

Postural changes in blood pressure and heart rate among healthy young adults in a Ghanaian university

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Introduction: There are contradictory and inconsistent reports on the effects of different body postures on measured blood pressure and heart rate. This relationship has not been previously tested in the Ghanaian population.

Aim of the study: The overall aim of the study was to investigate the effects of different body positions on blood pressure and heart rate among Ghanaian healthy young adults.

Methods: Blood pressure and heart rate were measured subsequently in eight different positions on the left arm in the following non-randomized order: (i) sitting with arm flexed at the elbow and supported at the heart level on the chair, (ii) sitting with legs crossed, (iii) standing, (iv) supine, (v) right lateral recumbent, (vi) left lateral recumbent, (vii) prone, and (viii) bent with hands holding knees with face pointing to the ground. The repeated measures for ANOVA were used to compare the means in different positions. Statistical significance was pegged at $p\text{-value} < 0.05$.

Results: The mean systolic and diastolic blood pressures were lowest in the right lateral recumbent position as compared to the other positions while the bent position recorded both the highest systolic and diastolic blood pressures and heart rate.

Conclusion: The highest mean blood pressure and heart rates are found in the bent position as compared to other body postures. The lowest mean systolic and diastolic blood pressures are found in the right lateral recumbent posture.

Keywords: Posture, blood pressure, heart rate, Ghanaian, Adults

INTRODUCTION

Blood pressure and heart rate are two of the fundamental clinical measurements in medicine used in evaluating a patient's health and also for research. Traditionally, blood pressure was measured non-invasively using auscultation with either aneroid gauge, or a mercury-tube sphygmomanometer [1]. Though auscultation is still generally considered to be the gold standard of accuracy, semi-automated methods have become common, largely due to concerns about the potential mercury toxicity, cost, ease of use, applicability to ambulatory blood pressure and home-based self-monitoring of blood pressure [2]. Numerous factors affect the result of the measurement of blood pressure, varying from the technique and the selection of an accurate device to intrinsic variability of blood pressure and white-coat hypertension [3].

The overall procedure itself influences the outcome of the measurement: the communication with the individual, patient education, attitude of observer, attitude of patient, arm circumference, cuff size, arm position, and patient posture. There is a general acceptance that posture affects the blood pressure. From supine to seated or standing position, the pressure usually drops [3]. The 2013 European Society of Hypertension (ESH)/European Society of Cardiology (ESC) guidelines for the management of arterial hypertension recommend the mean of at least 2 blood pressure measurements in the seated position, spaced 1 to 2 minutes apart. The position of the arm, even in supine position, should be adjusted at heart level to avoid changes in blood pressure [4]. However, there is still uncertainty regarding the importance of the postural differences in blood pressure measurements. In the 2003 ESH recommendations for blood pressure measurement, the researchers' state that the error made is unlikely to be significant in most people [3]. On the contrary, several authors claim that there is a significant difference in blood pressures measured in seated and supine position, [5,6,7] and therefore, they cannot be considered similar. A key driving factor of all these guidelines tend to point to correct diagnosis and management of hypertension or hypotension and not necessarily for identification of cardiovascular reactivity to postural changes. Moreover, it is rare that a nurse records the posture and the site of blood pressure measurement in the chart [8]. Nurses do not think this information is not pertinent due to the lack of literature and research that comments specifically on how blood pressure measurements differ depending on site and posture. In reality, clinical staff put blood pressure measurements to medical use on the assumption that the values are accurate and reliable irrespective of the measurement position [9]. The response of blood pressure and heart rate to change in body position is well suited as a measure of cardiovascular reactivity for epidemiological studies. There is a general acceptance that posture affects the blood pressure and heart rate. From supine to seated or standing position, the pressure usually drops [3, 7]. Several experimental studies have also suggested a differential response of blood pressure to body posture due to race/ethnicity [10] and gender [11,12]. However, other studies found no gender differences [13,14]. There are contradictory and inconsistent reports on the effects of different body postures on measured blood pressure and heart rate. To add to this challenge, there is limited data on the variations of blood pressure and heart rate in the lateral and bent positions. The measured sites in these positions are not at the same level with subject's heart level. This concept of cardiovascular reactivity to different body postures have not been previously investigated in the Ghanaian population. The findings of the study will serve as baseline data on this complex relationship among a cohort of Ghanaian healthy adults.

The overall aim of the study was to investigate the effects of different body positions on blood pressure and heart rate among Ghanaian healthy young adults.

