

## **Miscuffing Results in Blood Pressure Measurement Error and Misclassification**

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### **ABSTRACT**

Blood pressure (BP) is one of the most commonly measured vital signs. Errors in BP measurement may result in misdiagnosis, cardiovascular complications, and improper prescription of antihypertensive medications. Miscuffing (e.g. measuring one's BP with the wrong size BP cuff) is a common and significant source of error in BP measurement. Currently, two forms of BP cuff size selection are standard, the 80% rule (gold standard; cuff  $\geq$  80% of an individual's arm circumference) and a printed manufacturer's recommendation. Often, printed ranges differ from the 80% rule. The current study examined the occurrence of miscuffing and the outcome of BP measurement using the 80% rule versus the manufacturer's recommendation. Forty-four individuals had their upper arm circumference measured, and appropriate cuff(s) selected using the two sizing methods. An automated oscillometric device was used to measure BP. Using standard methods, 70% had two different cuff sizes identified, and a dependent t-test revealed a significant increase in systolic BP using manufacturer's recommendation ( $7.9 \pm 8$  mmHg difference;  $p < 0.05$ ). Approximately one in four individuals were misclassified as pre-hypertensive or hypertensive when the manufacturer's recommendation was utilized ( $12.5 \pm 5$  mmHg difference;  $p < 0.05$ ). BP cuff selection methods are not universal and contribute to reliability concerns. Miscuffing was a common observation when utilizing the manufacturer's recommendation for cuff selection and resulted in BP measurement error and misclassification.

**Keywords:** automated oscillometric device; cuff selection; 80% rule

### **INTRODUCTION**

Blood pressure (BP) is widely measured in order to diagnose hypertension and cardiovascular disease risk (Pescatello 2014; Pickering et al. 2005). Remarkably, an elevated BP is the largest single worldwide contributor to disease and mortality (Poulter et al. 2015). Further, BP measurement is paramount in the assessment of physical activity readiness, monitoring of safe exercise participation, and determination of prescription medication (Pescatello 2014; Pickering et al. 2005). Therefore, efforts toward health and disease prevention requires that BP

measurement error be reduced to the smallest possible increment in order to accurately diagnose hypertension (Bovet et al. 1994) and accurately prescribe both exercise and medications (Pescatello 2014; Pickering et al. 2005).

Common sources of error in BP measurement include inappropriate cuff size, incorrect body positioning, and cuff placement. Errors in BP measurement, regardless of the cause, may result in misdiagnosis and improper prescription of medications, cardiovascular complications during physical activity and exercise, and

may ultimately contribute to an increased risk of premature mortality. Interestingly, a recent study in our laboratory assessed procedural aspects of student BP measurement procedures throughout a health-sciences curriculum and identified a need for improvements in choosing an appropriately-sized BP cuff (Holmstrup et al. 2016).

Miscuffing, or selecting an inappropriate cuff size, has been widely reported as a potential pitfall in proper BP measurement (Pickering et al. 2005; Veiga et al. 2009). Veiga et al. (2009) evaluated the BP readings of 81 subjects admitted to a university hospital setting, and determined that the width of a standard-sized cuff used at the hospital was appropriate only ~17% of the time, leaving ~83% of patients miscuffed. These authors confirmed that incorporating different BP cuffs to account for the entire arm size spectrum greatly improved measurement (Veiga et al. 2009). However, we believe more clarity and greater emphasis in the sizing standards regarding cuff length may be needed as well, as equipment manufacturers continue to produce BP cuffs with printed circumference guidelines that do not align with evidence-based recommendations.

