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Blood Pressure Self-Measurement

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Abstract

Blood pressure self-measurement has been used extensively as part of several clinical processes including in the home monitoring setting for mitigating white coat effect and gaining more detailed insights into the blood pressure variability of patients over time. Self-measurement of BP is also being used as part of telemonitoring and telemedicine processes, as well as in the waiting rooms and self-measurement rooms of general practice clinics, specialized hospital department's outpatient clinics, and in other types of care facilitates and institutions.

The aim of this review is to provide an overview of where, when, and how blood pressure self-measurement is being used, which official clinical guidelines and procedures are available for its implementation, as well as the opportunities and challenges that are related to its use.

Keywords

Blood pressure • Self-measurement • Hypertension • Home blood pressure monitoring • Office blood pressure measurement • Automated office blood pressure measurement • Ambulatory blood pressure measurement • Guidelines • Recommendations

1 Significance of Blood Pressure Measurements

Blood pressure measurements are important in the diagnosis and monitoring of patients suffering from hypertension or receiving BP lowering medication, as well as for patients in high risk groups, including diabetics, kidney disease patients, and pregnant women suffering from pre-eclampsia (Campbell and McKay 1999; Pickering 1991; Pierdomenico et al. 2009). Hypertension is estimated to be affecting a quarter of the world's adult population with a prevalence as high as 50 % for senior citizens (Wagner et al. 2012a; Santamore et al. 2008).

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BP measurements are primarily performed in the clinical or in the home setting. In the clinical setting the BP measurements performed by healthcare staff, including medical doctors and trained nurses is called Office BP measurement (OBPM).

OBPM is considered to be the cornerstone of hypertension diagnosis with most evidence on the clinical importance of hypertension and benefits of treatment coming from studies using this technique (Parati et al. 2008). However, OBPM has important limitations, including the inability of OBPM to collect information on BP during usual daytime activities and during sleep, also known as the true blood pressure of the patient (Pickering 1996). Other limitations of OBPM include measurement bias originating from the clinical measurement context and conditions under which the measurement is performed, including the anxiety some patients feel during this process, also known as the white coat effect, which we shall discuss in more detail later (Parati et al. 2008).

Another alternative method for clinical use is called automated office blood pressure (AOBP). It is based on an automated BP device, where the cuff is mounted by a healthcare professional, after which a series of measurements automatically is taken by the device with 1–2 min interval (Leung et al. 2016).

As an alternative to OBPM, measurements in the home setting have proven successful for obtaining valid measurements (Pickering et al. 2008; AbuDagga et al. 2010). Measure ments in the home setting may be done using either ambulatory blood pressure devices (ABPM) which are typically worn by the patient for a single 24-h diagnostic period and provides a long range of samples typically at 15–30 min intervals, or automatic home blood pressure devices used for obtaining point measurements typically spanning several days, mornings and afternoons. Both ambulatory and home devices have proven their ability to provide reliable measurements, while home BP devices are more cost effective, less obtrusive and easier to use for the patient than ambulatory BP devices (Pickering et al. 2005a).

Blood pressure self-measurement can also be performed by patients in outpatient clinics and other clinical settings, e.g. in waiting rooms or special self-measurement rooms, as an alternative or supplement to home measurements, using the same BP device types and following the same techniques as in the home setting (Wagner et al. 2012a). In recent years, a range of additional BP devices targeting the clinical self-measurement context has been validated for clinical use.

In the clinic, measurements are either performed by healthcare professionals or as part of a self-measurement procedure handled by the patient themselves. The main motivation for introducing self-measurements relates to a phenomenon known as the white coat effect. Here patients are showing higher blood pressure readings at the clinic than at home, possibly due to the anxiety some people experience during a visit to the clinic or due to the presence of healthcare staff. This is estimated to affect as many as 20 % of all patients (Pickering et al. 2008; AbuDagga et al. 2010). White coat effect is also frequently used as one of the main arguments for home BP monitoring (Parati et al. 2010). Other incentives for increased use of self-measurement in the clinic include a higher number of samples, e.g. several blood pressures readings as opposed to a single point measurement, as well as reduced strain on healthcare personnel.

