Journal of Human Hypertension (2009) 23, 464–469

www.nature.com/jhh

ORIGINAL ARTICLE

Home blood pressure monitoring in paediatric chronic hypertension

ÉA Furusawa[1], UD Filho[2] and VH Koch[1]
[1]*Pediatric Nephrology Unit, Instituto da Criança do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil and* [2]*Biostatistics Unit, Instituto da Criança do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil*

Blood pressure (BP) measurement is the basis for the diagnosis and management of arterial hypertension. The aim of this study was to compare BP measurements performed in the office and at home (home blood pressure monitoring, HBPM) in children and adolescents with chronic arterial hypertension. HBPM was performed by the patient or by his/her legal guardian. During a 14-day period, three BP measurements were performed in the morning or in the afternoon (daytime measurement) and in the evening (night-time measurement), with 1-min intervals between measurements, totalling six measurements per day. HBPM was defined for systolic blood pressure (SBP) and diastolic blood pressure (DBP) values. HBPM was evaluated in 40 patients (26 boys), mean age of 12.1 years (4–18 years). SBP and DBP records were analysed. The mean differences between average HBP and doctor's office BP were 0.6 ± 14 and 4 ± 13 mm Hg for SBP and DBP, respectively. Average systolic HBPM (daytime and night-time) did not differ from average office BP, and diastolic HBPM (daytime and night-time) was statistically lower than office BP. The comparison of individual BP measurements along the study period (13 days) by s.d. of differences shows a significant decline only for DBP values from day 5, on which difference tends to disappear towards the end of the study. Mean daytime and night-time SBP and DBP values remained stable throughout the study period, confirming HBPM as an acceptable methodology for BP evaluation in hypertensive children and adolescents.
Journal of Human Hypertension (2009) **23,** 464–469; doi:10.1038/jhh.2008.167; published online 12 March 2009

Keywords: home blood pressure monitoring; chronic hypertension; oscillometric blood pressure monitors; children; adolescents

Introduction

Blood pressure (BP) measurement is the basis for the diagnosis and management of arterial hypertension. The increased interest in evaluating BP outside the hospital or clinic setting, to reduce the known negative influence of the observer and the environment on BP, and the development and validation of oscillometric automatic devices have favoured the creation of alternative BP measurement methods, such as home blood pressure monitoring (HBPM). This technique enables the patient to perform a large number of BP measurements at home, provides information for the diagnosis of white coat hypertension or masked hypertension and facilitates the long-term follow-up of patients on antihypertensive medication.[1]

Correspondence: Dr ÉA Furusawa, Pediatric Nephrology Unit, Instituto da Criança do Hospital das Clinicas da Faculdade de Medicina da Universidade de São Paulo, Av Dr Eneas de Carvalho Aguiar 647, Cerqueira César, São Paulo, SP, CEP 05403-000, Brazil.
E-mail: erika.furusawa@icr.usp.br
Received 19 July 2008; revised 7 December 2008; accepted 13 December 2008; published online 12 March 2009

Reproducibility of BP measurements is mandatory for validation of the different available monitoring modalities, including 24-h ambulatory blood pressure measurement (ABPM) and HBPM.[1,2]

The purpose of this study was to compare BP measurements performed in the doctor's office and at home (HBPM) in children and adolescents with chronic arterial hypertension.

Materials and methods

This was a prospective study, conducted at the Pediatric Nephrology Unit (Instituto da Criança do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo), after approval by the ethics committee of the institution. The study population included paediatric patients with controlled and uncontrolled chronic arterial hypertension, according to casual BP measurement in the outpatient clinic, with a minimum follow-up time of 6 months and arm circumference compatible with one of the three cuff sizes (9×18, 12×23 or 14×28 cm) marketed with the study device. Patients with clinically significant cardiac arrhythmia, severe uncontrolled hypertension, auscultatory

hiatus and zero diastolic pressure, as well as patients on chronic use of anti-inflammatory, anticonvulsive or allergy medications, bronchodilators and digitalis, were excluded from the study.

