Comparison of Forearm and Upper Arm: Automatic, Noninvasive Blood Pressures in College Students

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Citation

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Abstract

With increasing numbers of overweight and obese college students, routine screening of blood pressure (BP) is essential. Because use of a normal size cuff on an obese arm will yield inaccurate BP readings, practitioners in college health services sometimes obtain forearm pressures when large cuffs are unavailable. To determine whether these forearm readings are accurate, upper arm and forearm BPs were compared in 104 healthy college students between the ages of 18 and 25 years and with a wide range of body mass indices. Paired t-tests showed significant differences in diastolic BPs and mean arterial pressures with forearm pressures higher than upper arm pressures. Bland-Altman analyses indicated significant clinical differences for individual participants. Despite using correct cuff size and leveling the arm at heart level, upper arm and forearm BPs were not interchangeable. Further studies are needed to determine the reasons for the differences.

INTRODUCTION

Blood pressure (BP) measurement is a major indicator of patient health status regardless of age, race, or gender. Because hypertension is the most common risk factor for cardiovascular disease, accurate BP measurement is essential in providing healthcare to decrease the risks of cardiovascular morbidity and mortality.[1] Consequently, experts in both Europe and the United States have recently called for validation of BP measurement techniques.[1,2,3,4]

The use of automatic, noninvasive blood pressure monitors for obtaining routine and emergent vital signs is common in many settings where advanced practice nurses work including college health centers.[5,6] In recent years, college healthcare workers have, at times, been measuring BPs in the forearm rather than the traditional upper arm site. This practice is prompted when the standard-sized cuff does not fit an individual's arm or when it is difficult to physically access the upper arm.[7] The cited rationale for healthcare workers' selection of the forearm site is that using a cuff that is too small leads to overestimation of BP and misclassification of individuals as hypertensive.[1, 8, 9]

In 2004, the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[10] noted that hypertension is a significant health issue among overweight adolescents. Spencer[11] found that approximately 20% of 226 college students participating in cardiovascular screening had systolic BP values that could be considered borderline hypertensive. The most recent statistics from the National Center for Health Statistics indicate that obesity in young adults in the United States has more than doubled in the past 25 years to a level of roughly 25%.[12] The close relationship between obesity and hypertension suggests a parallel increase in cardiovascular risk factors and coronary heart disease in young adults, and the need for enhanced cardiovascular screening and counseling in college students.[11, 13, 14] Advanced practice nurses working in college centers are prepared and positioned to meet this need but must assure that BP measurements are properly performed prior to taking action.

Although the majority of young adults will have their BP taken in the upper arm, circumstances may arise that prompt forearm use. With increasing numbers of overweight and obese college students, [13] a larger cuff may not be available during routine screening. Another consideration is the potential difficulty of upper arm cuff sizing for the particularly muscular individual. Finally, the forearm site may be used in college students if injury and illness limit upper arm accessibility in emergency departments and other acute care settings.

Studies comparing forearm and upper arm BPs have been conducted on hospitalized patients who are on average, older and in less than optimal health.[7, 15, 19] Study procedures have not been consistent but results in older adults generally indicate that measurements from these two sites are not equivalent. This study expands the body of knowledge on forearm blood pressures by comparing readings on young healthy adults of various weights.

REVIEW OF THE LITERATURE

The use of forearm blood pressures has recently gained attention in the literature. One of the first clinically-based studies by Singer, Kahn, Thode, and Hollander[7] compared forearm and upper noninvasive BPs in 151 seated stable patients (mean age 35 ± 16.7 years) in an ambulatory emergency department. Appropriate-sized cuffs were used and arms were positioned at heart level. The correlation between forearm and upper arm systolic BPs was 0.75 and for diastolic BPs was 0.72 ($P < 0.001$). The differences between forearm and upper arm systolic and diastolic BPs were within 20 mm Hg in 86% and 94% of participants, respectively. The researchers reported that forearm BP was an acceptable predictor of the standard upper arm BP when measurement of upper arm BP was not possible. However, Bland-Altman analyses were not performed to analyze individual participant differences.

