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Inter-arm systolic blood pressure dependence on hand dominance

Harvey N. Mayrovitz

College of Medical Sciences, Nova Southeastern University, Ft. Lauderdale, FL, USA

Correspondence
Harvey N. Mayrovitz, College of Medical Sciences, Nova Southeastern University, 3200 S. University Drive, Ft. Lauderdale, FL 33328, USA
E-mail: mayrovit@nova.edu

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Summary

Inter-arm systolic blood pressure differences (SBP-DIFF) ≥ 10 mmHg have been reported useful to predict future cardiovascular-related morbidities. Although well studied in patients, there is little information on healthy young adults and the role of hand-dominance as a factor affecting SBP-DIFF. As dominant arms (DOM) tend to have greater girth and muscle development than nondominant arms (NDOM) it was reasoned that cuff pressures needed to obtain SBP may be greater on DOM causing DOM SBP to be greater. To test this hypothesis and also provide typical values, SBP was measured in left and right-handers (29·4 ± 10·4 years) in whom handedness was clearly defined. Handedness was determined by a multi-question form in 90 young adults (45 male) and SBP-DIFF determined via simultaneous measurements done in triplicate on seated subjects. The percentage of left-handers in male and female sub-groups were equal at 37·8%. Results show that the absolute SBP-DIFF in left-handers (mean ± SD) was 4·4 ± 3·8 mmHg and for right-handers was 5·0 ± 4·2 mmHg ($P = 0{\cdot}362$). There was also no statistically significant difference among 1st, 2nd and 3rd measured SBP-DIFF for either right or left-handers or differences between right and left-handers. Results show no evidence of a higher SBP in DOM and thus clarifies the hand-dominance issue as a factor not generally needing to be considered in clinical assessments. A potentially useful secondary outcome was the finding that 14·8% of this group had at least one measured SBP-DIFF ≥ 10 mmHg a fact that may have future relevance.

Introduction

A recent study of 700 patients with cardiovascular diseases of various types reported that an inter-arm systolic blood pressure (SBP) difference of 5 mmHg appears to be an optimal threshold for predicting subsequent cardiovascular events (Hirono *et al.*, 2018). Although the primary goal of that study was to suggest a useful threshold, their data revealed that in 11% of patients, the left arm exceeded the right arm SBP by at least 5 mmHg whereas in 16% of patients the right arm exceeded the left arm SBP by at least 5 mmHg with the remainder having inter-arm differentials of <5%. In contrast with the 5-mmHg threshold, prior work using a similar simultaneous SBP measuring system on 407 patients with coronary artery disease (CAD) and 250 without CAD but all having cardiovascular risk-factors, indicated a forward looking predictive threshold of 10 mmHg as predictive of cardiovascular morbidity (Tokitsu *et al.*, 2015). Other workers, who have considered the temporal variability of interarm blood pressure values, have suggested that differences >20 mmHg are needed for meaningful clinical use (Kleefstra *et al.*, 2007; Mehlsen & Wiinberg, 2014). There have been a variety of other studies that have focused on characterizing inter-arm pressure differences in variously compromised patients. These include patients with overt vascular disease (Kranenburg *et al.*, 2017), patients with hypertension (Kim *et al.*, 2017), patients admitted to intensive care units (Rosenberger *et al.*, 2018), and other patient populations as reported in several meta analyses (Cao *et al.*, 2015; Clark *et al.*, 2016; Zhou *et al.*, 2016). However, to a much lesser extent have inter-arm SBP differentials been studied in healthy populations (Fotherby *et al.*, 1993; Grossman *et al.*, 2013; Kim *et al.*, 2013) and none have separately considered the role of handedness as it may relate to measured inter-arm SBP differences. A possible exception with regard to the handedness issue may be found in the elegant pioneering work of Harrison and co-workers (Harrison *et al.*, 1960) who described simultaneous direct and indirect inter-arm pressures in 437 patients who had previously been questioned as to their handedness. Unfortunately, of these 437, only six self-reported themselves to be left-handed with the result that no consistent handedness-related interarm SBP difference was detected. One might argue that the imbalance in numbers of right and left handers that were included in that study may have obscured a dependency if such a dependency were actually present. An interesting related consideration derives from measurements of 237 patients whose bilateral pressures were measured at a general clinical practice with an outcome indicating right arm SBP greater than left by an average of 4·8 mmHg (Cassidy & Jones, 2001). A similar right arm SBP excess (2–3 mmHg) was reported for simultaneous measurements in 147 consecutive hypertensive patients (Eguchi *et al.*, 2007). Contrastingly, in 877 patients in whom an inter-arm SBP differential >2 mmHg was considered a difference (Grossman *et al.*, 2013) it was found that SBP was the same in 9% of patients, higher in the right arm in 48% of patients and higher in the left arm in 43% of patients with no overall difference in mean SBP between left or right arms. However, in that study pressure measurements were made sequentially as opposed to simultaneously with no documentation as to dominant handedness of patients evaluated.