The office BP was evaluated by three, 1-min apart, consecutive measurements, performed by trained paediatric nephrologists using conventional auscultatory technique and a standard mercury sphygmomanometer according to the methodological recommendations established by the 'Update' of the Second Task Force.[3]

HBPM was performed using a validated fully automated electronic device OMRON HEM 705 CP that stores and prints the last 12 measurements.[4] The patient and/or guardian were trained to use the equipment according to the study protocol. The OMRON HEM 705 CP can be used with three cuff sizes, 9×18, 12×23 or 14×28 cm; cuff selection for each patient was based on internationally accepted paediatric recommendations.[3] Before protocol initiation, OMRON HEM 705 CP calibration was checked by performing two consecutive measurements by oscillometry and by auscultation. The minimum accepted difference between the two measurements for SBP and DBP was 5 mm Hg. In addition to the device memory storage and printout, a form was supplied to the patients to report all HBPM values. Before the HBPM period, patients attended a training session in the HBPM technique and their performance was tested by three consecutive self-measurements made in the presence of a physician.

Home blood pressure was evaluated in a calm setting, with the patient comfortably seated, after a 5-min rest, preferably on the left arm positioned to level with the heart, with palms facing upwards, during a 14-day period. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were evaluated, respecting a fixed time schedule, three times in the morning (0800–1100 hours) or in the afternoon (1400–1800 hours; daytime measurement) and three times in the evening (1800–2300 hours; night-time measurement) with 1-min intervals between the measurements, totalling six measurements per day. As all patients involved in the study attended school, during morning or afternoon hours, daytime measurement was scheduled for the patient's free period from school. The patient and/or guardian were asked to keep a diary of the SBP and DBP values recorded by the device.

The BP results of the first day of HBPM were considered as an extended period of training on device handling and BP measurement routine organization and were not included in any calculation. HBPM results of the second day of the study period onwards were taken into consideration for study purposes. For the purpose of data quality control, only diaries that contained valid data on at least 62 of 78 (80%) readings between day 2 and day 14 of the protocol were accepted.

Statistical analysis

Data analysis was performed with the statistical program GraphPad InStat version 3.06, 2003. Pearson correlations were used for evaluating the relationship between different BP values. The average HBP was quantified using standard deviation of differences (s.d.d.) between repeated measurements and Fisher's test was used to compare s.d. of difference values. Mean office SBP and DBP values were calculated from the three measurements performed at the doctor's office. Mean daytime and night-time SBP and DBP values were calculated from the three measurements recorded by each patient in both periods. Office and home SBP and DBP mean values were compared using repeated measures analysis of variance. A significance statistical level of 5% was adopted.

Results

A total of 44 children and adolescents were included. Four patients were excluded because they provided inadequate HBPM measurements. The data from 40 of 44 patients, 14 girls and 26 boys, mean age 12.1 ± 3.6 (s.d.) years (range 4–18), average follow-up 4 ± 3.5 years, were analysed. All the included patients provided the 78 requested HBP measurements.

Average office BP, daytime and night-time systolic and diastolic HBPM of the 13 days study period are presented in Table 1. Average systolic HBPM (daytime and night-time) did not differ from average office BP, and diastolic HBPM (daytime and night-time) was statistically lower than office BP.

The mean differences between average HBPM and office BP were 0.6 ± 14 and 4 ± 13 mm Hg for SBP and DBP, respectively.

There was no significant difference between average daytime and night-time systolic HBP values, both of which did not differ significantly from SBP measurement values in clinic (Figures 1 and 2).

The s.d.d. between average HBPM values of different days are presented in Table 2. In addition, day 1 appears to be more stable (lower s.d.d.) than days 2 and 3. The average HBPM of the days 2 and 3 provided higher and more unstable values (higher s.d.d.) than the values obtained over the following days (days 4–8).

Table 1 Doctor's office BP and home BP (daytime and night-time) values in children and adolescents (mean ± s.d., mm Hg)

	Systolic BP	*Diastolic BP*
Doctor's office	113 ± 13	69 ± 10
Daytime HBP	111 ± 11	63 ± 9[a]
Night-time HBP	111 ± 10	65 ± 9[a]
Average HBP	112 ± 11	65 ± 13[a]

Abbreviations: BP, blood pressure; HBP, home blood pressure.
[a]Student's paired *t*-tests $P < 0.05$ vs doctor's office BP.

