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Mechanisms of Blood Pressure Measurement Inaccuracy: A Comparative Analysis of the Role of Occupation and Attire

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Abstract

Objectives: White coat hypertension (WCH) is defined as high blood pressure (BP) when measured by health care providers in medical environments, but normal BP in other settings. In this study, we examine the effects of occupation and attire on the accuracy of BP readings and WCH.

Methods: 50 individuals were recruited and had their BP assessed twice by a cardiologist, a cardiac nurse, and a cardiovascular technician, once wearing a white lab coat, and once without, in random order. All individuals underwent a 24 hour ambulatory BP monitoring (ABPM). The mean of the daytime measurements of the ABPM served as the control.

Results: Compared to the ABPM, the cardiologist recorded a 23.7 mm Hg higher systolic BP reading wearing a white coat and 13.3 mmHg without a white coat ($p<0.0001$). The cardiac nurse recorded a 14.2 mmHg higher reading with a white coat and 5.7 mmHg without a white coat ($p<0.0001$). There was no statistically significant difference between the measurements of the cardiovascular technician and the ABPM with a white coat, 2.8 mmHg, or without a white coat, -1.8 mmHg.

Conclusions: This study demonstrates that the incidence of WCH and BP measurement inaccuracy occurs more frequently when assessed by a cardiologist or nurse than when assessed by a cardiovascular technician. Wearing a white coat aggravates blood pressure measurement inaccuracy. It may be advisable for healthcare providers to avoid wearing white lab coats or attire that identifies their occupation when measuring blood pressure.

Keywords: White coat hypertension; Blood pressure; Accuracy; Attire; Occupation

Introduction

White Coat Hypertension describes individuals with elevated BP in medical environments, such as clinics or hospitals, but whose BP is normal when they are going about their daily activities [1-6]. 24-hour ambulatory blood pressure monitoring (ABPM) using an automated machine that records BP every 30 minutes while awake and every 60 minutes while asleep has been determined to be the most accurate method for BP recording [6-10]. It is also the most accurate method to distinguish White Coat Hypertension from "true" hypertension, because it records BP elevations that occur regardless of the external environment [6]. Due to barriers such as cost and a lack of availability, ABPMs are not readily available in many jurisdictions, and often blood pressure measurements taken by health care providers, conventionally nurses or physicians, are used for clinical diagnosis and treatment [11,12].

Prior studies show that White Coat Hypertension occurs in more than 20% of the hypertensive population, with some studies citing its incidence to be above 40% [1-6,13]. In such patients, the BP elevation responses in a medical setting may lead to misclassification and mistreatment of patients [1-6,13-18]. Studies show that individuals with white coat hypertension have a significantly lower number of cardiovascular events than true hypertensive, but a higher number of events than normotensive patients without white coat hypertension [1,14-18]. Thus, it is important to distinguish the difference between these three groups: true hypertensive, white coat hypertensive, and true normotensives.

This study assessed whether the profession and attire of the individual measuring the BP impacted the incidence of White Coat Hypertension. The specific question asked in this study was "How does the accuracy of BP recordings by a physician, a nurse and a technician compare to the ABPM gold standard and what is the impact of wearing a white lab coat on the accuracy of BP measurements and the incidence of white coat hypertension?" The environment, time of day, method of BP measurement, and device used to measure BP were all controlled variables in this study.

Methods

Design

This was a single-centre, observational study of 50 consecutive volunteers over a period of 4 months.

Ethics

A test protocol and written informed consent document were submitted and reviewed by Dr. S. Sykes of the University of Waterloo Human Research Ethics Board. We obtained written informed consent from all participants before any procedures were carried out. Ample time and opportunity was given for participants to ask questions, and consider the commitments necessary for participation in this study.

Setting

Recruitment and study procedures were carried out in the city of Cambridge (pop. 145 000), Ontario at a cardiology community practice (Cambridge Cardiac Care Centre).