MATERIALS AND METHODS

Subjects

The study included a total of 48 normotensive non-obese adults (20 - 44 years) recruited from the student population of Garden City University College, Kenyase. Exclusion criteria were hypertension and heart disease, other known chronic conditions, use of alcohol or psychoactive drugs, smoking or current illness.

Study protocol

Participation in the study was strictly voluntarily, by receiving signed informed consent from all the participants. All procedures were carried out according to the Helsinki declaration as revised in 2013. All measurements were conducted in the morning in a well-ventilated and quiet nursing skills laboratory. The day before the testing, subjects were advised not to engage in physical sports, or drink beverages containing caffeine or other psychoactive substances. All measurements were done with an automatic arm blood pressure and heart rate monitor (Omron M6 Comfort HEM-7221-E; Omron M2 Basic, Lacchiarella, Italy) with an appropriate standard bladder arm circumference related as indicated by the manufacturer's instruction manual. In all subjects BP and heart rate

were measured in eight different positions on the left arm in the following non-randomized order: (i) sitting with arm flexed at the elbow and supported at the heart level on the chair, (ii) sitting with legs crossed, (iii) standing, (iv) supine, (v) right lateral recumbent, (vi) left lateral recumbent, (vii) prone, and (viii) bent with hands holding knees with face pointing to the ground. After at least 5 minutes of rest, the first measurement was taken in the seated posture. Subsequent measurements were then done at 2 minutes intervals after assuming the next posture.

Statistical analysis

Statistical analysis was done using Graphpad Prism version 8.0.2. The data were expressed as means $\pm$ SD. The repeated measures for ANOVA were used to compare the means in different positions. Adjustment for multiple comparisons was done by using the Holm-Sidak correction. Chi-square analysis was done to compare proportion of large differences (<10 mmHg or ≥ 10 mmHg) [15] in pairwise comparisons of means in the different positions. Statistical significance was pegged at p -value < 0.05 .

RESULTS

The findings of the study are summarized in the tables 1-5. Table 1 shows the general characteristics of the study participants. Table 2 shows the mean blood pressure and heart rate recordings with posture, and tables 3-5 show the pairwise comparison of mean cardiovascular responses with posture.

Table 1 presents the general characteristics of the study population. The study population included a total of 48 normotensive adults, made up of 30 (62.5%) males and 18 (37.5%) females. The mean age of males was significantly higher than females ($p = 0.006$). However, no significant differences were observed in terms of mean systolic blood pressure, diastolic blood pressure and heart rate between males and females.

Parameter	Males	Females	P-value
Number	30 (62.5%)	18 (37.5%)	
Age (years)	24.3 $\pm$ 4.8	20.7 $\pm$ 2.1	0.006
Systolic BP (mmHg)	119.3 $\pm$ 11.7	112.7 $\pm$ 7.9	0.057
Diastolic BP (mmHg)	74.3 $\pm$ 9.4	73.3 $\pm$ 7.9	0.706
Heart rate (bpm)	75.5 $\pm$ 13.7	75.8 $\pm$ 10.6	0.923

Table 1. General characteristics of the study participants BP: Blood pressure

Mean blood pressure and heart rate recordings with posture

The mean blood pressure and heart rate recordings for all positions in the study are presented in table 2. The mean systolic and diastolic blood pressures were lowest in the right lateral recumbent position as compared to the other positions while the bent position recorded both the highest systolic and diastolic blood pressures. In terms of heart rate, the lowest mean recording was observed in the supine position whilst similar to blood pressure, the highest recording was in the bent position.

Posture	Systolic BP (mmHg)	Diastolic BP (mmHg)	Heart rate (bpm)
Sitting	116.9 ± 11.6	73.9 ± 8.8	75.6 ± 12.5
Sitting with crossed legs	117.5 ± 11.9	72.4 ± 9.4	73.0 ± 10.1
Standing	118.0 ± 11.3	80.4 ± 9.8	85.6 ± 11.9
Supine	114.2 ± 9.0	67.1 ± 6.6	67.4 ± 11.6
Right lateral recumbent	101.3 ± 8.8	58.9 ± 6.5	70.1 ± 11.8
Left lateral recumbent	109.1 ± 9.4	70.0 ± 8.8	70.5 ± 13.2
Prone	109.9 ± 9.1	66.9 ± 8.4	72.6 ± 10.8
Bent	122.2 ± 12.4	83.3 ± 10.8	84.7 ± 10.5
	F = 64.31p = <0.0001	F = 75.94p = <0.0001	F = 59.28p = <0.0001

Table 2. Mean blood pressure and heart rate recordings with posture. Postures with statistical difference are presented in bold italics. BP: Blood pressure

Pairwise comparison of mean cardiovascular responses with posture.