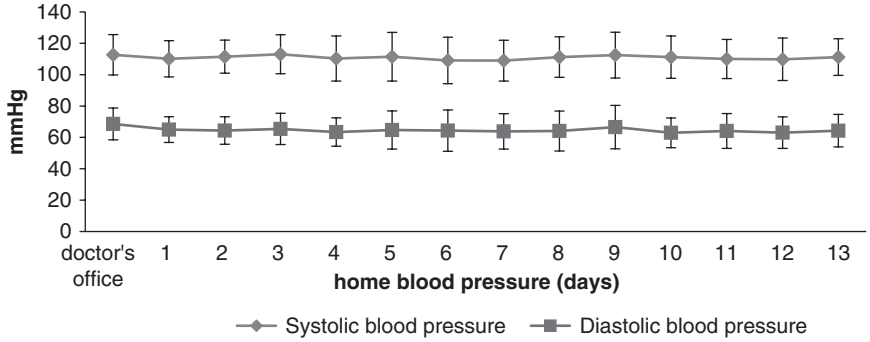

Figure 1 Systolic and diastolic average and standard deviations of office blood pressure and daytime home blood pressure (mm Hg) of days 1–13.

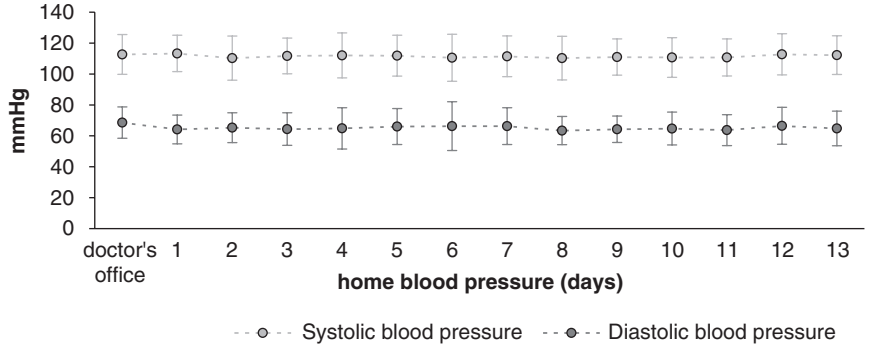

Figure 2 Systolic and diastolic average and standard deviation of office blood pressure and night-time home blood pressure (mm Hg) of days 1–13.

Table 2 HBP assessed by s.d.d. between average values of different monitoring days (systolic/diastolic)

HBP	*Day 1*	*Day 2*	*Day 3*	*Day 4*	*Day 5*	*Day 6*	*Day 7*	*Day 8*	*Day 9*	*Day 10*	*Day 11*	*Day 12*
Day 2	9.0/6.6											
Day 3	10.7/8.3	10.2/5.0										
Day 4	9.1/8.1	10.9/8.3	10.3/8.8									
Day 5	8.3/8.4*	10.4*/8.8	11.3/9.6	7.6/7.1								
Day 6	9.4/10.6	12.3/9.1	9.2/8.0	8.6/9.5	8.2/9.4							
Day 7	7.2/6.7	11.4/7.7	10.7/8.2	7.7/7.1	8.0/6.3	8.0/7.5						
Day 8	8.7/7.7*	9.6/7.6	10.1/8.6	8.5/7.8	9.4/8.0	8.9/8.0	8.9/6.5					
Day 9	9.0/9.8	13.4*/8.8	10.2/8.4	9.5/9.1	9.4/7.5	8.8/7.4	9.8/6.3	7.3/7.8				
Day 10	9.8/6.6	10.5/6.9	11.1/7.6	8.3/6.7	9.1/6.7	10.1/7.4	8.6/4.6	5.7/5.1	8.9/6.5			
Day 11	8.1/9.1	9.6/8.3	8.6/8.1	6.0/7.7	7.7/7.7	8.3/8.1	7.0/6.4	5.4/7.7	6.7/6.0	5.9/5.8		
Day 12	9.2/11.6	11.9/11.6	9.9/11.1	5.9/11.1	8.2/11.5	7.2/11.4	7.7/8.1	7.0/10.8	7.6/9.5	8.0/10.1	5.9/8.9	
Day 13	7.5/9.7	10.0/8.6	8.6/8.1	7.1 /9.5	6.9/8.5	6.8/7.9	7.5/6.8	6.6/9.0	7.3/6.1	7.6/7.5	5.7/5.5	7.0/9.4

Abbreviation: HBP, home blood pressure.
*Fisher's test $P<0.05$.