The American Heart Association (AHA) and American College of Sports Medicine (ACSM) both recommend that a BP cuff have a bladder length at least 80% of an individual's arm circumference and a bladder width at least 40% of arm circumference (Pescatello 2014; Pickering et al. 2005). While the printing of circumference guidelines on cuffs is present (Pickering et al. 2005), the established ranges set by BP cuff manufacturers often do not follow AHA and ACSM guidelines. Interestingly, and perhaps imprudently, the use of the 'large adult' cuff has been offered as a universal solution to the problem of miscuffing (Croft and Cruickshank 1990; Linfors et al. 1984). In a measurement like BP, which

has such wide application to health outcomes and safety, precision in measurement and adherence to evidence-based practice is paramount.

Our group identified potential differences between recommendations based on the 80% rule and manufacturer recommendations and measured the bladders on a set of widely-used cuffs for an automated oscillometric BP measurement device (Baumanometer Calibrated V-Lok Cuff, W.A. Baum Co, Copiague, NY). Based on these measurements, we calculated 80%-100% of bladder lengths, and compared these measured ranges with those printed on the cuffs by the manufacturer. Discrepancies were observed between the 80% rule and manufacturer recommendations, wherein many arm circumference measures would have required different cuffs based on the method of cuff selection chosen (e.g. an individual with an arm circumference would be fitted with an adult regular V-Lok cuff based on manufacturer recommendations, while an adult large cuff would be appropriate based on the 80% rule). In addition, when using manufacturer recommendations there were many instances of overlap between sizes (i.e. two different cuffs deemed acceptable for the same arm circumference). This lack of clarity is alarming, and widely opens the door to potential errors in cuffing, BP assessment, and informed health and activity-related decision making.

Therefore, this investigation was designed to examine the occurrence of miscuffing as well as the outcome of BP measurement using the 80% rule cuff selection method versus the manufacturer's recommendations. It was hypothesized that in individuals requiring two different size BP cuffs per the 80% rule and the manufacturer's recommendations, systolic BP will be higher when using the cuff recommended by the manufacturer.

## METHODS

### Participants

Individuals at least 18 years of age were recruited from Slippery Rock University. Prior to data collection, procedures were approved by the Slippery Rock University Institutional Review Board. All participants completed an informed consent document prior to completing the study, and researchers adhered to all ethical regulations.

### Procedures

All BP measurements were collected with an automated oscillometric device (Omron HEM907XL, Schaumburg, IL). Upon arrival to the lab, arm circumference was measured at the halfway point between the acromion process of the scapula and the olecranon process of the ulna in line with AHA recommendations (Veiga et al. 2009). Measures of arm circumference were used to determine an appropriate cuff based on the 80% rule and manufacturer recommendations (Table 1). When individuals had two different cuff recommendations, the order of BP measurement was randomly allocated. The participant's bare upper right arm was palpated and the midline of the cuff bladder was placed directly over the brachial artery. The upper arm was positioned at heart-level and maintained throughout measurement. After a 5-minute seated rest, the first set of systolic BP measurements was obtained, with a duplicate BP measure separated by a 1-minute interval. Following a 2-minute (rest) interval, an identical set of measures was obtained using the alternative cuff sizing method. Participants were instructed to completely relax, and not to cross their legs or talk during the BP measurements.

### Data Analysis

The means of duplicate BP measurements for each cuff selection

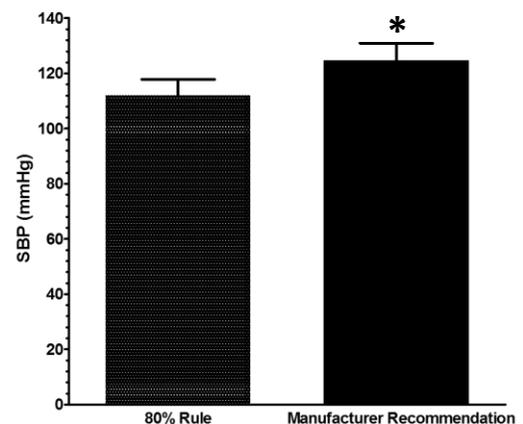
method were used for analysis. For measured systolic BP in participants with two different cuff sizes a dependent samples t-test was utilized to determine mean differences based on the selection methods. An *a priori* alpha significance level of 0.05 was established in order to indicate (significant) differences.

