Factors Predicting the Fall in Clinic Blood Pressure on Repeated Measurements

Cheung BMY and Cheung AJ

Abstract— **Aim: Clinic blood pressure (BP) readings tend to decrease towards the true value on repeated measurements. We aimed to identify factors associated with the fall in systolic and diastolic BP on repeated measurements.**

Methods: We used BP data on 4943 participants aged ≥20 (2475 men, 2468 women; mean age±SD, 50±18 years) in the United States National Health and Nutrition Examination Survey (NHANES) 2007-8. Repeated measurements analysis of variance was used to identify predictors of the change in BP with time.

Results: As expected, BP was significantly related to age, gender and body mass index (P<0.001). Both systolic and diastolic BP decreased significantly with time (P<0.001). These decreases were significantly related to age and the maximum cuff pressure (P<0.001). They were not related to body weight, arm dimension, triceps skinfold thickness, cuff size, and consumption of food, coffee and tobacco in the preceding 30 minutes.

Conclusion: Older persons and those with high systolic BP had larger decreases in BP on repeated measurements. Hence, adequate inflation of cuff and repeated measurements in the elderly are key factors for measuring clinic BP accurately.

Keywords-blood pressure; blood pressure measurement; NHANES

I. INTRODUCTION

Clinic blood pressure (BP) is known to be an approximate estimate of a person's true BP [1]. There are many reasons for this lack of accuracy. On one hand, the person undergoing BP measurement may not have rested for a long enough period of time, or the person is anxious and is unaccustomed to the clinical environment and the procedure [2]. On the other hand, because BP by its nature is a constantly changing variable, taking the mean of repeated readings is always superior to a single reading no matter how carefully it is measured. In recent years, many people have come to regard ambulatory blood pressure as the gold standard in the diagnosis of hypertension, white-coat hypertension and masked hypertension [1, 3, 4]. While it is very useful in the diagnosis of hypertension, it is not practical in the routine follow-up of patients to carry out repeated ambulatory blood pressure monitoring. Therefore, it has not replaced careful clinic BP measurements in daily practice.

In usual clinical settings, it is customary to take the BP more than once because it is well know that BP readings tend to decrease towards the true value on repeated measurements [5]. In this analysis, we aimed to identify the factors related to the change in systolic and diastolic BP on repeated measurements.

II. METHODS

The United States National Health and Nutritional Examination Survey (NHANES) 2007-8 database was used in this analysis [6]. Ethical approval for the study was granted by the Centers for Disease Control and Prevention Institutional Review Board. Participants were included in the analysis if they had undergone no fewer than three BP readings. All BP measurements were conducted in mobile examination centers by trained and certified personnel [7]. After giving informed consent, participants sat quietly for five minutes. The maximum inflation cuff pressure was determined, and the BP was then measured three times. A further reading could be taken if an earlier reading was interrupted or failed.

Data analysis was performed using SPSS version 22 (IBM). Repeated measurements analysis of variance was used to identify variables that showed significant interaction with time. A P-value of less than 0.05 was considered significant.

III. RESULTS

In NHANES 2007-8, there were 4943 participants aged 20 or over with repeated BP measurements. Their characteristics are shown in Table 1. As expected, BP was significantly related to gender, age, body mass index and pulse rate (Table 2). Systolic and diastolic BP both decreased significantly ($p<0.001$) with time (Table 1 and Fig. 1). The decrease in systolic BP with time was significantly related to age (partial $\eta^2=0.008$, $p<0.001$) (Fig. 1) and the maximum cuff pressure (partial $\eta^2=0.025$, $p<0.001$) (Fig. 2). The decrease in diastolic BP with time was also related to age

DOI: 10.5176/2345-7201_1.3.28

(partial η^2=0.002, p=0.006) (Fig. 1) and the maximum cuff pressure (partial η^2=0.002, p=0.001). The decrease in BP readings was not related to body weight, arm dimension, triceps skinfold thickness, cuff size, and consumption of food, coffee and tobacco in the preceding 30 minutes. It was observed in men and women alike, even though men and women had different levels of BP (Fig. 3). It was also not related to whether the participant was hypertensive and taking hypertensive medication (Fig. 4).

Plotting the decrease in SBP between the 1st and 3rd reading against the arithmetic mean of the 3 readings showed that there was some regression to the mean (r=0.2, p<0.001) (Fig. 5).

