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Home monitoring of blood pressure in children, pregnancy, and chronic kidney diseases via personal blood pressure meters- An updated review for pharmacists

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***Abstract*---Background:** Blood pressure (BP) monitoring is critical in managing hypertension across various populations, including children, pregnant women, and patients with chronic kidney disease (CKD). Traditional clinic-based BP measurements often lead to misdiagnoses due to white-coat and masked hypertension. **Aim:** This review highlights the significance of home BP monitoring in children, pregnancy, and CKD, evaluating its accuracy, practicality, and integration into clinical practice. **Methods:** A literature review was conducted, analyzing studies on home BP monitoring across pediatric, pregnancy, and CKD populations. Data on oscillometric devices and validation studies were included. **Results:** Home BP monitoring is increasingly used in pediatric hypertension, with an 80–85% agreement with ambulatory monitoring. In pregnancy, home monitoring aids in detecting preeclampsia and helps maintain optimal BP levels. For CKD, home BP readings are superior to clinical measurements, accurately predicting disease progression and cardiovascular risk. **Conclusion:** Home BP monitoring proves valuable in managing hypertension across vulnerable populations, offering convenience, reliability, and better diagnostic precision. Further research is needed to refine device accuracy and integrate home monitoring into routine care for children, pregnant women, and CKD patients.

***Keywords*---**blood pressure monitoring, home monitoring, hypertension, children, pregnancy, chronic kidney disease, preeclampsia.

Introduction

The gold standard for diagnosing and treating childhood hypertension has long been the conventional office-based blood pressure (BP) test. Current recommendations from the US and the European Society of Hypertension (ESH) stress the significance of exacting techniques for measuring blood pressure in the office. These include the requirement for multiple readings, validated monitors, and standardized conditions [1, 2]. Even with these thorough standards, the frequency of white-coat hypertension and masked hypertension—both widespread in pediatric and adult populations—means that relying solely on office blood pressure measures frequently leads to misdiagnoses [1, 2, 3]. In order to validate a diagnosis of hypertension, it is currently recommended that increased blood

pressure recorded outside of clinical settings be documented, with ambulatory blood pressure monitoring being the recommended technique [1, 2]. Large amounts of clinical and scientific data support the notion that ambulatory blood pressure monitoring is now crucial for accurately diagnosing pediatric hypertension [1, 2]. But in this situation, the value of home blood pressure monitoring is still unclear and little understood [4, 5]. However, research to date indicates that home blood pressure monitoring has a number of advantages over office and ambulatory blood pressure assessments, including greater convenience and the capacity to gather many readings over an extended period of time in the child's typical surroundings [1, 2, 3, 4,5]. According to surveys done in the USA, Canada, and Germany, home blood pressure monitoring is already a standard part of clinical practice for kids. Specifically, over 70% of pediatric nephrologists use home BP monitoring for kids with hypertension or renal conditions, and 64% prefer home readings over office-based ones [6, 7].

Preliminary results indicate that home blood pressure monitoring closely matches adult data, even though the evidence supporting ambulatory blood pressure monitoring in children is stronger. These results show that (a) home blood pressure measurements are more reliable than office blood pressure readings and comparable to ambulatory blood pressure monitoring [8, 9], (b) home blood pressure monitoring correlates with ambulatory blood pressure monitoring in diagnosing hypertension with an 80–85% agreement [10, 11], and (c) home blood pressure monitoring is associated with preclinical indicators of target-organ damage, like the left ventricular mass index, in a manner similar to ambulatory monitoring and superior to office readings [11, 12]. The majority of automated oscillometric devices are used for home and ambulatory blood pressure monitoring, yet there is little data regarding their accuracy in pediatric patients. 31 validation studies of oscillometric blood pressure monitors in pediatric populations were found in a recent systematic review [13], 42% of which were published more than ten years ago. Of them, 16 studies reviewed office blood pressure measuring equipment, of which five failed validation; 9 studies looked at ambulatory blood pressure monitors, of which three failed; and 6 studies looked at home blood pressure devices, of which one failed [13]. The normal blood pressure values for children and adolescents are based on a single, cross-sectional study conducted in Greece at schools with 778 participants. An oscillometric instrument approved for pediatric accuracy, the Omron 705 IT, was used in this investigation to collect home blood pressure readings [15]. It is significant to remember that children's associations with their office, home, and ambulatory blood pressure thresholds are different from adults'. Systolic home blood pressure in children and adolescents is much lower than diastolic home blood pressure during the day, probably because younger populations tend to be more physically active. Furthermore, except for systolic blood pressure in boys, office blood pressure tends to be lower than home or ambulatory blood pressure in younger children, however this difference closes with age [16].