Replicating Singer's study, Schell and colleagues[15] investigated differences in forearm and upper arm automatic noninvasive BPs in 204 seated, stable emergency department patients. Mean age of participants was 36.5 ± 16.5 years. Cuff size was based on forearm and upper arm circumference and both the forearm and upper arm were placed at heart level during readings. Sequence was alternated between participants. A paired t-test revealed significant differences ($t = 2.07$, $P = .04$) between mean upper arm and forearm systolic BPs. A 14 to 20 mm Hg difference was found between systolic, diastolic, and mean forearm and upper arm BPs as determined by Bland-Altman analyses indicating clinically significant differences between forearm and upper arm measurements. Therefore, forearm and upper arm BPs were not equivalent measures.

Pierin, Alvarace, Gusmão, Halpern, and Mion[16] studied forearm BPs in the obese population. Using appropriate cuff sizes, the researchers obtained 3 upper arm and 3 forearm oscillometric BPs, each 2 minutes apart, from 129 seated participants, mean age 45 ± 14 years, with mean body mass index (BMI) of 40 ± 7 kg/m^2. Leveling of the arm and forearm with the heart was not described. Analysis of variance revealed that upper arm systolic and diastolic BPs were significantly lower ($P < 0.05$) than forearm BPs. Pierin, et al.[16] concluded that forearm BP measurements could inappropriately inflate the prevalence of hypertension diagnoses in the obese.

Although using the auscultatory method, Palatini and colleagues[17] also compared wrist (distal forearm) and upper arm BP readings in 85 supine participants (mean age 47 ± 16 years). A pediatric cuff was used for wrist BPs while a standard cuff was used for the upper arm. The limb was placed at heart level for all readings. Six sequential ipsilateral BPs were obtained, alternating cuff sites. Auscultatory wrist BP measurement overestimated upper arm BP measurement with systolic BP differences 8.2 ± 9.7 mm Hg and diastolic differences 9.2 ± 6.4 mm Hg. Multivariate regression revealed a significant relationship between the systolic differences and both skin fold thickness and BMI for males ($P < 0.01$). Age was a significant independent predictor of diastolic differences among women ($P = 0.04$).

Milmaniene, Cormillot, Sarcona, and Diaz[18] compared oscillometric forearm BPs with upper arm BPs in 82 subjects with a mean age of 45 ± 16 years. A standard-sized cuff was used for 40 subjects with arm circumference less than 35 centimeters. A large cuff bladder was used in the remaining subjects. Leveling the limb at the heart was not described. With patients supine, systolic and diastolic BPs were higher in the forearm than the upper arm in over 90% of participants. The mean differences between the two sites were 9.7 ± 10 mm Hg for systolic BP and 9.9 ± 7 mm Hg for diastolic BP. Milmaniene, et al.[18] concluded that forearm measurements overestimated BPs.

The effect of body position on differences in forearm and upper arm automatic noninvasive BPs was also studied by Schell, et al.[19] Patients (mean age 61.5 years) on medical-surgical units (N=221) were placed supine and BPs were obtained on the forearm followed by the upper arm. Patients were then positioned with the head of the bed elevated 45? and BPs were obtained on the upper arm followed by the forearm. Cuff size was based on manufacturer's recommendations and starting body position was alternated for each subject. Paired t-tests showed significant differences between average upper arm and forearm systolic, diastolic, and mean BPs in both positions ($P < 0.0001$). Bland-Altman analyses revealed significant differences between systolic, diastolic, and mean BPs in the supine position and even greater differences between the same measurements in the

HOB 45? position. Greater differences in the HOB 45? position may be a reflection of not placing arms at heart level for all readings.

Overall, research suggests that forearm automatic noninvasive BPs are not interchangeable with upper arm BPs in older adults. The current study adds to this body of knowledge in healthy college students between the ages of 18 and 25 years old. The purpose of this study was to compare automatic, non-invasive blood pressures taken on the forearm with those taken on the upper arm in traditional college students without serious health problems.

METHODS

PARTICIPANTS

The target population included traditional college students on the main campus of a major university located in the Mid-Atlantic region of the United States. Inclusion criteria were age 18 to 25 years, ability to read and speak English, and no known history of serious illness.