TABLE 1
Characteristics of participants in NHANES 2007-8

	Men	Women
Number of participants	2475	2468
Age (years)	50.4±17.6	50.1±17.6
Race/Ethnicity		
Mexican American	422	445
Other Hispanic	253	305
Non-Hispanic white	1221	1122
Non-Hispanic black	480	507
Other	99	89
Systolic BP (mmHg)		
1st reading	127.4±17.7	124.5±20.9
2nd reading	125.6±16.9	122.5±20.0
3rd reading	124.1±16.4	121.4±19.5
Diastolic BP (mmHg)		
1st reading	72.5±12.7	68.7±12.7
2nd reading	71.7±12.9	68.3±12.6
3rd reading	71.5±13.0	67.8±12.8

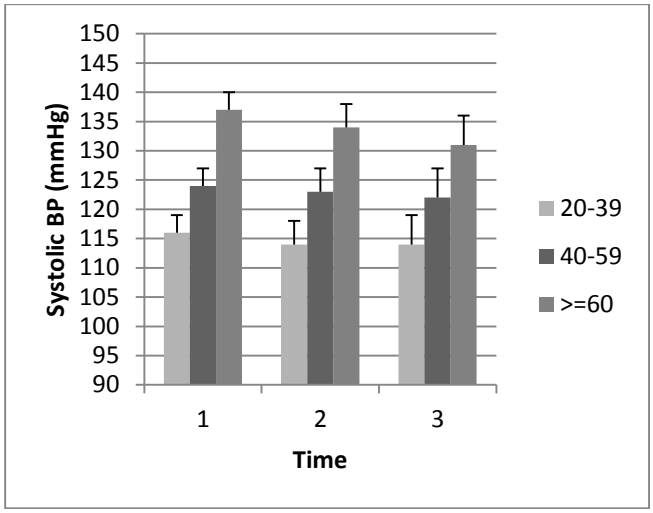
Continuous variables are expressed as mean±SD.

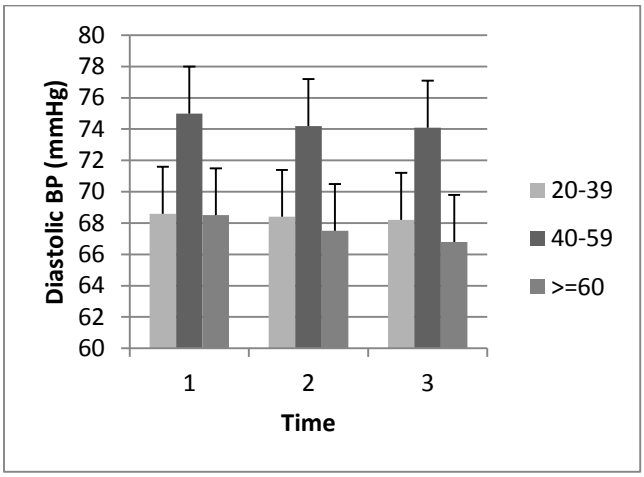
TABLE 2 Variables correlated with systolic and diastolic BP

	Systolic BP		*Diastolic BP*	
	ρ	**P-value**	**ρ**	**P-value**
Gender	0.079	<0.001	0.146	<0.001
Age	0.444	<0.001	-0.051	0.001
Body mass index	0.110	<0.001	0.077	<0.001
Pulse rate	-0.046	0.001	0.111	<0.001

ρ, Spearman correlation coefficient.

FIGURE 1 Repeated systolic and diastolic BP readings in three different age groups (20-39, 40-59 and ≥60)





Error bars denote SE of the group mean. The decreases in BP with time were significant (p<0.05) in all age groups.

FIGURE 2 Relationship between the change in systolic BP between the first and third reading with the maximum cuff pressure

