# Effect of Stethoscope Position on Auscultatory Blood Pressure Measurement

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## Abstract

*When measuring blood pressure (BP) using the auscultation method, a stethoscope is commonly used. In clinical practice, it is sometimes placed under the cuff, but more usually outside the cuff on the antecubital fossa. However, there is little scientific evidence to quantify the BP difference between the BP measurements taken with the stethoscope under the cuff or outside the cuff. The aim of this study was to provide these data.*

*Nine healthy subjects were studied, and there were two repeated measurements for each subject. Two electronic stethoscopes (one under the cuff, the other outside the cuff) were used to record the Korotkoff sounds. The signals of cuff pressure and two Korotkoff sounds were simultaneously recorded to a computer for off-line analysis. The sounds recorded from the two positions were then replayed to two operators to determine systolic and diastolic BPs (SBP and DBP). The BP difference from the two positions was finally quantified.*

*Variance analysis showed that there was no significant BP difference (for both SBP and DBP) between the repeat measurements and between the two operators ($p>0.1$). There was also no significant SBP difference between results with the stethoscopes placed at the two positions ($P>0.1$). However, a significant difference for DBP was observed, with a mean±SD difference of -3.0±1.4 mmHg ($P<0.001$).*

*In conclusion, this study quantified the effect of stethoscope position on BP measurement.*

## 1. Introduction

There are currently two main non-invasive ways of measuring blood pressure (BP): manual auscultatory method and automatic oscollometric method. Automated devices are easy to operate and are mainly preferred for home use. However, the accuracy of automatic devices is not satisfactory for clinical diagnosis, and the manual auscultatory method is still the most accurate technique and is considered as the gold standard clinical BP measurement, and so this study focused on the manual auscultatory method.

When measuring BP using the auscultation method, a stethoscope is commonly used. The appearance and disappearance of sounds are associated with systolic and diastolic BP (SBP and DBP) respectively, and the BPs at these times are read from a cuff pressure display.

Various international societies of hypertension [1-3] recommend that the stethoscope should be placed gently over the brachial artery at the point of maximal pulsation. In clinical practice, the stethoscope is sometimes placed under the cuff, but more usually outside the cuff on the antecubital fossa. However there is little scientific evidence to quantify the BP difference between the measurements taken with the stethoscope under the cuff or outside the cuff. This study was to provide these data.

## 2. Methods

### 2.1. Subject

Nine healthy subjects were studied (6 male and 3 female), with ages in the range of 22 to 30 years. The general subject information including age, height, weight and arm circumference are given in Table 1. This study received ethical permission, and all subjects gave their written informed consent to participate in the study.

Table 1. Demographic data for the subjects studied. Their means and standard deviations (SDs) are presented.

| **Subject information** | | |
|---|---|---|
| No. subjects | 9 | |
| No. male | 6 | |
| No. female | 3 | |
| | **Mean** | **SD** |
| Age (years) | 25 | 3 |
| Height (cm) | 167 | 7 |
| Weight (kg) | 62 | 11 |
| Arm circumference (cm) | 26 | 6 |

## 2.2. Blood pressure measurement

BP measurements were performed in a quiet and temperature controlled clinical measurement room. The subject was seated in a chair with their feet on the floor and with their upper arm supported at heart level. Before the formal measurement, the subject was asked to have a 5 min rest in order to allow cardiovascular stabilization.

Two electronic stethoscopes (one under the cuff, the other one outside the cuff) were used to record the Korotkoff sounds, which were simultaneously recorded with deflating cuff pressure. Cuff pressure was linearly deflated from 200 mmHg at a recommended rate of 2-3 mmHg/s. The signals of cuff pressure and two Korotkoff sounds were digitally saved to a data capture computer at a sample rate of 2000 Hz for off-line analysis.

For each subject, there were two repeated measurements with a time interval of at least 4 min, allowing a recovery of cardiovascular haemodynamics. The whole BP measurement procedure followed the guidelines recommended by the British Hypertension Society and the American Heart Association [1, 3].

## 2.3. Blood pressure determination

A software developed using Matlab 2011a (MathWork Inc. USA) was used to convert the recorded Korotkoff sounds into wav files, and they were replayed to two operators. The SBP and DBP were independently determined from the sound recorded from the stethoscope under the cuff and outside the cuff.

