish, Vietnamese, Punjabi, Bengali, Cantonese, Spanish, or Portuguese.	Booking for obstetric care after 22 weeks' gestation, requiring specialist obstetric care (more than visits to an obstetrician planned), or multiple pregnancy. Weighing less than 41 kg (Asian), 47 kg (Afro-Caribbean), or 45 kg (any other ethnic group), weighing more than 100 kg. Previous pregnancy history of: fetal loss (18 weeks' gestation or later); neonatal death; three or more consecutive spontaneous abortions; cervical suture; birth prior to 34 weeks' gestation or less than 2.5 kg; severe pregnancy-related hypertensive disorder with proteinuria in last pregnancy; severe non-proteinuric hypertension requiring induction of labor, medication, or epidural for raised blood pressure in last pregnancy; previous myomectomy or classical caesarean section; rhesus or ABO incompatibility antibodies. Medical history of: DBP >90 mm Hg at booking, essential hypertension, diabetes mellitus, renal disease, cardiac disease, previous postnatal, depression requiring medication (including puerperal psychosis), previous cone biopsy, assisted conception (other than clomiphene), current treatment for tuberculosis, taking drugs for a psychiatric disorder, substance abuse.
Rhode, 2007 <sup>79</sup>	All pregnant individuals who enrolled for care and delivered between November 2000 and March 2004.	Spontaneous abortion, transfer out of care, transfer to high-risk care, loss to follow up. Enrollment prior to and delivery after August 15, 2002 (transitional period).

**Abbreviations:** DBP = Diastolic blood pressure.

**Appendix D Table 2. Detailed Intervention Descriptions**

Author, Year	Intervention Group Detailed Description	Control Group Detailed Description	Adherence
Tucker, 2021 <sup>88</sup>	<p>Pregnant individuals attended usual antenatal care appointments and were provided with a monitor validated for use in pregnancy (Microlife WatchBP Home). They were given instructions for blood pressure self-monitoring and enrolled on a mobile phone-based telemonitoring system with an optional paper diary. Pregnant individuals were asked to monitor their BP three times a week from randomization to delivery. They were instructed to sit quietly and comfortably for one minute, take two readings one minute apart and submit their second reading to the telemonitoring system. The telemonitoring app transmitted blood pressure readings and received automated responses based on a color-coded chart developed for the trial. If the second reading was outside the expected range (110-134/70-84 mm Hg), this would automatically trigger the system to request a third reading (taken after 5 minutes). Persistently high (<math>\geq 135/85</math> mm Hg) or low readings (symptomatic and systolic BP <math>&lt; 85</math> mm Hg) automatically triggered a message to ask the participant to contact their local maternity unit. Once a persistently high readings were recorded (<math>\geq 135/85</math> mm Hg), the telemonitoring system would send a request to take daily readings for the remainder of their pregnancy.</p>	<p>Usual antenatal clinic visit schedule as required (at least seven times during an uncomplicated pregnancy) which included having their BP measured by their usual antenatal care team</p>	<p>IG: 98% (1198/1220) performed self-monitoring with 99.8% recording their readings in the app. Readings occurred approximately every third day (32.6% [SD 35.0] of the days) between randomization and delivery or clinic hypertension (whichever came first). Individuals followed the protocol of monitoring three times per week until delivery or clinic hypertension 76.7% (SD 51.3) of the time; if their SMBP rose to <math>\geq 135/85</math> mm Hg and they were monitoring daily until delivery or diagnosis if blood pressure, this happened 71.7% (SD 48.3) of the time.</p> <p>CG: NR</p>
Ross-McGill, 2000 <sup>81</sup>	<p>The reduced schedule intervention group were loaned a portable blood pressure monitor at 28 weeks and trained in its use. They were instructed to measure their blood pressure weekly at home and record the results in a pre-printed diary. If the systolic reading was between 140 and 160 mmHg or the diastolic between 90 and 100 mm Hg, they were instructed to repeat the measurement after four hours and to contact their midwife if either second reading was <math>&gt; 140</math> or 90 mm Hg, respectively. If any single systolic reading was <math>&gt; 160</math> mm Hg or diastolic <math>\geq 100</math> mm Hg, the women were instructed to contact their midwife immediately. Women in the home monitoring group were instructed to attend the midwife clinic at 34, 38 and 41 weeks.</p>	<p>Women in the routine care group were seen at 28, 30, 32, 34, 36, 37, 38, 39, 40 and 41 weeks</p>	<p>The mean number of antenatal visits in the intervention group was 4.5 (visits specifically related to pregnancy were 3.2). In the control group the mean number of visits was 7.4 (the number of visits related to pregnancy were 3.2)</p>