It is advised to use automated oscillometric instruments that have been specially validated for usage with minors. In order to minimize reporting biases, devices with automated memory or PC-link capabilities are preferred. Six to seven days (at least three days) should be allocated, with duplicate morning (before medication, if applicable) and evening measurements obtained while sitting

following a brief period of rest. This method has been proven to work well with pediatric populations and is in line with adult standards [17]. The average readings of the data from the first day—is used to calculate blood pressure. It is advised to use this method in addition to ambulatory blood pressure monitoring for the first diagnosis of hypertension. Children with treated hypertension should also adhere to this approach prior to follow-up appointments; in the long run, long-term monitoring may necessitate 1-2 weekly or even less frequent home measures [5].

Monitoring Blood Pressure In Pregnancy:

Pregnancy-related blood pressure (BP) measurement is extremely important because it helps detect and treat hypertensive disorders, which can have serious effects on the health of both the mother and the fetus [18]. Worldwide, hypertension during pregnancy, especially as a sign of preeclampsia, continues to be a major factor in maternal mortality (14%) and preterm birth (20%) [19]. Blood pressure monitoring is the main method used to identify preeclampsia, which is frequently asymptomatic even in cases of severe cases. Early detection is crucial. Preeclampsia is thought to be the cause of about 25% of stillbirths and infant mortality in low- and middle-income nations. Within two weeks, the illness can quickly advance to life-threatening stages if left undetected. Frequent blood pressure monitoring assists in identifying pregnant women who need careful observation, an early birth, and treatment to reduce their chance of developing cerebrovascular problems. Most preeclampsia-related deaths can be avoided with appropriate care [20]. For this reason, safe and efficient care of hypertensive diseases during pregnancy depends on adequate blood pressure monitoring.

Every prenatal visit should include a blood pressure check, but prenatal visits alone might not be enough to identify quickly developing preeclampsia, which can appear suddenly. Therefore, there is a great deal of promise for home blood pressure monitoring to help detect and treat this problem. In the third trimester, women should be advised to avoid aortocaval compression by choosing a cuff size that fits them properly and to lie in a left lateral position. It's usually advised to sit when taking home blood pressure readings. When auscultating for diastolic blood pressure, which is still dependable throughout pregnancy even with vasodilation, the fifth Korotkoff sound ought to be employed [21]. The digit preference bias present in manual blood pressure measurement is lessened by validated home blood pressure monitors. However, because interstitial edema, decreased intravascular volume, and decreased arterial compliance all distort the oscillometric waveform, oscillometric instruments frequently under-record blood pressure in preeclampsia by more than 10 mmHg [18]. Therefore, even if a device has passed validation for adults, it should still be tested specifically for pregnant women. Certain manufacturers, including Microlife and Omron, provide pregnancy-specific algorithms in their devices, which make them appropriate for usage at home. Pregnancy validation accuracy necessitates testing on preeclamptic women with a variety of blood pressures. Additionally, devices such as the Cradle VSA have a traffic light warning system for both high and low blood pressure, which has been demonstrated to accurately identify shock related to sepsis and obstetric hemorrhage [22]. With this feature, patients can benefit from

explicit action points for use at home. In order to confirm unexpected results, doctors can also manually measure blood pressure using the Cradle VSA.

Pregnancy-related blood pressure thresholds are comparable to non-pregnant levels; readings exceeding 140 mmHg systolic and 90 mmHg diastolic are deemed significant. While white-coat hypertension is still common, home measurements usually match clinical findings [23]. These thresholds are especially important in the early stages of pregnancy due to the normal blood pressure fall, but as pregnancy progresses, blood pressure becomes more significant. There is only one diagnostic threshold applied for practical reasons. Maintaining a systolic blood pressure of less than 150 mmHg can lower the risk of stroke. Postpartum blood pressure thresholds don't change. There is data to suggest that there is a 150 g reduction in birth weight for every 10 mmHg drop in blood pressure, although treating mild to moderate hypertension during pregnancy is controversial because lowering blood pressure may alter placental perfusion [24]. It is not advised to sharply drop blood pressure below 150/100 mmHg because this will not stop preeclampsia from progressing and may even mask its severity. Women who have hypertension during pregnancy are twice as likely to get a stroke, ischemic heart disease, or venous thromboembolism for up to 14 years after giving birth. This makes hypertension during pregnancy an important predictor of future cardiovascular illness. Moreover, these women had a four-fold increased risk of developing hypertension in their later years [25]. When necessary, postpartum cardiovascular risk evaluations with blood pressure monitoring should be carried out to apply lifestyle modifications and preventative therapies [26]. One benefit of home blood pressure monitoring is that it allows postpartum risk assessment to continue with the same equipment. Women who are at risk of developing preeclampsia, including those who already have hypertension, should take low-dose aspirin (75–150 mg). Validated blood pressure readings are a prerequisite for developing algorithms that seek to identify women who might benefit from aspirin [27]. Targeted aspirin use can be facilitated by using home blood pressure monitoring to differentiate between real hypertension and white-coat hypertension.