PROCEDURE

Following approval of the University Human Subjects Review Board in March 2005, participants were recruited through fliers posted in the hallways of the building where the nursing program was housed and in the two university student centers. An invitation to participate was also sent via electronic mail to students in undergraduate nursing courses in the spring semester. Potential participants were asked to attend one of the data collection sessions held over four weeks in March and April 2005. Appointments were not required for these “drop-in” sessions. Locations included two school of nursing laboratories and a multipurpose room at one of the student centers. Students who were interested and met inclusion criteria were given a formal explanation of the study and informed consent was obtained.

MEASURES

Participants were asked to complete a short demographic and health history form. Left upper arm and forearm circumferences were measured and cuff size determined based on manufacturer's recommendations for the Dynamap 8100T Vital Signs monitor (Critikon Inc., Tampa, Florida). With participants seated, BP measurement was conducted according to American Heart Association guidelines,[1] first in the forearm and then, within a minute, in the upper arm. The arm was placed at heart level for each measurement, using an adjustable hospital bedside table. Order of cuff placement was alternated on subsequent participants. Heart rate was also obtained from the BP monitor.

STATISTICAL ANALYSIS

Means and standard deviations were calculated for upper arm and forearm systolic, diastolic, and mean pressures. Pearson's correlation coefficient was used to determine the relationship between upper arm and forearm BPs. Paired t-tests were used to determine the differences between upper arm and forearm BPs.

Because measures of central tendency reflect a group of participants, they can be misleading. Clinicians are usually more focused on accuracy of readings for individual patients. Similarly, correlations for the group of participants may be high, while substantial differences in the actual values of the two measures may be present. For these reasons, Bland-Altman analyses were performed to determine the agreement between upper arm and forearm measurements for individual participants.[20] Correlations between forearm-upper arm differences and variables such as age, gender, race, and body mass index (BMI) were examined.

RESULTS

PARTICIPANT CHARACTERISTICS

The sample included 104 participants with a mean age of 20.69 ± 1.66 years. The majority of the sample were female (n=65, 62%), white (n=84, 81%), and nonsmokers (n=87, 84%). The average BMI for participants was 24.14 kg/m^2, and ranged from 18.33 to 43.06. The descriptive statistics for arm circumference, cuff size, blood pressure (systolic, diastolic, and mean), and heart rate are provided in Table 1.

Figure 1

Table 1: Descriptive Statistics of Arm Circumference, Cuff Size, Blood pressure and Heart Rate of Sample

Variable	Mean	S.D.	Range
Circumference, cm			
Upper arm	29.60	4.03	22-39
Forearm	22.25	2.77	18-31
Cuff size*			
Upper arm	3.28	.55	2-5
Forearm	2.36	.48	2-3
Systolic Blood Pressure, mm Hg			
Upper arm	115.71	12.69	85-155
Forearm	116.85	11.39	90-155
Difference	1.14		
Diastolic Blood Pressure, mm Hg			
Upper arm	60.41	8.42	44-86
Forearm	67.40	9.99	45-102
Difference	6.91		
Mean Blood Pressure, mm Hg			
Upper arm	78.84	8.23	62-101
Forearm	83.88	8.59	64-107
Difference	5.04		
Heart Rate, beats/minute			
Upper arm	75.38	11.66	56-111
Forearm	75.53	11.37	56-109
Difference	0.15		

* Dynamap Cuff Size: 1, child; 2, small adult; 3, adult; 4, large adult; 5, x-large adult