Discussion

HBPM is an increasingly accepted methodology for BP evaluation and follow-up. It is used in the clinical setting to characterize white coat hypertension and masked hypertension to evaluate the response to anti-hypertensive medications and to improve patient compliance to the anti-hypertensive therapy.[1,2] Studies conducted in adults have demonstrated that HBPM reproducibility is similar to ABPM[5,7] and superior to casual office BP measurements.[1,5–7] HBPM has not been extensively used in paediatric patients[8–10] but some centres already recommend the use of HBPM in children and adolescents with renal disease or hypertension, with the purpose of optimizing BP clinical control.[9] This recommendation might be difficult to follow, as it is necessary to evaluate the influence of factors such as age, patient acceptance and tolerance, compliance of guardians/family members with the HBPM routine and the availability of adequately validated automated blood pressure monitors and appropriate BP cuff sizes on the feasibility of this methodology in the paediatric population.

In the present study, the patient's age range varied from 4 to 18 years with a mean age of 12 years, which is similar to the mean age of patients in other paediatric studies,[8,9,11] as a consequence of the restricted sizes of BP cuffs available for HBPM use. The BP records were adequately reproduced in a diary, according to the proposed protocol, in 40 of 44 patients, which produced 78 measurements, that is 6 measurements per day, for 13 days, reflecting an adherence of 91%. The compliance of children with HBPM was excellent, probably because home monitoring was performed under the close supervision of the participants' parents and, in the younger children, the parents were responsible for all the measurements. Four adolescent patients were excluded from the analysis, because of inadequate diary data entry and refusal of parental assistance with BP measurement and data recording. The high adhesion rate of our patients to the HBPM protocol has not come as a surprise to us, as it has been a common practice in our Hypertension Clinic to ask for BP evaluation between clinic visits. Before the HBPM protocol, these BP measurements were performed in primary care paediatric facilities and brought to clinic in written reports. HBPM has provided our patients with the possibility to have BP measured at home, which is certainly a more practical and less time-consuming practice and might have been partially implicated in the high adhesion rate to the protocol. A recent school-based study of HBPM in 778 children and adolescents showed that this method is feasible.[12]

In the present study, we have chosen to exclude the first-day measurements because of patient adaptation to the equipment, following the protocol of studies in adults that also used a long study period.[6,13,14] Exclusion of the first-day measurements was adopted in these studies because of a larger s.d. than in subsequent days, as a result of the participant's adaptation to the device and to HBPM routine.[6] On the other hand, in a recent study, Stergiou *et al.*[15] used an evaluation period of 6 days and argued that the exclusion of first-day measurements increased the s.d. of average HBP values on account of the reduced number of measurements.

Despite the great variety of electronic devices available in the market, for non-invasive oscillometric BP measurement, it is important to emphasize that only devices duly validated by internationally recognized protocols[16–18] should be used in a clinical setting. Validation for use in special groups of patients, such as children, pregnant women and elderly people, should be taken into consideration, as the choice of the equipment must be restricted to those specifically validated for these groups.[16,18] In this study, the OMRON HEM 705 CP was used. This BP monitor was previously validated by us[4] according to the British Hypertension Society and AAMI regulations.[16,17,18] Among other existing equipment, the following models are also validated for use in paediatric population: OMRON M1, OMRON 711 IS,[11,19] OMRON MX1[19] and OMRON 705 IT.[12] Unfortunately availability of cuff sizes for paediatric use, in the existing validated automated blood pressure monitors, is restricted to 9×18, 12×23 or 14×28 cm bladder sizes.

The comparison of individual BP measurements along the study period (13 days) by s.d.d shows a significant decrease of DBP values from day 5, on which difference tends to disappear towards the end of the study.