As with non-pregnant people, home and mobile blood pressure monitoring offer more precise readings of blood pressure during pregnancy. Pregnant women are in favor of home monitoring, which has been linked to fewer prenatal visits and an improvement in overall surveillance [28]. This method has improved the ability to predict pregnancy early and has helped with treatment decisions by taking fetal medication exposure into account. While home blood pressure monitors are becoming more popular, ambulatory monitoring is not as common. This means that surveillance is developing. To prevent false comfort from unreliable gadgets, home monitors must be approved for use during pregnancy.

Monitoring Blood Pressure in CKD:

Ambulatory blood pressure (BP) monitoring is regarded as the gold standard for diagnosing hypertension, especially in individuals with chronic kidney disease (CKD). However, when compared to BP measurements taken in clinical settings—whether rigorously following proper techniques or using standardized methods, BP monitoring proves to be more effective in identifying uncontrolled hypertension

(29). A formal assessment of diagnostic performance indicated that home BP monitoring has a higher area under the receiver operating characteristic curve compared to clinic-based BP assessments (29). An average home BP reading exceeding 140/80 mmHg over one week correlates with an awake ambulatory BP of more than 130/80 mmHg, a threshold deemed hypertensive according to recent guidelines. A BP threshold of 140 mmHg systolic or 80 mmHg diastolic yields a sensitivity and specificity greater than 80% for diagnosing hypertension, making these values clinically useful for decision-making. Research suggests that home BP readings have significant prognostic implications. For example, in a cohort of 77 patients with type 1 diabetic kidney disease, home BP was a stronger predictor of glomerular filtration rate (GFR) decline over an average follow-up period of approximately six years, compared to office BP (30). Agarwal and Andersen, in a study of 217 predominantly male veterans with CKD, found that home BP monitoring (three readings per day for one week) was superior to clinic BP in predicting end-stage renal disease (ESRD) independently of other risk factors (31). Masked hypertension in this cohort was linked to a heightened risk of ESRD, while the risk of ESRD was notably higher in patients with sustained hypertension than in those with white-coat hypertension (31). These findings underscore the value of home BP monitoring in CKD management.

In dialysis patients, peridialysis BP measurements, routinely taken before and after dialysis without adhering to specific techniques, may offer qualitative insights but are inadequate for determining interdialytic BP (32). For example, in a study involving 70 chronic hemodialysis patients, Agarwal and Lewis found that the limits of agreement between pre/postdialysis BP and ambulatory BP were too wide to accurately estimate ambulatory BP (33). While a predialysis BP of over 150/85 mmHg has more than 80% sensitivity, it lacks the specificity required to diagnose hypertension. Similarly, a postdialysis BP exceeding 130/75 mmHg shows more than 80% sensitivity but insufficient specificity for diagnosing hypertension when ambulatory BP monitoring is used as the reference standard (33). A meta-analysis confirmed the poor correlation between pre/postdialysis BP and ambulatory BP measurements (34), with cohort studies indicating that home BP readings are superior in predicting all-cause mortality compared to peridialysis BP measurements (35, 36). To accurately assess usual BP levels in long-term hemodialysis patients with ESRD, the timing and frequency of home BP measurements are crucial. BP in these patients typically increases by around 4 mmHg every 10 hours during the first two days following dialysis (37). Thereafter, BP stabilizes, and ultrafiltration during dialysis leads to a significant reduction in systolic BP, proportional to fluid removal. Patients with substantial interdialytic weight gain experience larger BP fluctuations, while those with minimal weight changes show smaller BP variations (37). At approximately 24 hours post-dialysis, systolic BP in both high and low weight gainers becomes similar, while diastolic BP equalizes after around 36 hours. Consequently, it is recommended that home BP be measured twice daily—at bedtime and upon waking—following mid-week dialysis sessions for four days to capture a broad range of BP levels, which aligns well with interdialytic ambulatory BP monitoring (37). Home systolic BP readings of 150/80 mmHg have shown 80% sensitivity and specificity in diagnosing interdialytic ambulatory hypertension among long-term dialysis patients (37).