**Table 1.** BP Cuff Ranges for Current Standard Cuff Selection Methods

Size	80% Rule	Omron HEM907XL
Small	17.0 – 20.0 cm	17.0 – 21.8 cm
Regular	20.2 – 26.8 cm	22.0 – 31.8 cm
Large	27.0 – 31.2 cm	32.0 – 41.8 cm
Extra-Large	31.4 – 43.6 cm	42.0 – 50.0 cm

## RESULTS

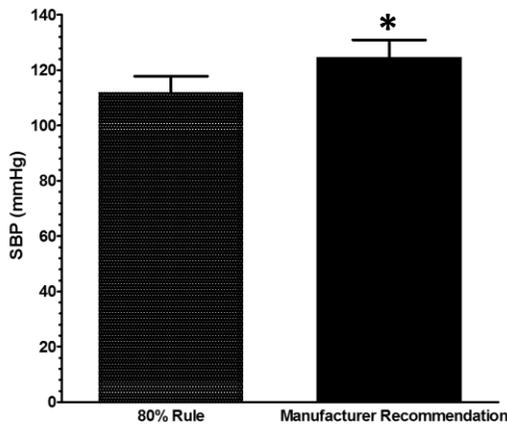
Forty-four individuals (33 females and 11 males) completed all of the requirements for this study. Participants averaged  $20.9 \pm 3.3$  years of age. The average female participant had an arm circumference of  $28.4 \pm 3.0$  cm (22.0-36.5 cm), and the average male participant  $31.9 \pm 4.4$  cm (26.5-39.5 cm).



**Figure 1.** Average systolic BP measurements for the manufacturer recommendations and the 80% rule for participants with different cuff size recommendations. \*Significantly higher than 80% rule  $p < 0.05$ ).

Seventy percent of participants (31/44) required the use of two different BP cuffs based on the two different selection

methods. The resulting average BP measured with the cuff recommended by the manufacturer was 7.9 mmHg higher than the BP measured when using the cuff recommended by the 80% rule (Figure 1;  $p < 0.05$ ). Further, within these individuals, 35% (11/31) resulted in misclassification (i.e. healthy, prehypertension, hypertension) based on discrepant measurements with a significantly elevated systolic BP (Figure 2; average increase 12.5 mmHg;  $p < 0.05$ ). Moreover, the higher systolic BP measured was always a result of the use of the cuff recommended by the manufacturer.



**Figure 2.** Average systolic BP measurements for the manufacturer recommendations and the 80% rule for participants misclassified by different cuff size recommendations. \*Significantly higher than the 80% rule  $p < 0.05$ .

## DISCUSSION

Miscuffing has been widely reported as a potential pitfall in BP measurement (Pickering et al. 2005; Veiga et al. 2009). Mitigating the risk of miscuffing is of importance for the accuracy of BP measurement (Graves 2001). Additionally, the frequency of situations wherein multiple cuffs are not available, or recommendations are made to the contrary (Croft and Cruickshank 1990; Linfors et al. 1984), is pervasive (Thomas et al. 2001). In the current investigation miscuffing was a common observation and

led to significant BP measurement error and misclassification.

To our knowledge, this study was the first to directly examine the effect of using two different methods of cuff selection on automated systolic BP measurement outcomes and classification. The clinical implications for miscuffing include misdiagnosis, improper prescription of antihypertensive medications, and increased risk of premature mortality (Pescatello 2014). In 2013, Mourad and colleagues reported using the 80% rule to examine the BP measurement difference when individuals with large arm circumferences (i.e.  $>33\text{cm}$ ) were miscuffed. The authors reported that when using the adult regular BP cuff a 6.9 mmHg difference existed when compared to the adult large cuff (i.e. the correct BP cuff identified by the 80% rule) (Mourad et al. 2013). In the current investigation, all participants with two recommended BP cuffs had a comparatively higher systolic BP (7.9 mmHg) when using the smaller of the two cuffs (i.e. manufacturer's recommendation).