In considering the role of handedness as a factor affecting inter-arm SBP differences, our original working hypothesis was that SBP as measured in the dominant arm would on average exceed that measured in the non-dominant arm. One basis for this reasoning was the notion that dominant arm girths and muscle development tend to be greater than non-dominant arms thereby requiring slightly greater cuff pressure in the dominant arm to achieve the SBP measurement. The goal of the present study was to test this hypothesis and also to provide some young adult typical values by assessing both left and right-handed persons in whom handedness was clearly defined. When studying potential interarm SBP differences it has been stressed that simultaneous measurements are more likely to be useful than serial measurements (van der Hoeven *et al.*, 2013). This might be especially true for persons who are highly anxious in anticipation of the first measurement but whose anxiousness resolves somewhat upon the second later sequential measurements. Thus, the present study used only simultaneously determined bilateral SBP measurements.

Methods

Subjects

A total of 90 (45 female and 45 male) self-reported healthy adult volunteer subjects participated after being informed of the nature of the research study and signing an Institutional Review Board approved informed consent. This total number was based on the estimated number needed to detect an overall mean interarm pressure difference of 6 mmHg at an α-level of 0·05 and β-level of 0·8 (80% power). Subjects were recruited mainly from university medical students and some faculty and were eligible for participation if they had no history of vascular disease, hypertension or diabetes and were not currently taking any medication with a potential vascular effect. Although not an entry requirement all subjects declared themselves as non-smokers. Before a subject was included in the study they were asked to complete an initial handedness classification questionnaire. The method for assigning dominant handedness classification was based on a 10−question questionnaire (Van Strien, 1992). According to this method, the subject answers a series of questions regarding which hand they would perform certain activities such as, which hand they would draw with or which hand they would hold a hammer if striking a nail or which hand they would use to stir their coffee. If they choose the right hand, a score of +1 is assigned, if they choose the left hand then a score of −1 is assigned. If they choose no clear preference (both), then a score of 0 is assigned. According to this system the range of composite scores is from −10 (extreme left handedness) to +10 (extreme right handedness). For the purpose of the present study, a subject was considered a left hander if their composite score was <−2 and a right hander if their composite score was >+2. Persons with scores between −2 and +2 were not evaluated as part of this study as they were deemed possible ambidextrous. The assignment as to handedness was binary (either right or left-hander) with no attempt to further breakdown right and left-handers as to strong or weak handedness. For the present studied, population no right hander's score was <+7 and no left hander's score was more positive than −8. Demographic and handedness features of the male and female studied population is indicated in Table 1 with the dominant hand indicated as DOM and the nondominant hand as NDOM.

Blood pressure measurement

Systolic and diastolic pressures were measured bilaterally and simultaneously using the WatchBP Microlife dual-cuff device (Microlife, Clearwater, FL, USA). Measurements were made in triplicate with 60 s between consecutive measurements while subjects were seated on a comfortable chair that had a padded support surface affixed to its front. The support surface was positioned at the approximate heart level of the subject with the subject's arms comfortably resting on it. The upper arm circumference of each arm was measured at the approximate mid-point of the bicep using a Gulick type tape measure with calibrated tension (Model 67019, Country Technology Inc., Gays Mills, WI, USA). For arm circumferences 22–32 cm the medium blood pressure cuff was used and for arm circumferences 32–42 cm the large cuff was used. No measured arm circumference was <22 cm or >42 cm. Subjects were asked to sit quietly with uncrossed legs for 5 min before blood pressures were taken. Average blood pressures of the studied population and their standard deviations are shown in Table 1. Individual subject PRESSURES were determined as the average of the six blood pressure measurements (three in each arm).