The results in table 3 showed that comparisons in mean systolic blood pressures that showed 'large' differences were: (1) sitting and right lateral recumbent, (2) sitting with crossed legs and right lateral recumbent, (3) standing and right lateral recumbent, (4) supine and right lateral recumbent, which showed higher 'large' differences while (1) right lateral recumbent and bent, (2) left lateral recumbent and bent, and (3) prone and bent positions accounted for lower 'large' differences. However, no significant differences were observed between sitting and sitting with crossed legs, sitting and standing, sitting and supine, crossed legs and standing and left lateral recumbent and prone positions.

Posture comparison	Mean difference	Adjusted p-value
Sitting vrs Sitting with crossed legs	-0.7	0.978
Sitting vrs Standing	-1.2	0.971
Sitting vrs Supine	2.7	0.708
Sitting vrs Right lateral recumbent	15.6	<0.0001
Sitting vrs Left lateral recumbent	7.8	0.005
Sitting vrs Prone	7.0	0.016
Sitting vrs Bent	-5.4	0.005
Sitting with crossed legs vrs Standing	-0.5	0.816
Sitting with crossed legs vrs Supine	3.3	0.006
Sitting with crossed legs vrs Right lateral recumbent	16.2	<0.0001
Sitting with crossed legs vrs Left lateral recumbent	8.4	<0.0001
Sitting with crossed legs vrs Prone	7.6	<0.0001
Sitting with crossed legs vrs Bent	-4.7	0.006
Standing vrs Supine	3.8	0.003
Standing vrs Right lateral recumbent	16.7	<0.0001
Standing vrs Left lateral recumbent	8.9	<0.0001
Standing vrs Prone	8.2	<0.0001
Standing vrs Bent	-4.2	0.028
Supine vrs Right lateral recumbent	12.9	<0.0001
Supine vrs Left lateral recumbent	5.1	0.000
Supine vrs Prone	4.3	0.000
Supine vrs Bent	-8.0	<0.0001
Right lateral recumbent vrs Left lateral recumbent	-7.8	<0.0001
Right lateral recumbent vrs Prone	-8.6	<0.0001
Right lateral recumbent vrs Bent	-20.9	<0.0001
Left lateral recumbent vrs Prone	-0.8	0.816
Left lateral recumbent vrs Bent	-13.1	<0.0001
Prone vrs Bent	-12.3	<0.0001

Table 3. Pairwise comparison of mean systolic blood pressure with posture vrs: versus

The results in table 4 showed that comparisons in mean diastolic blood pressures that showed large differences were: (1) sitting and right lateral recumbent, (2) sitting with crossed legs and rightlateral recumbent, (3) standing and supine, (4) standing and right lateral recumbent, (5) standing and left lateral recumbent, (6) standing and prone, which accounted for higher 'large' differences. Also, (1) sitting with crossed legs and bent, (2) supine and bent, (3) right lateral recumbent and left lateral recumbent, (4) right lateral recumbent and bent, (5) left lateral recumbent and bent, and (6) prone and bent positions showed lower 'large' differences. However, no statistical differences were observed between sitting and sitting with crossed legs, sitting with crossed legs and left lateral recumbent, standing and bent, supine and prone, and left lateral recumbent and prone positions.

Posture comparison	Mean difference	Adjusted p-value
Sitting vrs Sitting with crossed legs	1.6	0.164
Sitting vrs Standing	-6.4	0.0002
Sitting vrs Supine	6.9	<0.0001
Sitting vrs Right lateral recumbent	15.1	<0.0001
Sitting vrs Left lateral recumbent	3.9	0.009
Sitting vrs Prone	7.1	<0.0001
Sitting vrs Bent	-9.4	<0.0001
Sitting with crossed legs vrs Standing	-8.0	<0.0001
Sitting with crossed legs vrs Supine	5.3	<0.0001
Sitting with crossed legs vrs Right lateral recumbent	13.5	<0.0001
Sitting with crossed legs vrs Left lateral recumbent	2.3	0.085
Sitting with crossed legs vrs Prone	5.5	0.0005
Sitting with crossed legs vrs Bent	-11.0	<0.0001
Standing vrs Supine	13.3	<0.0001
Standing vrs Right lateral recumbent	21.5	<0.0001
Standing vrs Left lateral recumbent	10.3	<0.0001
Standing vrs Prone	13.5	<0.0001
Standing vrs Bent	-3.0	0.179
Supine vrs Right lateral recumbent	8.2	<0.0001
Supine vrs Left lateral recumbent	-2.9	0.028
Supine vrs Prone	0.2	0.851
Supine vrs Bent	-16.2	<0.0001
Right lateral recumbent vrs Left lateral recumbent	-11.2	<0.0001
Right lateral recumbent vrs Prone	-8.0	<0.0001
Right lateral recumbent vrs Bent	-24.4	<0.0001
Left lateral recumbent vrs Prone	3.2	0.085
Left lateral recumbent vrs Bent	-13.3	<0.0001
Prone vrs Bent	-16.5	<0.0001