2 Home Blood Pressure Monitoring

Self-monitoring of blood pressure by patients at home, also known as self-measured blood pressure (SMBP) monitoring, or home blood pressure monitoring (HBPM), is being increasingly used in many countries. SMBP and HBPM have been well received by hypertensive patients and other patient groups that require monitoring of their BP, such as kidney disease patients, diabetics, and pregnant women with BP related complications (Abdoh et al. 2003). HBPM has been shown to predict health outcomes better than office BP measurements (Bobrie et al. 2004; Asayama et al. 2004), and has been found to lower BP compared with usual care (Uhlig et al. 2013).

HBPM is usually performed using a validated blood pressure measurement device using either manual log book entries (paper and pen) or by utilizing the automatic memory of most modern BP devices (Parati et al. 2008). As an alternative, HBPM may also be done as part of a telemedicine or telemonitoring system setup (Parati et al. 2010). Here, the blood pressure device is usually part of a connected system that is able to automatically record data and relay these to the healthcare professionals, e.g. through the use of a secure web based system (Santamore et al. 2008).

Hypertension guidelines provided by the European Society of Hypertension (ESH) and the American Heart Association (AHA) have endorsed the use of HBPM in clinical practice as a useful supplement or alternative to conventional office measurements, especially in patients suspected of possible white coat effect (Parati et al. 2010; Pickering et al. 2005b).

The use of HBPM holds several advantages over conventional office blood pressure (BP) measurement: (1) it provides multiple measurements of BP over time allowing health professionals better insights into the causes and progression of elevated BP (Parati et al. 2010); (2) HPBM measurements are made in the usual environment of each individual, usually the home settings, away from the clinical setting, a setting known to cause white coat effect (Pickering 1996); (3) HBPM is more closely related to hypertension-induced target organ damage and predicts the risk of cardiovascular events better than conventional OBPM office measurements (Bobrie et al. 2004; Asayama et al. 2004; O'Brien et al. 2003); (4) HBPM can detect the white-coat and masked hypertension phenomena, and it shares most of the above features with 24-h ambulatory BP monitoring (ABPM) (Parati et al. 2010).

Compared with ABPM, HBPM provides measurements over a much longer period, is more cost efficient, more widely available, more convenient for patients particularly for repeated measurements, and has been shown to improve patients' adherence to treatment and hypertension control rates (Pickering et al. 2008, 2010; Parati et al. 2010;). Furthermore, HBPM can in theory be continued indefinitely, allowing the patient to self-monitor BP progression over time. However, unlike ABPM, HBPM does not allow for the monitoring of BP during sleep, leisure activities or at work, and does not support the quantification of short-term BP variability, e.g. in 15–30 min intervals.

One of the major shortcomings of HBSM is the design of the BP devices, most of which are based on designs targeting healthcare professionals (Wagner et al. 2012b). Thus, most HBSM devices validated for clinical use does not ensure that patients are adhering to the measurement regiment they have been provided with by their healthcare professional (Parati et al. 2010). This includes not being able to verify the time of day to take their measurements and the number of measurements to take, usually 2–3 measurements each morning and 2–3 each afternoon/evening depending on the provider guidelines, as well as a lack of meeting the guidelines for use of self-measurement in general (Pickering et al. 2005b).

HBPM may be perceived by healthcare professionals and patients to be more time consuming than OBPM, requiring the patient to be instructed in proper use, registering the equipment for lending, and testing and calibrating the equipment after use (Pickering et al. 2008). Furthermore, in case of manual paper based BP schemas or logbooks, the individual measurements needs to be checked for consistency, average values must be calculated and entered into the patient record, or alternatively, data needs to be entered into a decision support system (e.g. an electronic patient record system), for automatic calculations (Santamore et al. 2008). All of these mandatory activities are also error-prone and may result in low quality data sets (Wagner et al. 2012b).