Figure 2

Figure 1: Bland-Altman Analysis of Systolic Pressures

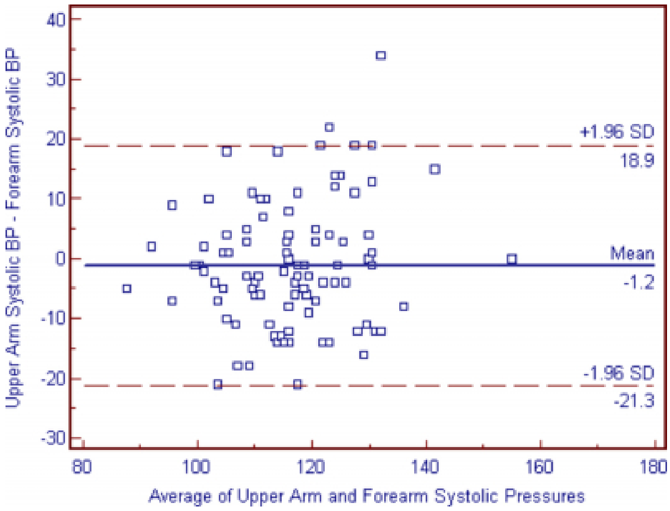
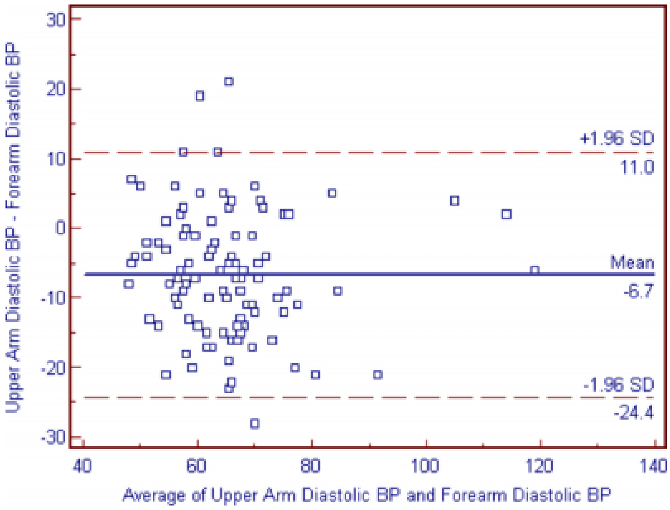


Figure 3

Figure 2: Bland-Altman Analysis of Diastolic Pressures



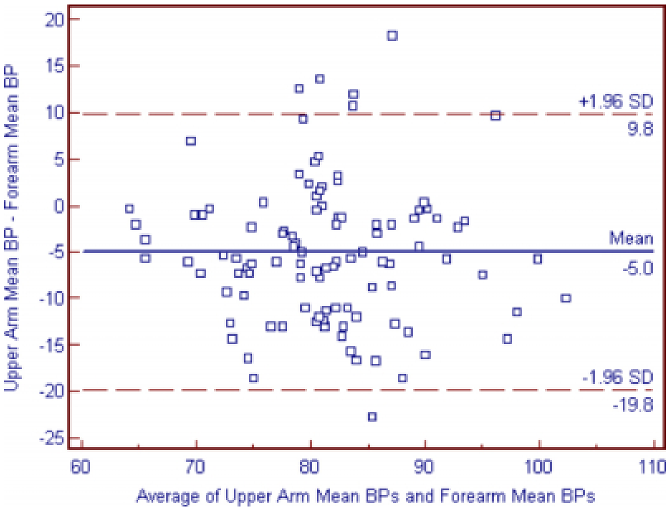
FOREARM AND UPPER ARM COMPARISONS

Pearson's correlations between forearm and upper arm BPs were .649 for systolic, .529 for diastolic, and .599 for mean ($p < .0001$), while the correlation between forearm and upper arm HR was .895 ($p<.0001$). Paired t-tests revealed statistically significant differences between upper arm and forearm diastolic BPs (t -7.83, $p < .0001$) and between upper arm and forearm mean BPs (t -6.73, $p < .0001$). Differences between systolic BPs and heart rates were not significant. Upper arm mean arterial BPs were positively correlated with differences between forearm and upper arm BP measurements (systolic differences: $r = .404$, $p < .0001$, diastolic differences: $r =.291$, $p = .0028$). No statistically significant differences in results were found based on gender, smoking status, race, arm circumference, or BMI.

Bland-Altman analyses were used to determine the level of agreement between forearm and upper BPs for individual participants. The bias (mean difference between forearm and upper arm readings) was -1.2 mm Hg for systolic BP. The computed upper and lower levels of agreement for systolic BP were -21.3 and +18.9 mm Hg, respectively (see Figure 1). The bias for diastolic BP was -6.7 mm Hg with computed upper and lower levels of agreement -24.4 and +11.0 mm Hg (see Figure 2). Mean BPs showed a bias of 5.0 with limits of agreement of -19.8 mm Hg and 9.8 mm Hg (see Figure 3).