Table 4. Pairwise comparison of mean diastolic blood pressure with posture vrs: versus

The results in table 5 showed that comparisons in mean heart rates that accounted for lower 'large' differences were: (1) sitting and standing, (2) sitting with crossed legs and standing, (3) sitting with crossed legs and bent, (4) supine and bent, (5) right lateral recumbent and bent, (6) left lateral recumbent and bent, and (7) prone and bent positions which. Those that showed higher 'large' differences were: (1) standing and supine, (2) standing and right lateral recumbent, (3) standing and left lateral recumbent, and (4) standing and prone positions. However, no statistical differences were observed for sitting and prone, sitting with crossed legs and supine, sitting with crossed legs and right lateral recumbent, sitting with crossed legs and left lateral recumbent, sitting with crossed legs and prone, standing and bent, supine and right lateral recumbent, supine and left lateral recumbent, right lateral recumbent and left lateral recumbent, right lateral recumbent and prone, and left lateral recumbent and prone positions.

Posture comparison	Mean difference	Adjusted p-value
Sitting vrs Sitting with crossed legs	2.6	0.010
Sitting vrs Standing	-10.0	<0.0001
Sitting vrs Supine	8.2	<0.0001
Sitting vrs Right lateral recumbent	5.5	<0.0001
Sitting vrs Left lateral recumbent	5.1	0.010
Sitting vrs Prone	3.0	0.143
Sitting vrs Bent	-9.1	<0.0001
Sitting with crossed legs vrs Standing	-12.6	<0.0001
Sitting with crossed legs vrs Supine	5.6	<0.0001
Sitting with crossed legs vrs Right lateral recumbent	2.9	0.063
Sitting with crossed legs vrs Left lateral recumbent	2.5	0.302
Sitting with crossed legs vrs Prone	0.4	0.933
Sitting with crossed legs vrs Bent	-11.7	<0.0001
Standing vrs Supine	18.2	<0.0001
Standing vrs Right lateral recumbent	15.5	<0.0001
Standing vrs Left lateral recumbent	15.1	<0.0001
Standing vrs Prone	13.0	<0.0001
Standing vrs Bent	0.9	0.896
Supine vrs Right lateral recumbent	-2.7	0.103
Supine vrs Left lateral recumbent	-3.1	0.143
Supine vrs Prone	-5.2	<0.0001
Supine vrs Bent	-17.3	<0.0001
Right lateral recumbent vrs Left lateral recumbent	-0.4	0.933
Right lateral recumbent vrs Prone	-2.5	0.103
Right lateral recumbent vrs Bent	-14.6	<0.0001
Left lateral recumbent vrs Prone	-2.1	0.460
Left lateral recumbent vrs Bent	-14.2	<0.0001
Prone vrs Bent	-12.1	<0.0001

Table 5. Pairwise comparison of mean heart rate with posture vrs: versus

DISCUSSION

The present study determined blood pressure and heart rate recordings in different body positions as a means of investigating the influence of body posture on blood pressure and heart rate in a cohort of healthy young Ghanaian adults. In the present study, the mean SBP in the sitting position was higher than all the recumbent positions including the supine position. Also, higher mean SBP was observed in the standing position as compared to other postures, with a notable exception of bent position which was significantly higher. Some reports on differences in blood pressure and body posture have shown inconsistencies. In one study, no influence of the subject's body posture on the systolic blood pressure between sitting and supine positions [16]. Higher SBP has been reported in sitting position as compared to supine position [15,17,18]. However, higher SBP was observed in supine position as compared to sitting position in other studies [4-7,19]. The ARIC study reported considerable variability in the response of SBP to change in posture in a population sample of middle-aged adults. While higher SBP was observed in standing as compared to supine position in some, others had higher SBP recordings in the supine position, with others showing no difference between supine and standing postures. Individuals who had lower SBP upon standing were significantly older while higher SBP upon standing was observed among subjects who are largely blacks [20]. Similar to SBP, while some studies [6,7,19] have reported higher DBP in the supine position, others [15,17,18] have observed DBP to be higher in the seated posture as