Population and Subject selection

50 consecutive individuals, both with and without known hypertension, who required an ambulatory blood pressure monitor for clinical indications were recruited. All participants were above 18 years of age, competent to provide informed consent, and were able to avoid caffeine and nicotine for the required 24 hour period. Children, mentally handicapped individuals, incarcerated individuals, those unable to provide informed consent, those unable to read and write in English, and those unable to adhere to the study protocol were excluded.

94 individuals were screened to participate in this study over a period of 4 months. 15 failed to meet the inclusion criteria and 29 declined to participate.

Study procedures

Demographic information, including age, gender, medical diagnosis, and medication list was collected, with permission, from the medical chart of the participants.

Participant had their BP assessed by 3 different health care providers: a nurse, a technician and a physician. 2 physicians, 4 nurses, and 4 technicians took blood pressure readings. The participants were informed in advance of the occupation of each of the health care providers. All healthcare providers were asked to adhere to the Pan-American Journal of Public Health standardized method of blood pressure measurement to assess blood pressure to eliminate potential sources of error and variation [19]. The health care providers measured the blood pressure of participants twice, once while wearing a standard white lab coat, and once while not wearing it. The sequence of healthcare providers measuring BP and whether they wore a white lab coats was randomized to reduce bias.

There was a 10 minute delay between each of the blood pressure assessments. All health care providers used an Omron manual blood pressure cuff (model#760 HEM 7220-Z) to assess blood pressure. All participants had their blood pressures assessed by health care providers in the morning hours, between 8:00 AM-12:00 AM.

Subsequently, a Spacelabs Ambulatory Blood Pressure Monitor (model#90207-30) was applied to each participant. Each patient's blood BP was recorded over a 24 hour period; one measurement was taken every ½ hour from 8 AM-10 PM, and every hour from 10:00 PM to 8:00 AM. The arithmetic mean of the BP readings in the daytime was compared to the readings obtained by the various healthcare providers.

Data collection

Baseline demographics, including age, gender, education levels, disease states, presence or absence of the diagnosis of hypertension, duration of hypertension, medications, height, weight, abdominal girth, BP readings by each healthcare provider with and without wearing a white lab coat, and 24 hour BP readings using ABPM were collected.

Subgroup analysis

We pre-specified specific subgroups for analysis to determine if they may be at a higher risk for WCH. These subgroups included males, females, non-elderly, elderly, extreme elderly (80+), normotensives, hypertensive for less than 1 year, hypertensive for more than one year, those with secondary education or less education and those with post-secondary education. The average results of the BP measurements in each of these groups were compared to the average results of the entire study population.

Statistical analysis

Statistical analysis was performed using Graphpad Instat 3.10 Statistical Analysis software. Paired, two-tailed Students t-tests were used for comparisons of two variables, such as the difference between the measurements of the physician with a white coat vs. the measurements of the physician without a white coat. ANOVA with Bonferroni correction was used for all comparisons with three or more variables with multiple comparisons, such as the subgroup analysis performed. A p-value of 0.05 or less was considered statistically significant.

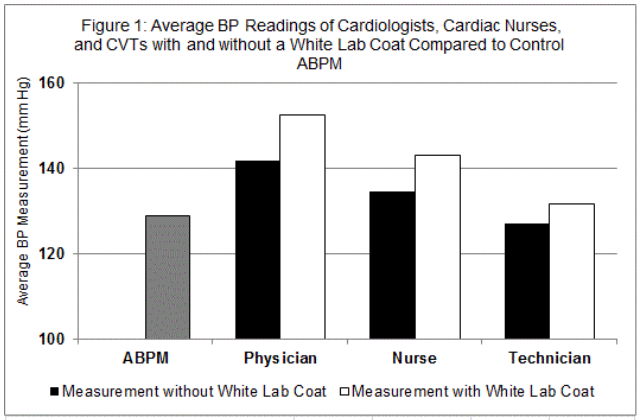
Results

No study participants dropped out, or withdrew consent at any point in the study.