3 Self-Monitoring vs. Self-Measurements

We need to distinguish between self-monitoring of BP in the home setting and time limited self-measurement of BP (BPSM). Self-monitoring is usually used to describe a series of self-measurements over time, usually in the home setting where it is called HBPM, whereas BPSM self-measurement often is constituted as a single point of measurement, or a series of single point measurements, e.g. performed in the clinic's waiting room (Wagner et al. 2012b). As such, BPSM can be viewed as being situated somewhere between the OBPM and HBPM methods with characteristics from both, and should thus be treated and studied in its own right. Thus, some of the challenges associated with OBPM could still apply to BPSM, including bias stemming from the anxiety of attending a clinical setting, something usually associated with the white coat effect phenomenon. However, as with HBPM, the reliability of BPSM measurements depends on the ability and willingness of the individual patient to comply with the provided guidelines (Wagner et al. 2012b). As we shall discus later in further detail, this is one of the major shortcomings of HBPM and BPSM when using state of the art equipment and methods.

4 Blood Pressure Self-Measurement in the Clinic

As an alternative to both OBPM and HBPM, some clinics provide the possibility of letting their patients self-measure their BP before consultation relying on patients performing BPSM in the clinic waiting room or similar. It has not yet been investigated whether this mitigates the white coat effect to the same extent as HBPM and ABPM. While the patient is still in the clinic, the patient is no longer in the same room as the healthcare professional, which could possibly help mitigate the white coat effect of some patients. This has not yet been studied in sufficient detail, and the mere presence of the patient in a clinical setting could cause similar symptoms of anxiety as with white coat hypertension, resulting in increased BP measurements. However, like with HBPM the BPSM process in the clinic requires the patient to follow the same range of recommendations as in HBPM in order to be valid and even though careful instructions and training are provided, BPSM may still be associated with problems.

Current state-of-the-art BP devices used in the HBPM and BPSM setups are not capable of sensing incorrect usage (Wagner et al. 2012a). Therefore, the ability of the patients to adhere to the instructions and related BPSM recommendations is very important. Only measurements following the recommendations are considered reliable (Campbell and McKay 1999; Pickering 1991; Pierdomenico et al. 2009). Thus, non-adherent patient behavior could lead to potential misdiagnoses and possibly result in inappropriate medication (Pickering et al. 2008; AbuDagga et al. 2010).

5 HBPM and BPSM in Clinical Practice

There are important prerequisites for the optimal application of HBPM and BPSM in clinical practice. HBPM and BPSM should be performed by patients who have been trained under medical supervision, and trained nurses and/or pharmacists can have an important part in the implementation of HBPM and BPSM in daily practice and in the diffusion of correct recommendations. Training should include information regarding hypertension, natural occurring and context induced BP variability, proper conditions and procedures to follow for self-monitoring, advice on equipment choice based on validation status (clinical or home use), technical features, price and individual experience, and its proper use and interpretation of results (Parati et al. 2010).

The HBPM and BPSM techniques, when applied using automated electronic devices, is not particularly complex and can easily be explained to most patient groups during a single training session. This could be combined with subsequent periodic verification of correct monitoring performance during office visits or visits by home nurses. Recent studies indicate that even well-trained patients are not following the recommended procedure over time, indicating the need for continuous control measures (Wagner et al. 2013a).

Also, in some patients, in particular elderly with motor or cognitive impairment as well as in young children, the support of a trained nurse, a friend or a relative, may be needed (Parati et al. 2010). Telephonic or video link assistance for patients having doubts or problems with correct HBPM performance could also prove to be useful. A standardized BP logbook structured according to the required monitoring schedule is useful for ensuring the accuracy of data reporting and for improving adherence to measurements schedule (Parati et al. 2010). Manufacturers can facilitate reliable HBPM and BPSM by providing devices with a range of cuffs for varying arm sizes and capable of automatically calculating average BP, and even for the detection of incorrect behavior during measurements. The provision of telemedicine or telemonitoring facilities may be of further advantage to some groups, particularly chronic patient groups.