**Appendix D Table 2. Detailed Intervention Descriptions**

Author, Year	Intervention Group Detailed Description	Control Group Detailed Description	Adherence
Walker, 1997 <sup>83</sup>	Pregnant individuals were scheduled to attend eight prenatal visits (an initial visit, and subsequent visits at 15-19 weeks, 24-28 weeks, 32 weeks, 36 weeks, 38 weeks, and weekly until delivery, unless a complication developed requiring more frequent care). Each woman was primarily cared for by one Certified Nurse-Midwife (CNM) during her pregnancy. Length of time allotted for outpatient prenatal visits for both groups was 45 minutes for an initial evaluation and 15 minutes for a return prenatal visit. At each return prenatal visit blood pressure, weight, fetal heart rate, and fundal height measurements were taken, and the urine was tested for glucose and protein. The timing of routine prenatal laboratory tests and other diagnostic tests and examinations was not altered by the study protocol.	After the initial visit, pregnant individuals returned for care every 4 weeks until 28 weeks, every two weeks until 36 weeks, and then weekly until delivery. More frequent visits were scheduled as needed.	On average individuals in the intervention group attended 3.2 visits fewer than those in traditional group (p=0.0001). Individuals in the intervention group attended a mean of 7.65 (1.62) visits (range: 3-11). The control group attended a mean of 10.84 (2.33) visits (range: 6-16).
McDuffie, 1996 <sup>80</sup>	Prenatal visits scheduled for 8, 12, 16, 24, 28, 32, 36, 38 and 40 weeks for a total of 9 visits. For parous women a telephone call was scheduled at 12 weeks instead of a visit. Ongoing risk assessment occurred at each visit and if risk factors were identified additional visits to providers or to nurses for fetal monitoring were scheduled. Blood pressure measured at each visit.	Routine prenatal visit schedule (14 visits)	Overall, 2.7 fewer visits occurred in the intervention group. Mean of 10.3 (2.8) visits in intervention group and 12.9 (2.8) visits to providers in control group.
Sikorski, 1996 <sup>82</sup>	Reduced prenatal visit schedule consisting of as seven visits for nulliparous women and six visits for multiparous women. Nulliparous women were seen at booking, 24, 28, 32, 36, 38, and 40 weeks; multiparous were seen at booking, 26, 32, 36, 38, and 40 weeks. Patients were informed that they could receive extra visits at any time they, or their caregivers, consider it to be necessary.	Standard prenatal visit schedule consisting of 13 visits	The difference between the mean number of visits between groups was smaller than intended. Those in the reduced visit schedule had an average of 8.6 visits; after adjusting for gestational age at booking and delivery this was an average of 2.6 more visits than intended. Those in the traditional group received an average of 10.8 visits (of 13 planned); after adjusting for gestational age at booking and delivery this was an average of 1.65 fewer visits than intended.

**Appendix D Table 2. Detailed Intervention Descriptions**

Author, Year	Intervention Group Detailed Description	Control Group Detailed Description	Adherence
Rhode, 2007 <sup>79</sup>	Urine testing with chemical reagent strips was performed on an indicated basis whenever any of the following were met: first prenatal visit, patient complaint of symptoms of urinary tract infection, severe vomiting, weight loss of $\geq 0.9$ kg since previous visit, blood pressure elevation ( $\geq 140$ mm Hg SBP or $\geq 90$ mm Hg DBP), pregnancy requiring periodic urine testing (e.g., chronic hypertension, renal disease). Clinicians could also request urine testing if other symptoms were detected such as persistent headache.	First prenatal visit included urine screening and culture, and blood pressure measurement. All subsequent visits included urine screening and blood pressure determination.	<p>In the intervention group the mean number of urinary tests during pregnancy were 1.4 (SD: 1.3). The range of tests was 0-16. It was unclear why 18.1% of the indicated urine tests were done.</p> <p>In the control group the mean number of urinary tests during pregnancy were 7.8 (SD: 3.4). The range of tests was 0-19.</p>

**Abbreviations:** BP = Blood pressure; CG = Control group; DBP = Diastolic blood pressure; NR = Not reported; SBP = Systolic blood pressure; SD = Standard deviation.

## Appendix E. Ongoing Studies

Trial identifier	Study name	Location	Estimated N	Interventions	Relevant outcome measures	Status
NCT03334149	Blood Pressure Monitoring in High Risk Pregnancy to Improve the Detection and Monitoring of Hypertension (BUMP)	UK	3042	Self-Monitoring of Blood Pressure vs. usual care	<ul style="list-style-type: none"> <li>- Time from recruitment to diagnosis of raised blood pressure</li> <li>- Quality of life</li> <li>- Stillbirth and early neonatal deaths</li> <li>- Gestational age at delivery</li> <li>- Mode of delivery</li> <li>- Birth weight, small for gestational age</li> <li>- STAI-6 short form anxiety questionnaire</li> </ul>	<p>Completed December 2020 (no published results)</p> <p>Results included in this report via author correspondence</p>
NCT03509272	LimPrOn: Limburg Pre-eclampsia Investigation (LimPrOn)	Belgium	2000	No intervention vs. home monitoring based on risk assessment via physiologic measures (e.g., hemodynamic measure and echocardiogram)	<ul style="list-style-type: none"> <li>- Birth weight</li> <li>- Gestational age</li> <li>- Mode of delivery</li> </ul>	<p>Recruiting</p> <p>Estimated completion: December 2030</p>
NCT04958057	Social Risks-Focused Lifestyle Intervention to Reduce Preeclampsia (SAIL)	US	100	Routine prenatal care vs. 6 monthly group sessions with the study nurse addressing preeclampsia education, coaching on stress management, resource navigation, and training in problem solving.	<ul style="list-style-type: none"> <li>- Preeclampsia</li> </ul>	<p>Not yet recruiting</p> <p>Estimated completion: June 2024</p>