The method of SBP and DBP determination is shown in Figure 1. The cuff pressure at which the Korotkoff sound appears is associated with SBP, and the cuff pressure at which the Korotkoff sound disappears is associated with DBP.

## 2.4. Data and statistical analysis

The overall mean and standard deviation (SD) of the BPs (SBP and DBP) were calculated across all subjects for the BPs determined from the Korotkoff sounds recorded under and outside the cuff. The BP differences between the measurements taken from the two positions were quantified. All differences were paired values in each subject.

The SPSS Statistics 19 software package (SPSS Inc., USA) was employed to perform ANOVA analysis to study the repeatability between the two measurements and between the two operators. The effect of stethoscope position on BPs was also investigated. The post-hoc multiple comparisons were then used to examine the statistical difference between the BPs taken from the two positions. A value of $p<0.05$ was considered a statistically significant difference.

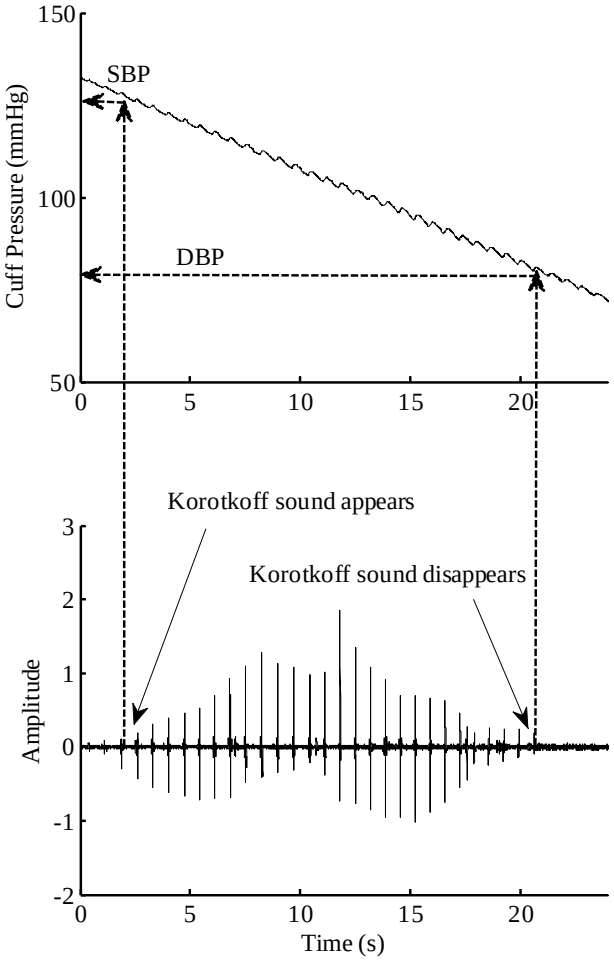


Figure 1. Illustration of SBP and DBP determination method.

# 3. Results

## 3.1. Overall blood pressures

Table 2 shows the overall mean SBP and DBP. The corresponding results from the two repeats and the two operators are given.

ANOVA analysis showed that, for SBP, there was no significant difference between the two operators and between the two repeat measurements (both $P>0.1$), also there was no significant difference between the two different stethoscope positions ($P>0.2$).

For DBP, there was no significant difference between the two operators and between the two repeat measurements (both $P>0.1$). However there was a significant difference between the two different stethoscope positions ($P<0.001$).

Table 2. Overall SBP and DBP results for the two stethoscope positions.

| | | Under the cuff | | Outside the cuff | |
|---|---|---|---|---|---|
| | | repeat 1 | repeat 2 | repeat 1 | repeat 2 |
| **SBP** | op1 | 106 | 104 | 104 | 104 |
| | op2 | 107 | 105 | 106 | 104 |
| **DBP** | op1 | 65 | 65 | 69 | 69 |
| | op2 | 67 | 67 | 69 | 70 |

op1: operator 1; op2: operator 2

## 3.2. Blood pressure difference between the two operators

Figure 2 gives the comparison of BP determined by the two operators. For both SBP and DBP, there was no significant difference between the two operators (P>0.1), with the overall mean difference less than 1.0 mmHg.