Body composition measurements

After blood pressure measurements subjects removed shoes and socks and stood on a scale to measure weight and body

Table 1 Study group parameters of male and female subjects.

	Male	Female	*P*-value	Total group
No. of subjects	45	45		90
Handedness (Left/Right)	17/28	17/28		34/56
Age (years)	31·2 ± 10·8	27·5 ± 9·8	0·097	29·4 ± 10·4
SBP, systolic pressure (mmHg)[a]	123·6 ± 11·3	108·9 ± 10·2	<0·0001	
DBP, diastolic pressure (mmHg)	73·7 ± 8·8	67·8 ± 8·5	0·002	
Heart rate (bpm)	68·7 ± 12·7	71·7 ± 11·2	0·285	
BMI, body mass index (kg m^{-2})	25·0 ± 3·1	22·7 ± 4·4	0·005	
TBF, total body fat (%)	17·2 ± 5·8	27·0 ± 9·2	<0·0001	
TBW, total body water (%)	58·9 ± 4·6	53·5 ± 6·0	<0·0001	
Bicep girth (cm)[b]	29·9 ± 2·6	24·9 ± 2·9	<0·0001	
AFP, arm fat (%)	17·3 ± 5·4	29·1 ± 9·5	<0·0001	
AMM, arm muscle mass (kg)	3·64 ± 0·54	1·87 ± 0·31	<0·0001	

[a]Systolic and diastolic pressures determined as arm average of triplicate measurements on each arm.
[b]Arm girth, fat and muscle mass determined as the average of left and right arms. Except for age and resting heart rate, differences between males and females were statistically significant as indicated by the associated P-values.

composition parameters using bioimpedance at a frequency of 50 kHz (InnerScan Segmental Body Composition Monitor, Tanita model BC558, TheCompetitiveEdge.com, Preston WA, USA). They stood for about 15 s while they gripped a handle-electrode in each hand. Parameters measured were total body fat percentage (TBF), total body water percentage (TBW), arm fat percentage (AFP) and arm muscle mass (AMM) in pounds. These values are all determined by device proprietary algorithms. Male and female group averages are shown Table 1.

Analysis

The minimum SBP difference between arms that was considered as different was taken as 2 mmHg following the criterion previously put forward (Grossman *et al.*, 2013). If the absolute difference was ≤2 mmHg then arm pressures were considered equal ($SBP_{DOM} = SBP_{NDOM}$). The absolute value of the inter-arm SBP difference was calculated as $|SBP_{DOM} - SBP_{NDOM}|$ and defined as δP. The δP was determined for each of the three-sequential (1st, 2nd and 3rd) paired simultaneous SBP measurements. This process yielded a total of 102 values for eft-handers and 168 values for right-handers. Possible differences among the δP values for 1st, 2nd and 3rd measurements were tested for using a general linear model analysis for repeated measures with δP values as the repeated measure and hand dominance as the between subject's factor. To test for differences in δp between left and right-handers, the composite of the 102 left-hander values were compared against the composite of the 168 values of right-handers using an independent t-test with a P-value of <0·01 taken as the threshold for statistical significance. An overall δP value was also determined. This included both left and right-handers and yielded 270 SBP measurements as an overall representation of the DOM-NDOM inter-arm SBP difference. In addition, the percentage of cases in which δp values were within three interval ranges was determined. The intervals were <5 mmHg, between 5 and 9·9 mmHg and ≥10 mmHg. Since δP, being an absolute value, does not specify which arm, DOM or NDOM had the higher pressure, an additional parameter denoted as ΔP was calculated. The ΔP was calculated the same as for δP as ($SBP_{DOM} - SBP_{NDOM}$) but the sign of the difference was retained. In this way a positive (+) sign indicated the DOM arm had a greater pressure and a negative (−) sign indicated that the NDOM arm had the greater pressure. ΔP values were then used to determine if DOM to NDOM relationships differed between left and right handers.

Results

Gender comparisons

Except for age and resting heart, male subjects differed significantly from female subjects with respect to blood pressure and all body composition parameters as summarized in Table 1. Systolic and diastolic blood pressures were greater in males as were BMI, TBW, arm muscle mass and upper arm girth. Contrastingly fat percentages for total body and arms were greater in females. The percentage of left-handers in male and female sub-groups were the same being 37·8% of each sub-group. This indicates that in the present study population left-handers are well-represented, at a level close to four-fold greater than the estimated 10% in the general population (Hardyck & Petrinovich, 1977).