compared to supine position. These latter reports are consistent with that observed in the present study, which showed mean DBP to be higher in the seated position as compared to the supine position. A 10 mmHg or greater increase in DBP from the supine to standing position has been reported [21]. Consistent with that, the present study showed that mean DBP was significantly higher in the standing position as compared to all the recumbent positions. However, the bent position still recorded the highest mean DBP as compared to all the other postures. Higher heart rates have reported in the seated position as compared to supine position [16]. Consistent with this, in the present study, mean heart rate was observed to be higher in the vertical positions (seated and standing) as compared to the recumbent postures (supine, prone, right and left lateral recumbent).

However, few studies have been conducted on the differences in postural positions in the recumbent posture. The findings of these studies suggest significant differences in blood pressure even in the different recumbence postures. In non-pregnant and pregnant women, it was observed that blood pressure tends to fall significantly when they turn from the supine to right or left lateral recumbent positions [22]. In another study, the mean blood pressure in the right lateral recumbent position was observed to be lower than the supine position [23]. Another study also observed a lower mean blood pressure in the prone position when compared to supine posture while heart rate was higher in the prone position as compared to supine posture [24]. In the present study, it was observed that the lowest mean systolic and diastolic blood pressures were in the right lateral recumbent posture as compared to all other postures while heart rate was lowest in the supine position as compared to the other postures. Of notable observation was that bent posture showed both the highest mean systolic and diastolic blood pressures and heart rate as compared to all other positions. It has been explained that after 1 minute of standing, gravity induces roughly 500mL of blood to shift to the lower body. As arterial pressure decreases the baroreceptors become unloaded initiating parasympathetic withdrawal and activation of the sympathetic nervous system via baroreflex-mediated autonomic regulation. The withdrawal of parasympathetic action rapidly increases heart rate (HR), within 1 to 2 cardiac cycles. The subsequent sympathetic activation, however, results in causing vascular resistance, vascular tone, and cardiac contractility to increase and further increase HR [25]. The response of blood pressure to change in body position has been used in epidemiological studies as a measure of cardiovascular reactivity. It has been reported that a 10-mm Hg or greater increase in diastolic blood pressure (DBP) from the supine to standing position significantly modified the effect of seated systolic blood pressure (SBP) and DBP on the incidence of myocardial infarction during 8.7 years of follow up in a cohort of middle-aged white men [21]. On further investigation of this population, the investigators concluded that the difference between the supine and seated blood pressures is positively associated with subsequent development of systemic hypertension independent of supine blood pressure [21]. Individual differences may exist in the interplay of hemodynamic, parasympathetic and sympathetic factors associated with vascular reactivity to changes in body posture, even during recumbency. Although this may account for some of the inconsistent results reported in some studies, it may also be important to identify those with consistently 'large' differences in cardiovascular reactivity with postural changes as a special target group for further monitoring.

This study included many positions in both vertical and recumbence postures than previously studied by other researchers. However, the relatively smaller sample size and number of measurements may affect the observed findings of the study. The study participants were not age- and sex-matched and therefore did not address potential age and gender differences in the outcome variables considered in the study. Also, the non-randomized order of the postures may influence the mean levels of the recordings observed in the study. Finally, the study included only healthy young adults and therefore generalized conclusions cannot be drawn in individuals with hypertension and other cardiovascular risk factors.

CONCLUSION

From the findings of the study, it is concluded that the systolic and diastolic blood pressures are significantly higher in sitting and standing positions as compared to supine and other recumbent positions. Additionally, the highest mean blood pressure and heart rates are found in the bent position as compared to other body postures. Lastly, the lowest mean systolic and diastolic blood pressures are found in the right lateral recumbent posture while the supine posture has the lowest mean heart rate as compared to other postures. Generally, the overall findings and the discussion of the study, we recommend that future research with a larger sample who are age- and sex-matched with recordings done in a randomized order should be used. Also, future research replicating the study protocol in individuals with hypertension and other cardiovascular risk factors is warranted. These may provide an enriched insight into the observed differences in cardiovascular reactivity to changes in body posture.

Acknowledgement :

We are very much grateful to all participants for their voluntary participation.

Source of financial support:

None.

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