The interpretation of these findings could be related to patients' reactions to the protocol with an initial tendency to decrease, representing an accommodation to daily measurements and a subsequent stress reaction secondary to the daily routine. On the other hand, these BP fluctuations may represent a biological rhythm.

The present study protocol was not designed to distinguish between these two possibilities; it is our plan to change the study protocol in the future to elucidate this interesting phenomenon.

The reproducibility of HBP has been reported to be directly dependent on the number of HBP measurements to be averaged,[13] but the number of daily measurements and the length of the monitoring period are still a matter of debate In the adult population, Chatellier *et al.*[13] showed that the maximal reduction in the s.d. of the mean difference between the average values of two HBP sessions was obtained with three measurements per day for 10 consecutive days. Imai *et al.*[20] provided evidence that no further improvement is obtained by increasing the number of HBPM readings above 5 days. The European Society of Hypertension recommends BP monitoring for 7 days with exclusion of the first one. In children and adolescents, the information on HBPM is limited. Paediatric studies HBP methodology has been based on different adult studies, which unfortunately produced methodologically heterogeneous results, making data comparison very difficult. The presently available HBPM paediatric studies performed measurements over 2–7 days,[8,9,11] with a patient population mean age of 10–13 years (age range 3–19 years), and demonstrated a better reproducibility of HBP in comparison to casual office BP measurement.[8–10] Stergiou *et al.*[15] in a recent publication determined that 3 days monitoring with duplicate morning and evening measurements appears to be the minimum schedule for a reliable assessment of HBP.

Our data show a striking stability of SBP and DBP mean values during the vigil hours, with very close daytime and night-time SBP and DBP mean values throughout the 13 monitoring days. A regression to the mean trend was not identified in the present study, contrary to the findings in some similar studies.[8,13,20] The diastolic HBP showed lower values than diastolic office BP. These differences might be attributed, at least in part, to reduced accuracy of the automated device in measuring DBP Our results are not in agreement with Stergiou

et al.[11] who showed that HBP values were significantly lower than clinic measurements and recommended caution in the interpretation of out-of-clinic BP measurements obtained using home monitoring.

In conclusion, HBPM was well accepted by our patient population. The reproducibility of SBP and DBP means, throughout the study period, at daytime and night-time, was remarkable, suggesting HBPM to be a robust methodology for BP follow-up in chronically hypertensive paediatric patients.

HBPM could be viewed as promising tool to be used in the clinical setting, where its accuracy, acceptable cost and user-friendly characteristics make BP measurement at home a feasible and reliable methodology.

HBPM is also an interesting method to be evaluated in clinical research, either in sequence or in parallel to ABPM, which is equally non-invasive but costlier than HBPM. As a note of caution, it is necessary to emphasize that only devices duly validated for paediatric use should be used for HBPM in the paediatric age range. Unfortunately, HBPM's future application for paediatric patients can be severely hindered if the lack of BP cuffs of appropriate sizes to cover the needs of all the paediatric population, according to internationally accepted recommendations,[4] persists.

What is known about the topic

- Evidence shows that monitoring of blood pressure (BP) at home is being used in clinical practice for the assessment of out-of-office BP in children
- The information about home blood pressure monitoring (HBPM) in children and adolescents is limited

What this study adds

- HBPM to be a robust methodology for BP follow-up in chronically hypertensive pediatric patients
- HBP could be viewed as promising tool to be used in the clinical setting, where its accuracy, acceptable cost and user-friendly characteristics make BP measurement at home a feasible and reliable methodology