Dominant and non-dominant side values

DOM and NDOM arm values for blood pressures, girth, muscle mass and fat percentage are summarized in Table 2 for females and males separately. Differences between DOM and NDOM arm values for males were minor and were not statistically significant. For females DOM arms tended to have a

Table 2 Dominant and nondominant side values.

	Females (N = 45)			Males (N = 45)		
	DOM	NDOM	P-value	DOM	NDOM	P-value
SBP, systolic BP (mmHg)	109·5 ± 10·4	108·3 ± 10·3	0·054	123·3 ± 12·2	123·9 ± 10·9	0·407
DBP, diastolic BP (mmHg)	67·7 ± 9·6	67·8 ± 8·2	0·860	73·3 ± 8·9	74·2 ± 9·0	0·071
Bicep girth (cm)	25·0 ± 3·0	24·8 ± 2·9	0·010	30·0 ± 2·7	29·8 ± 2·5	0·188
AFP, arm fat (%)	28·6 ± 9·9	29·6 ± 9·3	0·009	17·0 ± 5·1	17·5 ± 5·8	0·106
AMM, arm muscle mass (kg)	1·90 ± 0·36	1·88 ± 0·33	0·095	3·66 ± 0·56	3·63 ± 0·54	0·269

Table entries are mean ± SD for dominant (DOM) and non-dominant (NDOM) arm parameters. Overall differences between DOM and NDOM for males were not statistically significant. DOM arm of females tended to have less fat percent and muscle mass than the NDOM arm.

slightly higher SBP then NDOM (P = 0·054) and a slightly, but statistically significant (P = 0·01) lower fat percentage and greater girth of the DOM arm.

DOM-NDOM absolute SBP differences (δP)

Table 3 summarizes the main results for comparisons among absolute pressure differences (δP) for left and right-handers in which δP is the absolute value of the inter-arm SBP difference calculated as $|SBP_{DOM} - SBPN_{DOM}|$. The overall δp for left-handers (mean ± SD) was 4·4 ± 3·8 mmHg and for right-handers was 5·0 ± 4·2 mmHg. These values did not statistically differ from each other (P = 0·362). There was also no statistically significant difference among 1st, 2nd and 3rd δP values for either right or left-handers nor did any of these values differ between right and left-handers. Although the mean δP was not >5 mmHg for either left or right handers, each demonstrated a modest fraction of measurements that were either within the range of 5–9·9 mmHg or ≥10 mmHg as summarized in the last three columns of Table 3. Considering all measurements, right-handers (n = 168) tended to have a greater percentage (16·7%) of measurements in which δp ≥ 10 mmHg then for left-handers (n = 102) who had 11·8% of cases with δp ≥ 10 mmHg. However, a chi square analysis of these relative proportions indicates that they are not statistically different (P = 0·272). For the entire group (left and right handers combined) the percent of measurements for which δp ≥ 10 mmHg was 14·8%. Calculations of the percentage of subjects that had at least one pressure measurement for which δp ≥ 10 mmHg, indicates a distribution for 1st, 2nd and 3rd measurements of 15·6%, 16·7% and 12·2%, respectively, with 14·8% of all subjects having at least one inter-arm difference ≥10 mmHg.

DOM-NDOM signed SBP differences (ΔP)

Table 4 compares percentages of SBP measurements greater or less or not different between dominant (DOM) and non-dominant (NDOM) arms calculated as $\Delta P = SBP_{DOM} - SBP_{NDOM}$. The percent of measurements for which the DOM arm pressure exceeded the NDOM arm was 34·8% whereas the NDOM arm pressure exceeded the DOM arm pressure in 27% of cases. Although this appears to suggest a tendency for a greater DOM arm pressure, chi square analysis indicates these proportions not to be statistically significant (P>0·800). Exploratory analyses, aimed at determining if subjects with either higher or lower dominant arm SBP differed with respect to any body composition parameter, failed to show any meaningful relationship.