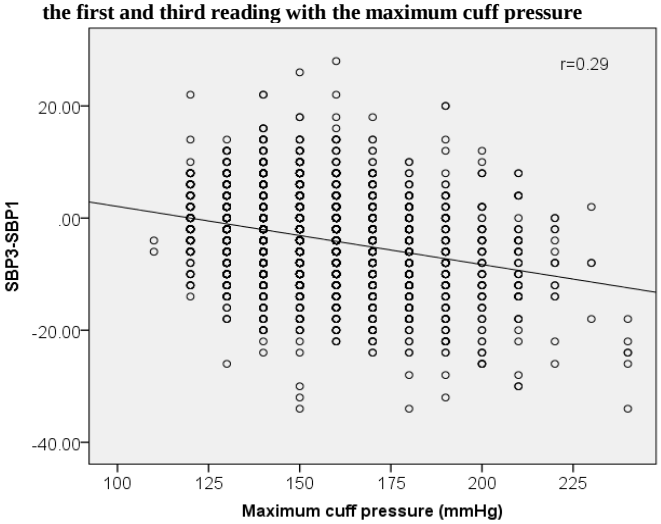
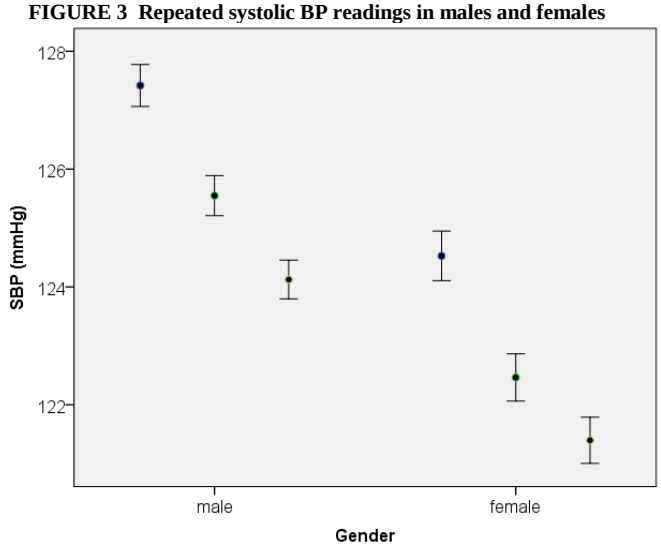
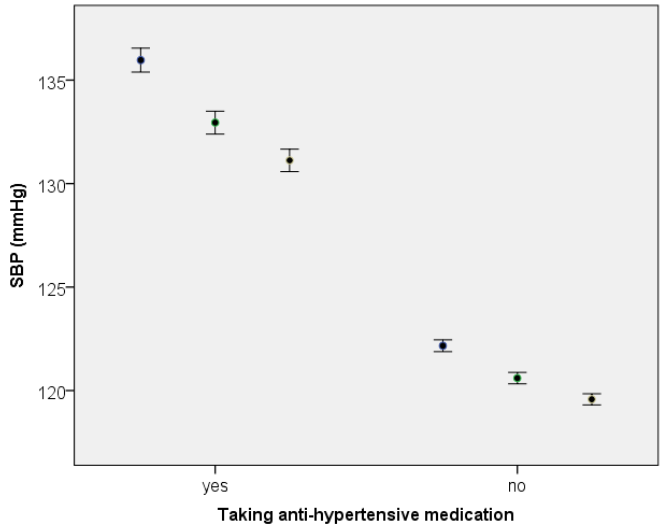


FIGURE 3 Repeated systolic BP readings in males and females



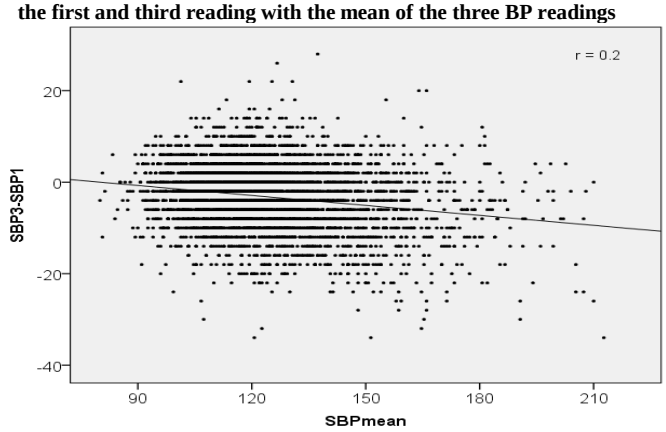
Error bars denote SE. The decreases in BP with time were significant ($p<0.05$) in both groups.

FIGURE 4 Repeated systolic BP readings in participants taking or not taking antihypertensive medication



Error bars denote SE. The decreases in BP with time were significant ($p<0.05$) in both groups.