Studies also suggest that home BP monitoring can guide decisions regarding the necessity of antihypertensive medications in dialysis patients. For instance, Bishu et al. conducted a prospective study where antihypertensive drugs were gradually discontinued, and patients' BP was monitored using 44-hour ambulatory BP measurements and echocardiography. Patients whose home BP was well-controlled and who had no ventricular hypertrophy left were able to discontinue antihypertensive medications cautiously (39). Additionally, the HDPAL trial, which randomized dialysis patients to either atenolol or lisinopril, demonstrated that home BP monitoring led to significant reductions in interdialytic ambulatory BP within three months (40). Thus, twice-daily home BP measurements, taken at bedtime and upon waking after mid-week dialysis sessions for four consecutive days, are recommended, with the target being an average BP of less than 140/90 mmHg (41-42). This strategy is also suggested for peritoneal dialysis patients, with BP measurements taken over four consecutive days.

Personal Home Blood Pressure Monitors:

Home blood pressure (BP) monitors are commonly used devices that allow individuals to measure their blood pressure outside clinical settings, providing more frequent and reliable readings. These monitors can help track hypertension, guide treatment decisions, and improve overall health outcomes. They come in various forms, including upper-arm, wrist, and finger monitors. Upper-arm monitors are generally recommended for their accuracy and reliability. Personal home BP monitors are particularly useful for patients with chronic conditions like chronic kidney disease (CKD), for pregnant women who may be at risk of preeclampsia, and for children with specific hypertension risks. Proper usage and interpretation of results are key for different populations.

Instructions for Use in Children:

- **Device Selection:** Ensure the BP monitor is suitable for children, as cuff size is crucial for accuracy. Pediatric cuffs that match the child's arm size should be used. Most upper-arm BP monitors come with options for pediatric-sized cuffs.
- **Measurement Protocol:** It is recommended to measure BP in a calm environment, ensuring the child has rested for at least 5 minutes before the reading. The child should sit with their back supported, feet flat on the ground, and arm supported at heart level. BP should be taken at the same time daily to ensure consistent readings.
- **Multiple Measurements:** Since children can be more sensitive to stress or movement, it's advisable to take two or three consecutive readings, spaced one to two minutes apart, and average the results.
- **Interpretation:** BP readings for children should be compared to pediatric-specific percentiles based on age, height, and gender, as standard adult values don't apply to children.

Instructions for Use in Pregnancy:

- **Device Selection:** Choose a BP monitor validated for use in pregnancy, particularly for detecting preeclampsia, as some devices may not be as accurate in pregnant women. Upper-arm monitors are preferred over wrist monitors.

- **Measurement Protocol:** Pregnant women should take their BP readings while seated comfortably, with their feet flat on the floor and arm supported at heart level. Measurements should be taken at the same time each day, ideally in the morning before eating or drinking.
- **Position:** If readings need to be taken while lying down, it's important that the woman lies on her left side, as this prevents compression of the blood vessels and gives a more accurate reading.
- **Monitoring Frequency:** Regular monitoring, typically twice daily, can help detect early signs of pregnancy-related hypertension or preeclampsia, allowing for timely intervention.

Instructions for Use in Chronic Kidney Disease (CKD):

- **Device Selection:** Ensure the BP monitor is validated for use in patients with CKD, as they may have specific vascular conditions that could impact the accuracy of BP measurements. The cuff size should be appropriate for the patient's arm circumference.
- **Measurement Protocol:** Similar to other populations, patients with CKD should measure their BP in a seated position with feet flat on the ground and arm supported at heart level. BP should be measured twice daily (morning and evening), at consistent times, and over several days to get an accurate picture of BP trends.
- **Frequency:** CKD patients may be advised to monitor BP more frequently, depending on their stage of disease and treatment plan. This frequent monitoring can help identify masked hypertension or white-coat hypertension, conditions that are common in CKD patients.
- **Record Keeping:** It's important for CKD patients to keep a log of their BP readings, as trends over time are more significant than single readings. This data can help guide medication adjustments or other treatments.

General Tips for All Populations:

- **Avoid Caffeine, Smoking, or Exercise:** Ensure no consumption of caffeine or smoking at least 30 minutes before taking a BP measurement, and avoid physical activity that may artificially raise BP levels.
- **Consistency:** Consistent times for daily monitoring and using the same arm for measurements provide better accuracy and comparability of readings over time.
- **Interpretation of Results:** Readings should be discussed with healthcare providers to ensure proper management, especially if readings are consistently elevated or irregular.

Conclusion

Home blood pressure (BP) monitoring has emerged as an essential tool for managing hypertension in various populations, including children, pregnant women, and patients with chronic kidney disease (CKD). In pediatric patients, home BP monitoring offers practical advantages over traditional office-based measurements by reducing the influence of white-coat hypertension and allowing for multiple readings over extended periods in familiar settings. While office-based and ambulatory BP measurements remain important, the increasing use of home

monitoring provides a more accurate reflection of a child's typical BP levels, contributing to better hypertension management in clinical practice. In pregnancy, home BP monitoring plays a crucial role in the early detection and management of preeclampsia, a leading cause of maternal and fetal morbidity. Frequent BP monitoring at home allows for timely intervention, reducing the risks associated with hypertensive disorders during pregnancy. Importantly, validated home BP devices designed for pregnancy, such as those with specific algorithms for preeclampsia, ensure that accurate readings are obtained, contributing to improved maternal and fetal outcomes. For patients with CKD, home BP monitoring offers a reliable alternative to clinic-based measurements, providing more precise data on hypertension control and disease progression. Studies demonstrate that home BP readings have strong prognostic value, especially in predicting the decline in kidney function and the risk of end-stage renal disease. This makes home monitoring a key component of hypertension management in CKD, offering superior predictive power compared to traditional office readings. Overall, home BP monitoring enhances the detection, management, and long-term monitoring of hypertension across these vulnerable populations. As technology advances and devices become more accessible, integrating home BP monitoring into routine care will improve patient outcomes and provide a more personalized approach to hypertension management. Further research is needed to refine the accuracy of home BP devices, particularly for pediatric and pregnant populations, and to establish clear guidelines for their use in clinical practice.

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مراقبة ضغط الدم في المنزل للأطفال، والحمل، وأمراض الكلى المزمنة عبر أجهزة قياس ضغط الدم الشخصية - مراجعة محدثة للصيادلة.

الملخص:

الخلفية: يُعتبر مراقبة ضغط الدم (BP) أمرًا بالغ الأهمية في إدارة ارتفاع ضغط الدم بين فئات متعددة، بما في ذلك الأطفال، النساء الحوامل، والمرضى الذين يعانون من أمراض الكلى المزمنة .(CKD) غالبًا ما تؤدي القياسات التقليدية لضغط الدم في العيادات إلى تشخيصات خاطئة بسبب تأثيرات ارتفاع الضغط داخل العيادة أو انخفاضه المتخفي.

الهدف: تسلط هذه المراجعة الضوء على أهمية مراقبة ضغط الدم في المنزل لدى الأطفال، النساء الحوامل، ومرضى الكلى المزمنة، مع تقييم دقتها، قابليتها للتطبيق، ودمجها في الممارسة السريرية.

الطرق: تم إجراء مراجعة للأدبيات، تم فيها تحليل الدراسات المتعلقة بمراقبة ضغط الدم في المنزل لفئات الأطفال، الحوامل، ومرضى الكلى المزمنة. شملت البيانات الأجهزة التي تعتمد على قياس الضغط الأوسيلومتري والدراسات التي تناولت التحقق من دقة هذه الأجهزة.

النتائج: تُستخدم مراقبة ضغط الدم في المنزل بشكل متزايد في حالات ارتفاع ضغط الدم لدى الأطفال، مع توافق بنسبة 80-85% مع مراقبة الضغط المتنقلة. وفي فترة الحمل، تساهم المراقبة المنزلية في الكشف عن تسمم الحمل وتساعد في الحفاظ على مستويات ضغط الدم المثلى. بالنسبة لأمراض الكلى المزمنة، فإن قراءات ضغط الدم المنزلية تتفوق على القياسات السريرية، حيث تُعد دقيقة في التنبؤ بتطور المرض والمخاطر القلبية الوعائية.

الخلاصة: أثبتت مراقبة ضغط الدم في المنزل فائدتها في إدارة ارتفاع ضغط الدم بين الفئات الضعيفة، حيث توفر الراحة، الموثوقية، ودقة تشخيصية أفضل. هناك حاجة إلى مزيد من الأبحاث لتحسين دقة الأجهزة ودمج المراقبة المنزلية بشكل أكبر في الرعاية الروتينية للأطفال، النساء الحوامل، ومرضى الكلى المزمنة.

الكلمات المفتاحية: مراقبة ضغط الدم، المراقبة المنزلية، ارتفاع ضغط الدم، الأطفال، الحمل، أمراض الكلى المزمنة، تسمم الحمل.