6 Guidelines on Self-Measurement

A range of guidelines on the self-measurement procedure to follow for HBPM and BPSM, as well as the conditions under which they should be performed exist. Care should be taken to follow these recommendations, as the level of compliance can greatly affect the measured BP levels. These set of recommendations differs between organizations such as the AHA and the ESH (see Table 1).

Healthcare professionals should also be aware of any national or local guidelines to follow, as well, as even the smallest deviations in protocol could result in differences in the resulting measurement levels.

Table 1 Comparison of ESH and AHA guidelines on HBPM procedure and schedule

ESH guidelines	AHA guidelines
Measurement procedure and schedule:	Measurement procedure and schedule:
Seven-day home measurements (minimum of 3 days). At initial assessment, when assessing treatment effects, and in the long-term follow-up before each clinic/office visit. Take two readings morning (before drug intake if treated) and two readings evening (before eating). Readings should be 1–2 min apart. Long-term follow-up: less frequent measurements (for example, once or twice per week) could be regularly performed aimed at reinforcing compliance, although isolated readings should never be used for diagnostic purposes. Overuse of the method and self-modification of treatment should be avoided.	Take multiple readings. Each time you measure, take two or three readings one minute apart and record all the results. Measure at the same time daily. It is important to take the readings at the same time each day, such as morning and evening, or as your healthcare professional recommends. Accurately record all your results. Keep a record of all of your readings, including the date and time taken. Share your blood pressure records with your healthcare team. Some monitors have built-in memory to store your readings; if yours does, take it with you to your appointments. Some monitors may also allow you to upload your readings to a secure web site.

6.1 Monitoring Schedule

Most guidelines suggest that for the initial evaluation of blood pressure levels, including for the diagnosis of hypertension, as well as for the assessment of the effects of antihypertensive treatment including changes in drug or dose, HBPM should be performed daily during at least 3 days before the appointment at the clinic (Parati et al. 2010; Pickering et al. 2005b). Duplicate measurements should be obtained in the morning before drug intake, and in the evening before eating. Measurements of the first monitoring day are usually higher and unstable and are excluded. Well-treated hypertensive patients may also perform regular home BP measurements as a long-term follow-up, e.g. once per week, with the additional aim to reinforce their treatment compliance levels, but the diagnostic value of such long-term measurements is not well-established (Parati et al. 2010).

6.2 Measurement Recommendations

Common to all guidelines, it is recommended that the cuff should be wrapped around the arm with its inflatable bladder centered on the arm with the lower edge of the cuff approximately 2–3 cm above the bend of the elbow. The bladder should always be positioned at the heart level. Also, the measurement should be performed in a quiet room and the patient should remain seated comfortably, not moving during measurements, with the arm resting on a table or other support. Also, the patient should not talk during measurements, and refrain from talking in the minutes before the measurement is taken if feasible.

Please note the subtle differences between ESH and AHA guidelines, where AHA requires the upper arm to be supported at heart level, while ESH only requires the cuff to be placed at heart level. In a recent study by O'brien et al. from 2003, it was found that the forearm also should be at the level of the heart as denoted by the mid-sternal level. Dependency of the arm below heart level leads to an overestimation of systolic and diastolic pressures and raising the arm above heart level leads to underestimation. According to O'brien et al. the magnitude of this error can be as great as 10 mmHg for systolic and diastolic readings, underlining that the source of arm position errors are especially important for the sitting and standing positions. Furthermore, there is evidence that even with a patient in the supine position, an error of up to 5 mmHg for diastolic pressure may occur if the arm is not supported at heart level (O'Brien et al. 2003).