FIGURE 5 Relationship between the change in systolic BP between the first and third reading with the mean of the three BP readings



IV. Discussion

Data from NHANES, which is a large continuous survey of the health and nutrition of the American general population, is uniquely useful in the study of BP in the general population [8]. The advantage of NHANES is not only its large sample size, but also its generalizability to the general population. The sample population includes many who have no known chronic medical conditions and do not see a doctor regularly. In NHANES, the personnel who perform BP measurements are trained and certified, and readings are made under controlled conditions according to a strict protocol. Due to the rigor with which BP measurements were made, many of the variables commonly assumed to affect BP readings did not do so. Thus, the decreases in BP readings with repeated measurements were not related to body weight, arm dimension, triceps skinfold thickness, cuff size, and consumption of food, coffee and tobacco in the preceding 30 minutes. Instead, we found that age and the level of maximal pressure to which the cuff was inflated were related to the amount of fall in BP on repeated measurements. Older persons had a larger fall in BP on repeated measurements. Inflating the cuff to a higher initial pressure was associated with a definite fall in the BP reading on repeat measurements. These findings are relevant to clinical practice; they suggest that BP should be measured slowly and carefully in the elderly, and that inflating the cuff to a higher initial pressure may give more accurate readings. Both are related to time and patience when measuring BP.

We included a wide range of adults in our analysis. Of note, diastolic BP increases in middle age but it decreases in old age, when isolated systolic hypertension is often found. Because the diastolic BP is normal in isolated systolic hypertension, the accurate measurement of systolic BP is especially important in the elderly.

Due to the physiological variation in BP from beat to beat, and the inaccuracy of non-invasive measurements of BP, regression to the mean can occur with repeated BP readings. This commonly occurs when people with initially elevated readings undergo repeated measurements. In our analysis, there was no selection of participants based on their initial BP readings. Moreover, even among participants with lower than average BP, there was still a tendency, albeit smaller, for BP readings to fall with repeated measurements. Therefore, while there was a degree of regression to the mean, this did not entirely account for the fall in BP with repeated measurements in our sample population.

The NHANES study is not without limitations. The participants were examined only once and so this study does not reproduce the situation in general practice in which patients can come on repeated visits to have blood pressure measurements.

In conclusion, systolic and diastolic BP readings decrease on repeated measurements. Care should be taken when measuring BP in the elderly, and the BP cuff should be inflated to adequate levels.

REFERENCES

[1] Hodgkinson J, Mant J, Martin U, Guo B, Hobbs FD, Deeks JJ, Heneghan C, Roberts N, McManus RJ. Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. BMJ. 2011 Jun 24;342:d3621. doi: 10.1136/bmj.d3621.

[2] McGrady A1, Higgins JT Jr. Effect of repeated measurements of blood pressure on blood pressure in essential hypertension: role of anxiety. J Behav Med. 1990 Feb;13(1):93-101.

[3] Mancia G, Bombelli M, Seravalle G, Grassi G. Diagnosis and management of patients with white-coat and masked hypertension. Nat Rev Cardiol. 2011 Aug 9. doi: 10.1038/nrcardio.2011.115.

[4] National Institute for Health and Clinical Excellence. Clinical management of primary hypertension in adults. http://egap.evidence.nhs.uk/CG127 [accessed 29 August 2014]

[5] Burstyn P, O'Donovan B, Charlton I. Blood pressure variability: the effects of repeated measurement. Postgrad Med J. 1981 Aug;57(670):488-91.

[6] Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS): National Health and Nutrition Examination Survey questionnaire, examination protocol and laboratory protocol. Hyattsville, Maryland: United States Department of Health and Human Services, Centers for Disease Control and Prevention, 1999-2010. Available at: http://www.cdc.gov/nchs/ nhanes.htm. Accessed July 29, 2014.

[7] Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS): National Health and Nutrition Examination Survey. 2007 - 2008 Data Documentation, Codebook, and Frequencies. Blood Pressure (BPX_E). Available at: http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/BPX_E.htm#Protocol_and_Procedure. Accessed November 3, 2014.

[8] Ong KL, Cheung BMY, Man YB, Wong LYF, Lau CP, Lam KSL. Prevalence, awareness, treatment and control of hypertension among United States adults 1999-2004. Hypertension 2007; 49(1):69-75.

AUTHORS' PROFILE

Bernard M.Y. Cheung, PhD (Cantab), FRCP, is the Sun Chieh Yeh Heart Foundation Professor in Cardiovascular Therapeutics at the University of Hong Kong, and heads the Division of Clinical Pharmacology and Therapeutics. He is the Director of the Institute of Cardiovascular Science and Medicine as well as the Phase 1 Clinical Trials Centre. He is the current President of the Hong Kong Pharmacology Society.

Adrian J. Cheung was educated at Tonbridge School and is a young researcher. His school research project prompted a paper in British Medical Journal Case Reports. He has made original discoveries in the blood pressure of children and is currently working on low level exposure to heavy metals in the general population.