Figure 4

Figure 3: Bland-Altman Analysis of Mean Arterial Pressures



DISCUSSION

Upper arm blood pressures were somewhat lower than those reported in earlier studies.[15,16,17, 19]This finding was expected since the participants in this study were younger and had fewer health problems than participants in previous studies. In earlier research on older adults, forearm BPs were higher than upper arm BPs but statistical significance varied among systolic, diastolic and MAP readings. In this study, forearm BPs were also greater than upper arm BPs but differences were statistically significant only for diastolic BPs and MAPs. Systolic differences were similar but diastolic and MAP differences were larger than those values reported in Schell, et al.[15]However, all differences were smaller than those reported by Pierin, et al.,[16] Palatini, et al.,[17] and Milmaniene, et al.[18]

Results of the Bland-Altman analyses suggested a wide range of differences for individual participants in the study, with forearm pressures most often higher than upper arm readings. Many readings varied by as much as 20 mmHg for systolic pressures, 17 mmHg for diastolic pressures, and almost 15 mmHg for mean pressures. These differences were much larger than the 5 mm Hg difference that is generally considered clinically significant, [21]and indicate that upper arm and forearm blood pressures are not interchangeable in healthy college age individuals. As in previous studies, no demographic variables were identified that were helpful in predicting which individuals would have the greatest differences between upper arm and forearm readings.

The positive correlations between MAPs and BP differences suggest that greater differences occur between upper arm and forearm pressures in individuals with higher pressures. This relationship has not been reported in previous studies, and will require further investigation.

LIMITATIONS

Limitations of the study include convenience sampling and ethnic similarity of most of the participants. More than one half of the participants were nursing majors who may not be representative of the total college population in some way.

IMPLICATIONS

Despite placing the forearm and upper arm at heart level and using the proper sized BP cuff, forearm BP was not interchangeable with upper arm BP in college students. This finding suggests that differences found in upper arm and forearm BPs in earlier studies were not due to older age, obesity, or poor health status.

Comparison of forearm and upper arm BPs of individual subjects from this study illustrates the risk of misdiagnosis of hypertension using forearm BPs. A 21-year-old man whose upper arm BP was 115/64 but whose forearm BP of 129/76 could be misdiagnosed with pre-hypertension. In another 21-year-old man, suspicion of systolic hypertension could result from an upper arm BP of 132/63 and forearm BP of 140/62. A third example of the danger of relying on forearm pressure is seen in a 21-year-old female whose upper arm BP was 112/67 but her forearm BP was 120/87, a possible indication of pre-hypertension. While a diagnosis of hypertension is never based on one reading, these examples emphasize the risk of interchanging forearm and upper arm BPs. Advanced practice nurses, particularly nurse practitioners, make treatment decisions based on BP measurements and should be aware of the potential for inaccuracy.

The importance of accurate BPs in screening for and treatment of cardiovascular and other diseases dictate that correct BP measurement techniques are used in young adults. Experts strongly recommend that healthcare providers are periodically educated on proper measurement techniques.[1] Availability of appropriately sized BP cuffs is also necessary to minimize the use of forearm BPs in individuals who are overweight, obese, and/or who have large muscular arms. For managers of college student health services, this may necessitate budgeting for additional cuffs. If forearm BPs are the only option in emergency situations and/or when the properly sized cuff is unavailable in a college health setting, documentation in the medical record should indicate that the forearm site was used so that the same site can be used for trending of BPs on subsequent assessments.[15, 19]

As with earlier studies, these findings suggest that further research is needed to identify predictors of significant forearm-upper arm BP differences so that advanced practice nurses and other practitioners can correctly interpret forearm BPs. In addition, studies should be conducted to compare forearm and upper arm BPs with participants seated and the arm below heart level, positioned in the individuals' laps, as would be typical in an ambulatory setting such as college student health services. Finally, replication of this study with a larger and more diverse sample would increase the external validity of the findings.

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