Figure 1 displays a direct comparison between the average BP measurements of the physician, technician and nurse, compared to the control ABPM. This analysis was performed with the data from both measurements taken with, and without a white lab coat. The physician was observed to have the most inaccurate BP readings, with an average systolic BP reading 23.7 mmHg higher than that of the ABPM while wearing a white lab coat, and 13.3 mmHg higher while not wearing a white lab coat ($p<0.0001$ versus ABPM control). Through a paired, two-tailed Student's t-Test, a p-value of less than 0.0001 was obtained. The nurses' readings were modestly more accurate, with an average systolic BP reading 14.2 mmHg higher than the ABPM while wearing a white lab coat, and 5.7 mm Hg higher while not wearing a white lab coat ($p<0.0001$ versus ABPM control). The technician was observed to have the most accurate BP readings, with an average systolic BP reading 2.8 mmHg higher than that of the ABPM, while wearing a white lab coat, and 1.8 mmHg lower than that of the ABPM while not wearing a white lab coat (p=NS versus ABPM control). There was no statistically significant difference between the results of the ABPM and those of the technician.

Figure 1 illustrates that wearing a white lab coat appeared to result in elevations of blood pressure readings by all health care providers resulting in greater inaccuracy compared to the ABPM control. The difference between the average systolic BP measurement of the physician wearing a white lab coat, and the average BP measurement of the physician not wearing a white lab coat was 10.4 mmHg

(p=0.001). The difference between the average systolic BP measurement of the nurse wearing a white lab coat, and the average BP measurement of the nurse not wearing a white lab coat was 8.5 mmHg (p=0.002). The difference between the average systolic BP measurement of the technician wearing a white lab coat, and the average BP measurement of the technician not wearing a white lab coat was 4.0 mmHg (p=0.02).

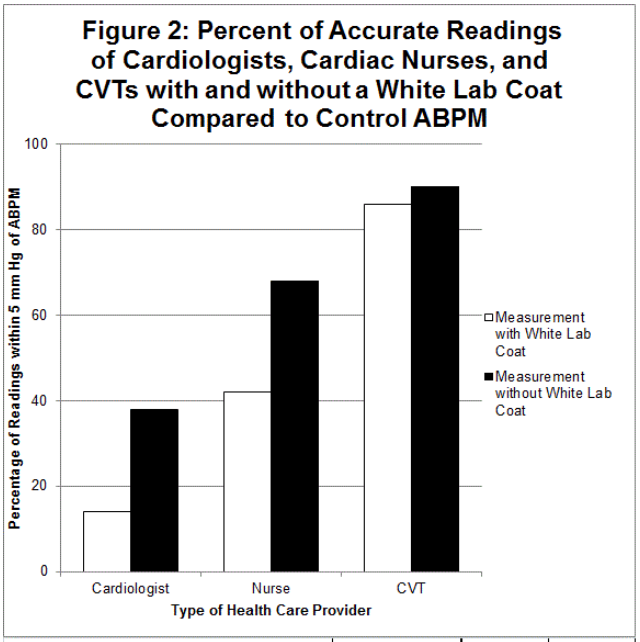


	ABPM	Physician	Nurse	Technician
Measurement without White Lab Coat		141.9	134.6	127.1
Measurement with White Lab Coat	128.9	152.6	143.2	131.7

Figure 1: Average BP readings of physicians, nurses, and CVTs with and without a white lab coat compared to control ABPM-This graph shows a comparison between the BP measurements of various health care providers compared to the daytime readings of a 24-hour ambulatory blood pressure monitor in 50 patients. Health care providers measured the blood pressure twice using a standardized method; once with a white lab coat, and once without. These results are displayed in separate columns. Abbreviations- ABPM: Ambulatory Blood Pressure Monitor, BP: Blood Pressure, CVTs: Technicians, mmHg-Millimeters of Mercury.

Figure 2 illustrates a comparison of percentage of accurate blood pressure readings, defined as a systolic blood pressure reading within 5 mm Hg of the reading of the ABPM. The physician was observed to have recorded the fewest percent of accurate BP readings. Only 14% of readings while wearing a white lab coat, and 38% of readings while not wearing a white lab coat by the physician were within 5 mmHg of the daytime readings of the ABPM. 42% of readings while wearing a white lab coat, and 68% of readings while not wearing a white lab coat by the nurse were within 5 mm Hg of the daytime readings of the ABPM. The technician was observed to have recorded the greatest percent of accurate BP readings. 86% of readings while wearing a white lab coat, and 90% of readings while not wearing a white lab coat by the technician were within 5 mmHg of the daytime readings of the ABPM.

Pre-specified subgroup analysis examined the differences between the blood pressure measurements obtained by each health care provider and the blood pressure result of the ABPM in subgroups stratified by age, gender, duration of hypertension, disease states, and education level, compared to that of the entire study population and other sub-groups.



	Cardiologist	Nurse	CVT
Measurement with White Lab Coat	14	42	86
Measurement without White Lab Coat	38	68	90

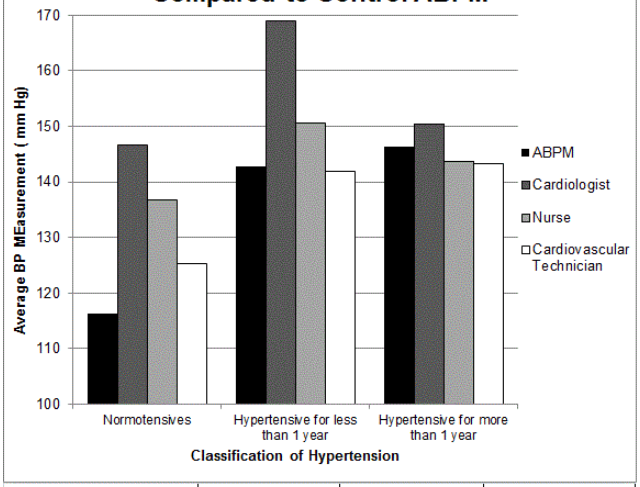
Figure 2: Percent of accurate readings of physicians, nurses, and CVTs with and without a white lab coat compared to control ABPM. This graph shows a comparison between the percent of accurate readings of various health care providers, defined as BP readings within 5 mmHg of the daytime readings of a 24-hour ambulatory blood pressure monitor. Health care providers measured the blood pressure twice using a standardized method; once with a white lab coat, and once without. These results are displayed in separate columns. Abbreviations- ABPM: Ambulatory Blood Pressure Monitor, BP: Blood Pressure, CVTs: Technicians, mmHg: Millimeters of Mercury.

Sub-group analysis stratified by age, gender, and individuals with comorbidity disease states (prior MI, CHF, COPD, AFIB, Stroke, and Renal Failure), as well as sub-groups stratified based on the amount of BP medications prescribed, were observed to have similar results to that of the entire study population (p<n.s.).

Educational status (Figure 3) and prolonged history of hypertension (Figure 4) did appear to affect the differences in blood pressure readings of various health care providers. Individuals with post-secondary education had similar blood pressure readings by all 3 types of health care providers. These readings were also closer to the readings obtained by the ABPM. Similarly, individuals with a history of hypertension of longer than one year's duration appeared to have fewer differences in BP readings by the various health care providers.

The percentage of individuals each healthcare provider caused to be white coat hypertensive was additionally analysed (Figure 5). Patients whose BP was greater than or equal to 140/90 mmHg when assessed by a healthcare provider but less than 135/85 mmHg compared to the daytime readings of the control ABPM were classified as white coat hypertensive.

Figure 3: Sub-Group Analysis of presence and duration of pre-existing hypertension: Average BP Readings of Cardiologists, Cardiac Nurses, and CVTs Compared to Control ABPM



	Normotensives	Hypertensive for less than 1 year	Hypertensive for more than 1 year
ABPM	116.4	142.8	146.4
Cardiologist	146.6	168.9	150.5
Nurse	136.7	150.6	143.6
Cardiovascular Technician	125.4	141.9	143.2

Figure 3: Sub-group analysis of presence and duration of pre-existing hypertension: Average BP Readings of physicians, nurses, and CVTs compared to control ABPM. This graph shows a comparison between the BP measurements of various health care providers compared to the daytime readings of a 24-hour ambulatory blood pressure monitor in 50 patients split into three sub-groups; normotensives, those with a history of hypertension for less than 1 year, and those with a history of hypertension for more than 1 year. Abbreviations- ABPM: Ambulatory Blood Pressure Monitor, BP: Blood Pressure, CVTs: Technicians, mmHg: Millimeters of Mercury.

Physicians caused 33% of participants while wearing a white lab coat and 24% of participants while not to be white coat hypertensive. Nurses caused 24% of participants while wearing a white lab coat and 15% of participants while not to be white coat hypertensive. Technicians caused 6% of participants while wearing a white lab coat and 0% while not to be white coat hypertensive ($p<0.0001$).

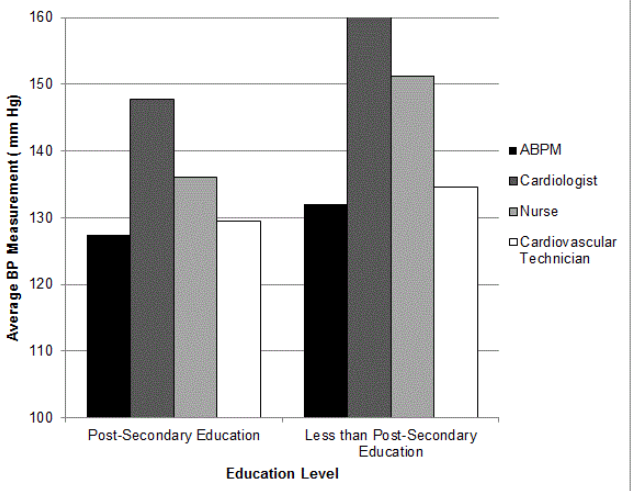
Discussion

Sources of error

Participants were informed in advance of each health care provider's occupation; however visual differences, such as gender, size and age of the health care provider may have impacted the results.

This study was conducted in a random group of individuals with varying BPs. Some were normotensive, some were mildly hypertensive and some were severely hypertensive. This resulted in a great deal of variability and large standard deviations for the average or mathematical means of BP readings as taken by the ABPM device as well as the various health care providers.

Figure 4: Sub-Group Analysis: Average BP Readings of Cardiologists, Cardiac Nurses, and CVTs Compared to Control ABPM stratified by Education Level



	Post-Secondary Education	Less than Post-Secondary Education
ABPM	127.5	132
Cardiologist	147.8	160.3
Nurse	136.1	151.2
Cardiovascular Technician	129.5	134.6