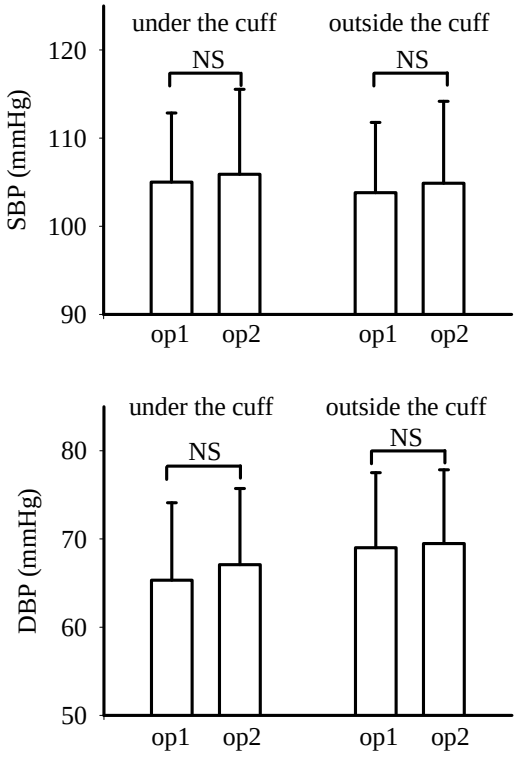


Figure 2. Comparison of SBP and DBP determined by two different operators.
op1: operator 1; op2: operator 2.

## 3.3. Blood pressure difference between the two stethoscope positions

As shown in Figure 3, there was no significant SBP difference between stethoscopes placed at the two positions (mean±SD, under the cuff: 105±8.9 vs outside the cuff: 104±8.7 mmHg) (P>0.1). However, a significant difference for DBP was observed (under the cuff: 66±8.9 vs outside the cuff: 69±8.6 mmHg), with a mean±SD difference of -3.0±1.4 mmHg (P<0.001).

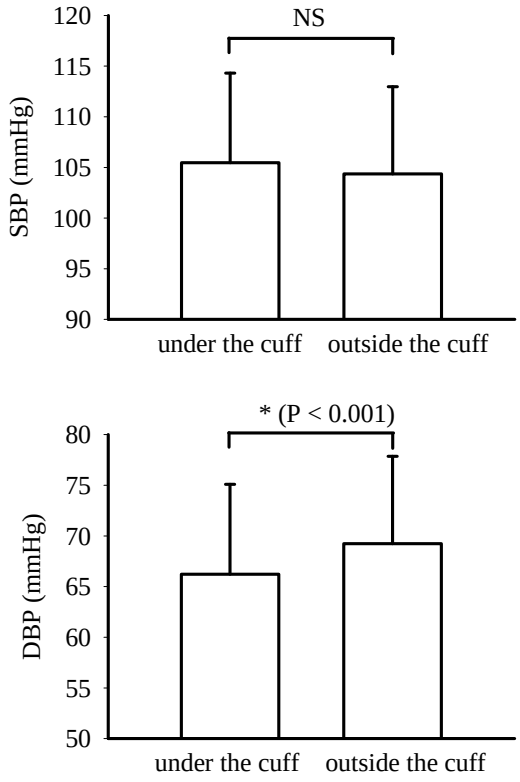


Figure 3. Comparison of SBP and DBP between the two stethoscope positions (under and outside cuff).

## 4. Discussion and conclusion

In this study, the effect of stethoscope position on auscultatory BP measurement was quantified. There was no effect on the SBP, but the DBP was affected by the stethoscope position. DBP determined from outside the cuff was significantly higher than that determined from under the cuff.

However, our study could not conclude which position is the best for accurate BP measurement because there was no reference value available. Further investigation therefore needs to be followed up. Nevertheless, our results from this study provide scientific evidence that the stethoscope is one of the factors influencing BP measurement variability.

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## References

[1] Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN et al. Recommendations for blood pressure measurement in humans and experimental animals. Part 1: Blood pressure measurement in humans. A statement for professionals from the subcommittee of professional and public education of the American Heart Association Council on high blood pressure research. Hypertension 2005; 45: 142-61.

[2] Williams B, Poulter NR, Brown MJ, Davis M, McInnes GT, Potter JF et al. British Hypertension Society. Guidelines for management of hypertension: Report of the fourth working party of the British Hypertension Society. J Hum Hypertens 2004; 18: 139-85.

[3] O'Brien E, Asmar R, Beilin L, Imai Y, Mallion JM, Mancia G et al. European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. J Hypertens 2003; 21: 821-48.

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