References

1 O'Brien E, Asmar R, Beilin L, Imai Y, Mancia G, Mengden T *et al.* On behalf of the European Society of Hypertension Working Group on blood pressure monitoring: European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. *J Hypertens* 2003; **21**: 821–848.
2 Guidelines Committee of the 2003. European Society of Hypertension–European Society of Cardiology guidelines for the management of arterial hypertension. *J Hypertens* 2003; **21**: 1011–1053.
3 National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* 2004; **114**(2): 555–576.
4 Furusawa EA, Ruiz MFO, Saito MI, Koch VH. Evaluation of the Omron 705-CP blood pressure measuring device for use in adolescents and young adults. *Arq Bras Cardiol* 2005; **84**(5): 367–370.
5 Stergiou GS, Baibas NM, Gantzarou AP, Skeva II, Kalkana CB, Roussias LG *et al.* Reproducibility of home, ambulatory and clinic blood pressure: implications for the design of trials for the assessment of antihypertensive drug efficacy. *Am J Hypertens* 2002; **15**: 101–104.
6 Stergiou GS, Skeva II, Zourbaki AS, Mountokalakis TD. Self monitoring of blood pressure at home: how many measurements are needs? *J Hypertens* 1998; **16**: 725–731.
7 Brueren MM, van Limpt P, Schouten HJA, Leeuw PW, van Ree JW. Is a series of blood pressure measurements by the general practitioner or the patient a reliable alternative to ambulatory blood pressure measurements? A study in general practice with reference to short-term and long-term between visit variability. *Am J Hypertens* 1997; **10**: 879–885.
8 Stergiou GS, Alamara CV, Salgami EV, Vaindirlis IN, Dacou-Voutetakis C, Mountokalakis TD. Reproducibility of home and ambulatory blood pressure in children and adolescents. *Blood Press Monit* 2005; **10**: 143–147.
9 Wuhl E, Hadtstein C, Mehls O, Schaefer F, The Escape Trial Group. Home, clinic, and ambulatory blood pressure monitoring in children with chronic renal failure. *Pediatric Res* 2004; **55**: 492–497.
10 Bald M, Bohn W, Feldhoff C, Bonzel KE. Home blood pressure self measurement in children and adolescents with renal replacement therapy. *Klin Padiatr* 2001; **213**: 21–25.
11 Stergiou GS, Alamara CV, Kalkana CB, Vaindirlis IN, Stefanidis CJ, Dacou-Voutetakis C *et al.* Out-of-office blood pressure in children and adolescents: disparate findings by using home or ambulatory monitoring. *Am J Hypertens* 2004; **17**: 869–875.
12 Stergiou GS, Yiannes NG, Rarra VC. Validation of the Omron 705 IT oscillometric device for home blood pressure measurement in children and adolescents: the Arsakion School Study. *Blood Press Monit* 2006; **11**(4): 229–234.
13 Chatellier G, Day M, Bodrie G, Menard J. Feasibility study of N-of-1 trials with blood pressure self-monitoring in hypertension. *Hypertension* 1995; **25**: 294–301.
14 Chatellier G, Dutrey-Dupagne C, Vaur L, Zannad F, Genes N, Elkik F *et al.* Home self-blood pressure measurement in general practice: the SMART study. *Am J Hypertens* 1996; **9**: 644–652.
15 Stergiou GS, Christodoulakis G, Giovas P, Lourida P, Alamara C, Roussias L. Home blood pressure monitoring in children: how many measurements are need? *Am J Hypertens* 2008; **21**: 633–638.
16 O'Brien E, Petrie J, Littler W, de Swiet M, Padfield PL, O'Malley K *et al.* The British Hypertension Society protocol for the evaluation of automated and semi-automated blood pressure measuring devices with special reference to ambulatory systems. *J Hypertens* 1990; **8**: 607–619.
17 O'Brien E, Atkins N. A comparison of the British Hypertension Society and Association for the advancement of medical instrumentation protocols for validating blood pressure measuring devices: can the two be reconciled? *J Hypertens* 1994; **12**: 1089–1094.

18 O'Brien E, Petrie J, Littler W, de Swiet M, Padfield PL, Altman DG *et al.* Short report: An outline of the revised British Hypertension Society protocol for the evaluation of blood pressure measuring devices. *J Hypertens* 1993; **11**: 677–679.
19 Barker ME, Shiell AW, Law CM. Evaluation of the Dinamap 8100 and Omron M1 blood pressure monitors for use in children. *Paediatr Perinat Epidemiol* 2000; **14**: 179–186.
20 Imai Y, Ohkubo T, Hozawa A, Tsuji I, Matsubara M, Araki T *et al.* Usefulness of home blood pressure measurements in assessing the effect of treatment in a single-blind placebo-controlled open trial. *J Hypertens* 2001; **19**(2): 179–185.