The use of an adult large cuff has been offered as a sufficient means of a universal recommendation for all adults (Croft and Cruickshank 1990; Linfors et al. 1984). In support of this recommendation, Linfors et al. (1984) reported that the recorded prevalence of Class I and Class II hypertension in individuals measured with a standard, adult large, and a thigh cuff were identical in nonobese patients. Interestingly, they also reported a significant increase (doubling) of the prevalence of Class I and Class II hypertension with a standard cuff on obese individuals (Linfors et al. 1984). Moreover, several studies from the 1980s and 1990s have recommended the use of a range of BP cuff sizes to avoid miscuffing based on inappropriate cuff width or length (Bovet et al. 1994; Manning et al. 1983; Maxwell et al. 1982; Veiga et al. 2009); similar to our

findings, the systolic BP measure was altered by the determined cuff size.

Our finding that measurement error is introduced with ambiguous cuff selection has potentially serious implications and is in agreement with a previous study by Maxwell and colleagues in which cuffs of three different sizes were used in order to measure the BP of over 1200 obese individuals (1982). It was concluded that the measurement error of BP was dependent on the degree of obesity in their participants (Maxwell et al. 1982). In this sample, the adult standard cuff showed the greatest amount of error and was implicated as a contributor to the overestimation of hypertension in obese individuals (Maxwell et al. 1982). As the reported prevalence of obesity has risen since the time of Maxwell's (1982) publication and now stands around 36% in American adults (Ogden et al. 2015), these considerations may be even more vital. Similarly, when compared to femoral intra-arterial pressure, standard auscultation with an 'obese' cuff underestimated systolic BP by an average of 7.9 mmHg compared to a standard cuff in middle-aged to older individuals (Russell et al. 1989). Collectively in the literature, the most commonly reported variance in systolic BP is nearly identical to the observed 7.9 mmHg increase in the current investigation.

An important aspect of the present study was the elimination of potential administrator error through the utilization of an automatic BP measurement device. Automatic BP measurement devices are often used in situations where technical consistency is desired, and time or personnel demands are restricted (Nelson et al. 2008). While some evidence already exists in support of the importance of following AHA guidelines and having a range of available cuff sizes when using traditional auscultation methods in a hospital setting (Manning et al. 1983), the present study is one of the first to examine the effect of miscuffing with an automated

device using two different methods of BP cuff selection. In a similar trend, Ringrose and colleagues recently published a paper (2015) that supports the use of multiple BP cuff sizes with oscillometric devices due to concerns with miscuffing (Ringrose et al. 2015). Thus, the importance of choosing the appropriate cuff sizes when using an automated device is strongly supported by our findings and maintains the relevance to both non-clinical and clinical settings.

Several limitations within our study design and implementation warrant mention. The present study had a small sample size and narrow band of age and health criteria. While other populations have been studied (Nielsen et al. 1983), a larger and more comprehensive study may be warranted. In addition, this study only examined the cuff selection recommendations based on one manufacturer and device (Omron HEM907XL), neglecting potential variance within other popular BP cuff brands.

Based on our findings, it is suggested that individuals who use an automated oscillometric device purchase the full range of BP cuffs for the entire spectrum of arm circumferences. Further, we suggest that healthcare professionals measure arm circumference and determine the appropriate size BP cuff based solely on the 80% rule contrary to what manufacturer recommendations are printed on the cuff as the standards of acceptable BP cuff selection are not universal. Using two common methods for BP cuff selection resulted in miscuffing, BP measurement error, and misclassification. Therefore, assuming the current standard cuff selection methods are interchangeable may lead to the ineffective use of BP as a valuable screening, monitoring, and diagnostic assessment.

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