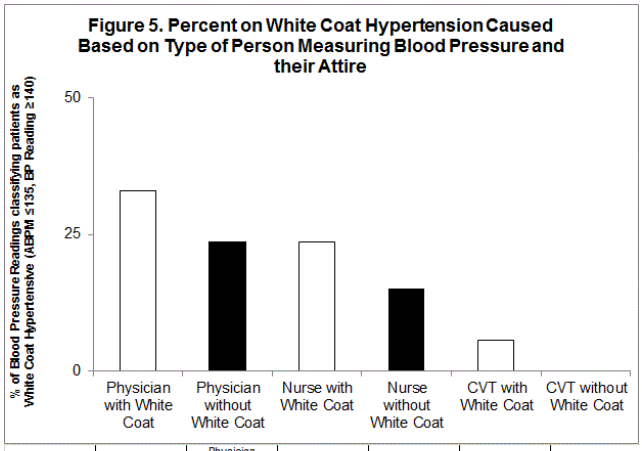
Figure 4: Sub-group analysis: Averages BP readings of physicians, nurses, and CVTs compared to control ABPM stratified by education level. This graph shows a comparison between the BP measurements of various health care providers compared to the daytime readings of a 24-hour ambulatory blood pressure monitor in 50 patients split into two sub-groups; those with secondary education or less, and those with post-secondary education. Abbreviations- ABPM: Ambulatory Blood Pressure Monitor, BP: Blood Pressure, CVTs: Technicians, mmHg: Millimeters of Mercury.

Conclusion

The accuracy of systolic BP readings varied based on the type of health care provider taking the BP measurements and independently whether the health care provider wore a white lab coat or not.

The measurements taken by the physician were the most erroneously elevated when compared to the gold standard ABPM. Readings taken by the technician were closest to the ABPM. Readings by the nurse were intermediate in accuracy; closer to the ABPM readings than the physician, although not as accurate as the technician. Similarly, in the second analysis, the physician recorded the fewest number of accurate readings (within 5 mmHg of the ABPM). The nurse recorded an intermediate amount of accurate readings, and the technician recorded the largest percentage of accurate readings, with only 10% of all readings without a white coat diverging greater than 5 mmHg from those of the ABPM. Potential explanations of the observed results may include that patients may be more stressed or

anxious around physicians or nurses more so than when in the presence of a technician, which could lead to erroneously elevated blood pressure when measured by these health care providers.



	Physician with White Coat	Physician without White Coat	Nurse with White Coat	Nurse without White Coat	CVT with White Coat	CVT without White Coat
White Coat Hypertension	33.01886792	23.58490566	23.58490566	15.09433962	5.660377358	0

Figure 5: Percent on white coat hypertension caused based on type of person measuring blood pressure and their attire. This graph shows that certain types of health care providers are more prone to causing white coat hypertension than others. Specifically, physicians caused the greatest amount of white coat hypertension, with nurses causing an intermediate amount, and technicians causing limited white coat hypertension. Wearing a white lab coat increased the amount of white coat hypertension caused by each healthcare provider. Abbreviations- ABPM: Ambulatory Blood Pressure Monitor, BP: Blood Pressure, CVTs: Technicians, mmHg: Millimeters of Mercury.

The inaccuracy of the blood pressure readings was further exaggerated when each of the health care providers wore a white lab coat. Similarly, the number of accurate readings (within 5 mmHg of the ABPM) was significantly less when each of the health care providers wore a white lab coat compared to when they did not. An explanation for these results may be that individuals develop more stress and anxiety when a professional sporting a white lab coat assesses their BP.

All but two sub-groups displayed similar trends to those of the entire study population. Individuals with a history of hypertension for more than one year had significantly more accurate recordings by all health care providers, compared to those with a history of hypertension for less than one year and normotensives. This may be because normotensives or those with hypertension for less than a year would be less familiar with BP measurements than those who have a history of hypertension for more than one year as these individual may have had their BP checked more frequently and become accustomed to this procedure and thus may be less intimidated or anxious about having their BP measured. Perhaps autonomic damage resulting from hypertension over a longer duration of time may result in less blood pressure fluctuations, reducing the potential of white coat hypertension. Individuals with post-secondary education appeared to have less erroneous blood pressure readings with all health care providers compared to those with less than post-secondary education. Perhaps people with less education may be more intimidated by health care providers.

This data suggests that perhaps health care facilities should have blood pressures measured, where possible, by technicians rather than nurses or physicians to ensure more accurate readings. Also, it may be advisable for health care providers measuring blood pressure to refrain from wearing a white lab coat or attire that identifies the occupation of the measurer to reduce erroneous results.

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