Discussion

One consideration motivating the present research was that dominant arms tend to have greater muscle mass and biceps girth than do nondominant arms. This view is supported by some published work (Olmedillas *et al.*, 2010) and it has been suggested that larger circumference arms may be associated with higher measured SBP (Loenneke *et al.*, 2016). An additional motivation was triggered by literature reports that indicated a higher SBP recorded in the right arm of patients (Cassidy & Jones, 2001; Eguchi *et al.*, 2007). A third motivating factor was that most prior assessments of inter-arm pressure differences focused on either older persons or those with already present cardiovascular symptoms. This meant that there was little data on young and apparently healthy adults. Furthermore, because of the widely reported potential significance of inter-arm SBP differences as a predictor of cardiovascular morbidity (Cao *et al.*, 2015; Tokitsu *et al.*, 2015; Zhou *et al.*, 2016; Kranenburg *et al.*, 2017; Hirono *et al.*, 2018) it was believed that the issue concerning the role that handedness might play in such inter-arm pressure differences was of significance and should be specifically addressed. This led to the working hypothesis that the magnitude of cuff pressures needed to compress the underlying brachial artery in determining SBP would be greater in the dominant arm thereby rendering the dominant arm to have a greater SBP. The natural consequence if this hypothesis were true would be that in left handers the left arm pressure would be greater than the right and in right-handers the right arm pressure would be greater than the left. Because no prior study that could be found systematically targeted handedness by including and documenting the percentage of left-handers evaluated, the literature data on the handedness-issue was sparse. Adding to the uncertainty

Table 3 DOM-NDOM absolute systolic blood pressure differences (δP).

	Systolic pressure differences between dominant (DOM) and non-dominant (NDOM) arms			
	δP (mmHg)	% <5 mmHg	% 5–9·9 mmHg	% ≥10 mmHg
Left handers (N = 34)				
1st measurement	4·4 ± 3·6	55·9	35·3	8·8
2nd measurement	4·9 ± 4·2	52·9	29·4	17·6
3rd measurement	3·9 ± 3·5	58·8	32·4	8·8
Combined (N = 102)	4·4 ± 3·8	55·9	32·3	11·8
Right handers (N = 56)				
1st measurement	4·9 ± 3·7	51·8	28·6	19·6
2nd measurement	5·0 ± 4·3	57·1	26·8	16·1
3rd measurement	5·3 ± 4·6	51·8	33·9	14·3
Combined (N = 168)	5·0 ± 4·2	53·5	29·8	16·7
All measurements (N = 270)	4·8 ± 4·0	54·4	30·7	14·8

The quantity δP is the absolute value of inter-arm systolic blood pressure (SBP) difference calculated as $|SBP_{DOM} - SBP_{NDOM}|$. There is no statistically significant difference among 1st, 2nd and 3rd δP values for either right or left-handers. There is also no significant difference between right and left-hander δP values.

was the fact that much of the literature available concerning inter-arm SBP differences were derived from serial rather than simultaneously determined pressure measurements. Therefore, the present study undertook to include in the studied population a reasonable percentage of well-documented left-handers and relied on simultaneous inter-arm blood pressure measurements. The overall findings and interpretation of the composite data-set of the present study shows no indication of there being a significantly higher SBP in the dominant arm whether left or right-handed dominant and thus the working hypothesis is not supported by the present data. The absence of a finding in support of a role of hand-dominance with respect to inter-arm SBP differences is in-of-itself a new finding that clarifies this issue and suggests that handedness is not a factor that needs to be taken into account in clinical assessments with the proviso that the current data-set applies specifically to a young adult population.

An additional new finding of the present study was that among all measurements for the entire group the average absolute inter-arm SBP (δP) was found to be 4·8 ± 4·0 mmHg. If one accepts that a normal reference range can be estimated as the mean ± 2SD, this data-set indicates a normal reference range on the inter-arm δP of −3·2 to 12·8 mmHg. This pressure range may be compared to values obtained in a group of 364 subjects, free of known cardiovascular disease in which an average (right arm − left arm) difference was reported as 1·1 ± 4·6 mmHg (range −8·1 to 10·3 mmHg; Orme *et al.*, 1999). Although that study included an older average age population (49 years) and took no specific account of handedness, the reported pressure range is not much different that herein determined. Perhaps the closest comparable population to the present with respect to age and apparent health is that reported for a group of 877 Israeli aviators and aviator applicants whose mean age was 26 ± 10 years (Grossman *et al.*, 2013). