INSTRUCTIONAL DESIGN AND ASSESSMENT

Assessment of Manual Blood Pressure and Heart Rate Measurement Skills of Pharmacy Students: A Follow-Up Investigation

Katherine E. Elliott, PharmD, Kenneth L. McCall, PharmD, David S. Fike, PhD, Jill Polk, PharmD, and Cynthia Raehl, PharmD^a

^aSchool of Pharmacy, Texas Tech University Health Sciences Center

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Objectives. To evaluate the impact of a laboratory course on the manual blood pressure (BP) and heart rate (HR) measurement skills of pharmacy students.

Methods. After 1 lecture and 1 laboratory session on vital sign technique, pharmacy students enrolled in a patient assessment laboratory course were randomly paired with a classmate and manually measured the classmate's BP and HR. Within 2 minutes, the BP and HR were measured by an Omron 711-AC automatic monitor. The same assessment procedures with manual and automatic measurements were repeated near the end of the laboratory course. Student skills were also evaluated through direct observation by faculty members.

Results. Student and machine measurements of systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR significantly correlated at the final assessment ($r = 0.92, 0.83, \text{ and } 0.91$ respectively; $p < 0.001$ for each). The proportion of student and device values agreeing to within 5 units (mmHg and beats-per-minute) at baseline versus at the final assessment significantly improved from 38% to 67% for SBP, 51% to 77% for DBP, and 52% to 79% for HR ($p < 0.001$ for each). The percentage of students correctly performing all 13 AHA endorsed steps for BP measurement improved significantly from 4.6% to 75.6% ($p < 0.001$).

Conclusions. Significant improvement and the attainment of competency in manual vital signs measurement were demonstrated by pharmacy students after 11 weeks of skill rehearsal in a laboratory course.

Keywords: vital signs, blood pressure, heart rate, physical assessment, pharmacy students

INTRODUCTION

Arterial blood pressure and heart rate are important indicators of a person's health. The accurate measurement of these vital signs is essential to many diagnostic and therapeutic decisions. Although the manual, indirect method of blood pressure measurement with a sphygmomanometer appears simple, there are many possible causes of inaccuracy.¹ Too small of a blood pressure cuff compared to the patient's arm circumference; body position, such as lack of back support or crossing the legs; arm position in relation to heart level; and rapid deflation of the blood pressure cuff are among the many technical mistakes that can cause up to a 10 mmHg error in blood pressure measurement.²⁻⁷ Therefore, a systematic ap-

proach to skill training, assessment, and retraining is important.

Traditionally, healthcare trainees, including pharmacy students, have learned vital sign measurement skills in a physical assessment lecture and laboratory course.⁸ Several new instructional strategies for blood pressure measurement training have been described in pharmacy education literature. These strategies include the use of standardized patients in the classroom, public health screenings in early experiential courses, and simulation-based learning with a computerized patient-manikin.⁹⁻¹¹

The Texas Tech University Health Sciences Center (TTUHSC) School of Pharmacy has also utilized standardized patients in the patient assessment course and early experiential courses to teach vital sign techniques, among other skills. Our previous study involving a comparison between pharmacy student manual measurements and Omron machine (Omron Healthcare, Inc., Bannockburn, IL) measurements near the completion of a patient assessment course revealed room for improvement in

Corresponding Author: Kenneth L. McCall, PharmD, BCPS, CACP, Assistant Professor of Pharmacy Practice, TTUHSC, School of Pharmacy, 1300 Coulter Dr, Amarillo, TX 79106. Tel: 806-356-4000, ext 321. Fax: 806-356-4018. E-mail: Ken.McCall@ttuhsc.edu

vital sign skill mastery.¹² Student and machine measurements of systolic and diastolic blood pressure and heart rate significantly correlated in the previous study ($r = 0.79, 0.62$, and 0.92 , respectively; $p < 0.001$ for each). However, the proportion of student and device SBP, DBP, and HR readings agreeing to within 5 units (mmHg or beats-per-minute) was only 51%, 47%, and 59%, respectively. Furthermore, terminal digit bias of DBP readings was observed in the previous study. Therefore, the course team designed the present study to evaluate these skills at the beginning and end of a patient assessment laboratory course. Furthermore, we improved our assessment methods in the present study by using mercury-column sphygmomanometers rather than aneroid manometers for manual blood pressure measurement. We also had all students manually measure blood pressure twice, rather than once, and report the average SBP and DBP reading for comparison with the Omron machine reading. Instructional methods were improved in the present study by adding a pharmacy practice resident to the course team, which enabled more facilitators per laboratory session to focus on improving skill-based teaching.

METHODS

This study was approved by the TTUHSC Institutional Review Board for the Protection of Human Subjects. Students ($n = 87$) enrolled in a patient assessment laboratory course participated in this study. This laboratory course was a 2 semester-credit hour course in the second year of the PharmD curriculum. The baseline skills assessment was conducted near the beginning of the course, after a 50-minute didactic lecture and 3-hour laboratory session on vital sign measurement technique. Each student was randomly matched with a fellow classmate and manually measured that classmate's blood pressure by auscultation of the brachial artery and heart rate by palpation of a radial pulse. A second blood pressure measurement was manually obtained within 1 minute of the first. Each of these manual readings, including the average SBP and average DBP, were recorded on a standardized data collection form. Next, the blood pressure and heart rate were measured by an Omron 711-AC automatic monitor, and these results were recorded. Both the manual and automatic measurements were taken using the same cuff size (either a standard adult or large adult cuff), placed on the left arm while the student was in a seated position, which was in accordance with the manufacturer's instructions.

Students practiced these vital sign skills at each subsequent laboratory session throughout the next 11 weeks (9 laboratory sessions where vital sign skills were practiced with peers and 2 sessions where the skills were prac-

ticed with standardized patients). The students were also evaluated at baseline and midterm through direct observation by faculty members using the American Heart Association (AHA) endorsed 13-step process for blood pressure measurement.¹³ If a student failed a step on either of the 2 manual BP measurements, (eg, too rapid deflation of the cuff on the first manual measurement, but not the second) then that step was counted as having been performed incorrectly. A final skill assessment was conducted at the end of the course. The same procedures, including randomly selected student partners for manual and machine vital sign measurement, were used during the baseline and final assessments. All activities were supervised by faculty members.

The Omron 711-AC monitor has been tested for accuracy with 2 protocols: that of the Association for the Advancement of Medical Instruments and that of the International Protocol of the European Society of Hypertension.¹⁴⁻¹⁶ In March 2001, the European Society of Hypertension recommended the Omron HEM-737 monitor (the European equivalent to the Omron 711-AC).¹⁶ The accuracy of the Omron 711-AC is ± 3 mmHg, or 2% for blood pressure and $\pm 5\%$ for heart rate.¹⁷ Furthermore, our previous study revealed significant correlation between readings obtained using the Omron 711-AC and manual student measurements.¹² The manual blood pressure equipment consisted of an Omron Cardiology III stethoscope, an Omron blood pressure cuff, and a Baumometer mercury sphygmomanometer.

Student and machine measurements were transcribed into SPSS Release 11.5 (SPSS, Inc, Chicago, IL). All student data was de-identified. The data were cleaned to provide quality assurance that there were no transcription errors. Following data validation, basic descriptive statistics including means, standard deviations, and percentages were produced. Manual blood pressure measurements were graded using criteria established by the British Society of Hypertension.¹⁸ The grade awarded by the British Society of Hypertension protocol for sphygmomanometers (Table 1) ranges from an A (greatest agreement to

Table 1. British Society of Hypertension Grading Criteria^a

Grade	Cumulative Percentage of Readings That Were		
	≤ 5 mmHg	≤ 10 mmHg	≤ 15 mmHg
A	60	85	95
B	50	75	90
C	40	65	85
D	Worse than C		

^aFor each grade, all 3 percentages must be greater than or equal to the values shown

mercury standard) to a D (least agreement to mercury standard). Inferential statistical tests were also employed. Means were compared using a student's *t* test. Pearson correlation and linear regression were used to evaluate associations between student and device measurements. Chi square was used for goodness of fit tests to evaluate for terminal digit bias in manual SBP and DBP readings.

RESULTS

Eighty-seven students (100% of class enrollment) participated in the baseline assessment. One student withdrew from the course and did not participate in the final assessment. At the baseline assessment, the average manual and device SBP readings were 117 ± 11 mmHg and 122 ± 14 mmHg, respectively. The average manual and device DBP readings at baseline assessment were 78 ± 9 mmHg and 75 ± 9 mmHg, respectively. The average manual and device HR readings at the baseline assessment were 70 ± 11 beats-per-minute and 75 ± 13 beats-per-minute, respectively. At the final assessment, the average manual and device SBP readings were 117 ± 12 mmHg and 120 ± 12 mmHg, respectively. The average manual and device DBP readings at the final assessment were 75 ± 9 mmHg and 74 ± 9 mmHg, respectively. The average manual and device HR readings at the final assessment were 76 ± 10 beats-per-minute and 78 ± 11 beats-per-minute, respectively. Thus, the mean difference at the final assessment between manual and device measurements was -3.0 ± 4.9 mmHg, 0.8 ± 5.2 mmHg, and -2.1 ± 4.5 beats-per-minute for SBP, DBP, and HR, respectively.

Table 2 shows the cumulative percent of student readings within 5, 10, and 15 units (mmHg or beats-per-minute) of the Omron 711-AC measurement at the baseline and final assessments. The proportion of student and device values agreeing to within 5 units at baseline versus the final assessment significantly improved from 38% to 67% for average SBP, 51% to 77% for average DBP, and 52% to 79% for HR ($p < 0.001$ for each). Applying the British

Society of Hypertension grading criteria, the agreement between the student and device measurements improved from scores of "D" to "A" for SBP and "B" to "A" for DBP, respectively, from baseline to final assessment (Table 1 and Table 2).

The correlations between manual and device measurements are shown in Table 3. At both the baseline and final assessment, there were significant correlations between student manual readings and the Omron 711-AC readings ($p < 0.001$ for each) heart rate. These correlations were higher at the end of the course than at baseline assessment. At the final assessment, the average SBP and DBP readings correlated higher with the machine reading than either the first or second manual measurements. This finding is consistent with the AHA recommendation to perform 2 blood pressure measurements and report the average.

The number and percentages of the final digits recorded by students for the manual measurements of SBP and DBP are presented in Table 4. Since the mercury column of the sphygmomanometer is marked in even number increments, the final digit of each SBP and DBP measurement should not be an odd number. Based on the assumption that each of the 5 even-number final digits should be equally likely to occur, a goodness of fit test revealed that the distribution of final digits for SBP and DBP readings significantly differed from a uniform distribution at the baseline and final assessments. Digit bias presented in such a way that manual readings ending in 0, 2, or 8 were significantly more likely than 4 or 6. There was no evidence of digit bias with either the baseline or final assessment Omron 711-AC readings.

At the baseline assessment, faculty observation revealed that on average each student correctly performed 10 out of 13 AHA-endorsed steps for BP measurement. The 5 most common errors at baseline included incorrect stethoscope placement, incorrect BP cuff placement, too rapid deflation of the sphygmomanometer, incorrect position of the patient (back unsupported, legs crossed, arm

Table 2. Cumulative Percentage of Average SBP, Average DBP, and HR Student Readings Within 5, 10, and 15 Units of the Machine Measurement

Vital Sign	Absolute Difference Between Student and Machine, %			Grade, ^a Baseline/Final
	≤5 units	≤10 units	≤15 units	
	Baseline/Final	Baseline/Final	Baseline/Final	
SBP	38/67	60/92	83/99	D/A
DBP	51/77	84/95	94/99	B/A
SBP & DBP	18/51	53/83	80/97	NA
HR	52/79	76/95	89/99	NA

Abbreviations: SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate, NA = not applicable

^aBritish Society of Hypertension grading criteria

Table 3. Correlation Between Manual and Machine Vital Sign Measurements Taken by Pharmacy Students

Readings	Baseline	Final
Manual SBP1 and Machine SBP	0.634	0.907
Manual SBP2 and Machine SBP	0.731	0.919
Manual SBPavg and Machine SBP	0.705	0.920
Manual DBP1 and Machine DBP	0.579	0.813
Manual DBP2 and Machine DBP	0.641	0.813
Manual DBPavg and Machine DBP	0.630	0.827
Manual HR and Machine HR	0.672	0.907

Abbreviations: SBP1 = first manual systolic blood pressure; SBP2 = second manual systolic blood pressure; SBPavg = the average of SBP1 and SBP2; DBP1 = first manual diastolic blood pressure; DBP2 = second manual diastolic blood pressure; DBPavg = the average of DBP1 and DBP2; HR = heart rate

not resting at heart level), and lack of verification of correct cuff size. The percentage of students correctly performing each of these 5 BP measurement steps improved significantly from baseline to midterm ($p < 0.01$ for each). Overall, the percentage of students correctly performing each procedure of the AHA-endorsed process for BP measurement improved significantly in 9 of 13 steps ($p < 0.01$ for each). The 4 BP steps that did not show significant improvement were also the least-missed steps at baseline with the least room for progress. These 4 steps included placing the manometer at eyelevel and in a position that is easily visible to the observer, using the palpatory method to provide a preliminary approximation of the SBP, noting the manometer pressure at Korotkoff Phase I and Phase V, and allowing the subject to rest for at least 30 seconds before performing the second manual BP measurement.

DISCUSSION

The vital sign ability test near the beginning of this course enabled an initial assessment of student skills. This assessment information established a baseline that revealed room for improvement in terms of blood pressure

measurement procedure and accuracy. Furthermore, the baseline assessment documented an initial skill level from which progress was evaluated and demonstrated by the end of the course. The final assessment revealed significantly improved BP measurement procedure, vital sign measurement reliability as demonstrated by a higher correlation between manual and machine readings, and vital sign measurement validity as demonstrated by an increased percentage of student readings within 5 units of the machine reading. The mean difference between manual and device measurements at the final assessment (-3.0 mmHg, 0.8 mmHg, and -2.1 beats-per-minute for SBP, DBP, and HR, respectively) were within the range of accuracy of the Omron 711-AC monitor. Thus, pharmacy students in the present study demonstrated an acceptable level of vital sign measurement accuracy by the end of the laboratory course.

In the final assessment of the present study, correlation values between manual and machine measurements for SBP and DBP were higher (0.92 and 0.83, respectively) than the same correlation values in the final assessment of our previous study (0.79 and 0.62, respectively).¹² Furthermore, a higher percentage of manual SBP and DBP readings agreed within 5 units of the machine reading in the present study. The final assessments of both studies were conducted near the end of the patient assessment course after weeks of student skill rehearsal with fellow trainees and standardized patients. The machine vital sign measurements in both studies were provided by the Omron 711-AC monitor. The major instructional design and assessment differences between these 2 studies included the use of mercury-column sphygmomanometers rather than aneroid, 2 manual BP readings per measurement rather than 1, and a higher instructor-to-student ratio.

Despite the documented improvement in blood pressure measurement skill, SBP and DBP terminal digit bias remained evident in the final assessment of the present study. The observer should read the BP to the nearest

Table 4. Number and Percentages of the Final Digits Recorded for All Manual Measurements of Systolic and Diastolic Blood Pressure Taken by Pharmacy Students

Blood Pressure	Final Digits, No. (%)						Total ^a	<i>p</i>
	0	2	4	6	8	Odd		
Baseline SBP 1 & 2	42 (24)	38 (22)	26 (15)	17 (10)	46 (26)	5 (3)	174 (100)	17.1 (0.002)
Baseline DBP 1 & 2	43 (25)	45 (26)	19 (11)	23 (13)	41 (24)	3 (2)	174(100)	17.5 (0.002)
Final SBP 1 & 2	38 (22)	32 (19)	22 (13)	24 (14)	53 (31)	3 (2)	172 (100)	18.5 (0.001)
Final DBP 1 & 2	45 (26)	24 (14)	33 (19)	23 (14)	45 (26)	2 (1)	172 (100)	13.6 (0.009)

Abbreviations: SBP 1 & 2 = first and second manual systolic blood pressure measurements; DBP 1 & 2 = first and second manual diastolic blood pressure measurements

^aOne student withdrew from the course and did not participate in the final assessment

2 mm Hg, but terminal digit bias in manual BP determinations have been reported in numerous clinical and research settings.^{19,20} The pharmacy students in this study have had limited experience measuring vital signs in older adults and patients with hypertension. Thus, further training and reassessment of our pharmacy students may be necessary to overcome digit preference. The TTUHSC School of Pharmacy has added a vital sign skill test to the annual student assessment as described in previous publications.^{21,22} This addition to the annual assessment will enable a follow-up skill evaluation as these students progress through early and advanced experiential courses. Vital sign measurement ability should further improve as students apply these skills in patient care settings.

The most recent report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure includes a “prehypertension” level in the classification scheme for blood pressure.²³ Additionally, a new AHA scientific statement recommends that the lower blood pressure goal of <130/80 mm Hg for patients with diabetes or renal disease should be expanded to include patients at high risk or with established coronary artery disease.²⁴ These changes in the classification and treatment goals of hypertension require the ability to detect smaller changes in blood pressure. The potential consequences of inaccurate blood pressure measurement, including both the risks of undertreatment and overtreatment, require training, assessment, and retraining of healthcare providers including pharmacists.

CONCLUSIONS

After 1 lecture and laboratory session, manual vital sign measurements obtained by pharmacy students significantly correlated with device measurements. The correlation between manual and device measurements significantly improved from the baseline to the final assessment after weeks of laboratory skill training. Improved learning outcomes in the present study may be due to the use of mercury-column sphygmomanometers rather than aneroid manometers, 2 manual BP readings per measurement rather than one, and a higher instructor-to-student ratio by using a pharmacy practice resident in the laboratory course.

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