BP measurement results should be reported in a paper schema or logbook format immediately after each measurement according to both ESH and AHA guidelines (Parati et al. 2010; Pickering et al. 2005b). Alternatively, memory equipped devices can store the readings with time and date for each measurement. BP devices designed for telemedicine and telemonitoring purposes are also capable of sending data to a computer or tablet device, and even to an online record system, such as the OpenTele telemedicine system (Wagner 2015). Such systems can distinguish data originating from different device users, removing such bias. Sometimes devices are used to measure BP in other family members and it is important to ensure that these are not erroneously included into a patient BP measurement data set (Parati et al. 2010). Finally, in the rare case of a significant and consistent BP difference between arms, defined as more than 10 mmHg, the physician should advise the patient to use the arm with the highest BP values for HBPM and BPSM purposes (Pickering et al. 2005b).

Table 2 Comparison of ESH and AHA guidelines on HBPM recommendations

ESH guidelines	AHA guidelines
Measurement recommendations:	Measurement recommendations:
At least 5-min rest, 30 min without smoking, meal, caffeine intake or physical exercise. Seated position in a quiet room, back supported, arm supported (for example, resting on the table). Subject immobile, legs uncrossed, not talking and relaxed. Correct cuff bladder placement at heart level. Results immediately reported in a specific logbook or stored in device memory.	Make sure the cuff fits. Measure around your upper arm and choose a monitor that comes with the correct size cuff. Be still, do not smoke, drink caffeinated beverages or exercise within the 30 min before measuring your blood pressure. Sit correctly. Sit with your back straight and supported (on a dining chair, for example, rather than a sofa). Your feet should be flat on the floor; do not cross your legs. Your arm should be supported on a flat surface (such as a table) with the upper arm at heart level. Make sure the middle of the cuff is placed directly above the eye of the elbow. Check your monitor's instructions for an illustration or have your healthcare provider show you how.

As may be seen in the comparison of ESH vs AHA guidelines in Tables 1 and 2, there are several differences in measurement procedure and schedule as well as measurement recommendations. For instance, the ESH highlight the need to take the measurements before drug intake (in the morning) and before eating (in the evening). Guidelines from other organizations differ even more, including guidelines from the British Hypertension Society that recommends two measurements be taken in the seated position with 1 min apart in the morning and evening for 4–7 days, ensuring a relaxed, temperate setting, with the patient quiet and seated, and their arm outstretched and supported. No other indications are provided, e.g. on rest time before the first measurement (NICE 2011).

6.3 Interpretation of HBPM

The average of a series of measurements taken following the chosen set of guidelines should be used for the clinical decisions based on HBPM and BPSM readings. Casual, isolated home measurements can be very misleading and should not by themselves constitute the basis for clinical decisions. The users should be informed that BP may vary between measurements and be instructed not to be alarmed by lone standing high or low BP measurements. Optimal blood pressure is defined as systolic pressure less than 120 mmHg and diastolic pressure less than 80 mmHg. Average systolic home BP greater than or equaling 135 mm Hg and/or diastolic greater than or equaling 85 mm Hg indicates elevated BP. The levels of 'normal' and 'optimal' home BP are still under investigation, provisionally suggested values being below 130 mmHg systolic and below 80 mmHg diastolic for normal home BP (Parati et al. 2010) (Table 3).

Table 3 Comparison of ESH and AHA guidelines on interpretation of measurements

ESH guidelines	AHA guidelines
Interpretation of measurements:	Interpretation of measurements:
Average BP from several monitoring days should be considered. BP values measured on the first monitoring day should be discarded.. Mean home systolic BP greater than or equal to 135 mmHg and/or diastolic BP greater than or equal to 85 mmHg should be considered as elevated. Systolic and diastolic home BP less than 130 and less than 80 mmHg, respectively, should be considered normal in most subjects. In high-risk subjects home BP targets should probably be lower.	Optimal blood pressure is less than 120/80 mmHg (systolic pressure should be less than 120 mmHg and diastolic pressure should be less than 80 mmHg). Consult your healthcare professional if you get several high readings. A single high reading of blood pressure is not an immediate cause for alarm. However, if you get a high reading, take your blood pressure several more times and consult your healthcare professional to make sure you (or your monitor) do not have a problem. When blood pressure reaches a systolic (top number) of 180 or higher OR diastolic (bottom number) of 110 or higher, emergency medical treatment is required.

7 Challenges of HBPM and BPSM

7.1 Patients Ability to Report Self-Measured BP Data

There are several well-known challenges associated with both BPSM in general and HBPSM in particular, including failure to correctly report self-measured data, as well as failure to comply with one or more recommendations as described in the guidelines provided by the healthcare professional. A recent study by Wagner et. al. of 113 chronic kidney disease patients self-measuring in the outpatient clinic, in a special purpose self-measurement room, found that over a third of the participants failed to self-report accurately, either omitting, doubling, rounding, or even fabricating one or more parameters in one or more of their measurements. This represents a challenge to the validity of the data being self-reported by patients (Wagner et al. 2013a). These findings are in line with previous work in the area studying HBPM (Johnson et al. 1999; Mengden et al. 1998; Myers 1998). In these studies patients were equipped with home BP devices, but where not informed that the devices were capable of storing the measurements automatically in device memory. This was done in order to investigate the participant's ability to correctly self-report measurements. After a period of self-monitoring and filling out of the paper records, these records were compared with BP device memory values. In total, more than half the patients had either omitted or fabricated readings indicating unacceptable levels of reporting bias, in line with previous work (Wagner et al. 2013a). In a later study on HBPM using a telemedicine web-based system and a home BP device, 161 patients' ability to accurately report self-measured BP data was investigated (Santamore et al. 2008). The study compared the self-reported data from the web, being manually input by the patients after each measurement, with the data stored in the memory of the devices. The authors found that around 16 % of the reported data deviated from the actual data stored in the device memory, which is significantly less reporting error compared with previous work (Johnson et al. 1999; Mengden et al. 1998; Myers 1998). Also, the study found the average reporting error to be below 4 mmHg, and thus not of major importance to the prognostic value for diagnostic or monitoring purposes (Santamore et al. 2008). The lower error rate reported in this study could be due to participants entering data into a web solution rather than keeping a paper logbook. This implies that the participants were aware of technology being involved and thus presumably less likely to be tempted to misreport. Also, as we cannot expect all patient types to be able to utilize a web solution for self-reporting of data, it could indicate that the Santamore study included a population with higher competencies than was the case in the four related studies. Of the five presented studies, only the first investigated adherence to the recommendations, such as rest time before measurement, talking, and noise levels, the other four focusing solely on the patients' ability to correctly and accurately self-report BPSM data. These findings provides us with an indication of the challenges related to relying on HBPM and BPSM obtained in the unsupervised setting with regard to patients' ability to accurately report self-measured data, but not on their ability to self-measure reliably.

In conclusion, self-reported data should not be trusted to be accurate with currently available technology. Either the use of device memory or telemonitoring and telemedicine solutions should be used to overcome reporting-bias.

7.2 Patient Adherence to the Recommendations

A recent study of kidney disease patients who were trained to self-measure their BP at regular intervals at special purpose self-measurement room at an outpatient clinic found that only 8 % of patients adhered to the required rest time before taking the first measurement (Wagner et al. 2013a). Rest time is considered one of the most central requirements for patients to comply with in order to provide a valid rested BP reading, and failing to rest at least 5 min could cause unacceptable bias to the measurement if not properly adhered to (Pickering 1991; Pickering et al. 2008). The study found that less than half of all measurements, including the second and third measurement, where performed after the required 5 min rest time. Furthermore, when analysing the overall ability of participants to adhere to the recommendations: "no talking", "legs not crossed", "back supported", and being in a "quiet setting", the study found that none of the participants followed all of the five recommendations, while most participants did avoid talking during measurements (Wagner et al. 2013a). Not complying with just a single of these HBPM recommendations has been shown to potentially create significant bias to the measurement, in effect rendering the data unusable or even harmful (Campbell and McKay 1999; Pickering 1991; Campbell et al. 1990). As no single participant were able to follow all of the five measured recommendations, and only a minority adhered to four out of five, and less than half adhered to two out of five, this indicates a serious challenge associated with the BPSM method.

In a related study, 81 pregnant diabetic women were observed self-measuring BP while preparing for their weekly or bi-weekly medical consultation in the waiting room of the outpatient clinic. The study found that the pregnant diabetics predominantly did not adhere to given instructions when performing BPSM in the waiting room (Wagner et al. 2013b).

In conclusion, these two chronic patient groups, both of which being well trained in BPSM guidelines and techniques, failed to follow their training.

Likewise, in a recent study of healthy pregnant women's ability to perform BPSM as part of a screening process for pre-eclampsia, where an interactive system provided partial guidance, including on rest time, time between measurements, and number of measurements (a total of three measurements), the authors found that most participants (85 %) performed exactly the three required BP measurements when guided throughout the process by an interactive video screen (Sandager et al. 2013). The remaining performed either four (12 %) or five measurements (3 %) respectively, the system allowing for additional measurements (Sandager et al. 2013). There were also three incidents of "premature measurements" typically taken within 15–60 s after the patient was first seated. However, these three patients eventually managed to wait a further 5 min before taking the next measurement, achieving three valid measurements in the end. The ability to recover from the erroneous process is likely due to the context-aware adherence aid which would subsequently inform the patient of the insufficient rest time and instruct her to redo the measurement when a premature measurement was detected. Also, one patient had actually rested sufficiently before starting the measurement process, but continued to take an additional two measurements after the system had indicated the successful receipt of the required three measurements. The authors also observed adequate patient adherence to the recommendations with regard to rest time in general where 96 % complied (Pickering et al. 2010). Compared with the non-guided results of 8 % compliance reported by the authors in (Wagner et al. 2013a), this indicates the relevance for proper interactive guidance. Also, refraining from talking during measurements was adhered to by 98 % of patients, without interactive guidance, which is in line with previous results. However, the recommendation on keeping legs not crossed was only adhered to in 85 % of measurements, while back supported was only adhered to by 44 % of the patients. Common to the recommendations "legs not crossed" and "back supported", was that no interactive feedback was provided during the BPSM process. Inadequate patient adherence to these recommendations could cause critical bias and erroneously increased BP levels (Pickering et al. 2010).

These results indicate that patients primarily comply to recommendations when they are actively guided. Using instructions and passive adherence aids did not seem to be sufficient for ensuring reliable measurements. Thus, it should be considered whether interactive aware adherence aids should be introduced to verify and aid during the BPSM and HBPM processes (Wagner et al. 2013c).

Within the field of telemedicine, several state-of-the-art platforms exists that features BP measurement and automatic data collection in order to avoid reporting errors. This includes the Intel Health Guide (IHG), which has been used in several telemedicine studies (Intel 2011; Takahashi et al. 2012). The IHG allows the patient to take the recommended three successive measurements, after which it automatically calculates the average values and reports the data to the healthcare provider, thus enforcing correct reporting procedure eliminating the risk of reporting bias. The IHG also features the capability of enforcing a one minute wait between the three measurements as recommended in most guidelines. However, the system does not have any context-aware sensors, and cannot check whether the patient has remained silent and still during measurements, or observed the proper rest time. It does feature a range of interactive questionnaires, allowing the user to self-report whether he or she has rested sufficiently, been drinking coffee, or smoking cigarettes. Similar systems include the Tunstall Mymedic (Tunstall 2011), and the Bosch Health

Buddy (Koff et al. 2009), which both features automatic collection of BP data and interactive questionnaires, thus avoiding reporting errors, but still relying on self-reporting for relevant context. However, none of these three systems supports the detection of patients not following the recommendations during BPSM and HBPM.

8 Conclusion

HBPM and BPSM are valuable tools in the daily management of hypertension. However, due to the lack of medical supervision during the measurement process, care should be taken to carefully instruct patients of the risks associated with it.

Conflict of Interest No conflict of interests exists.

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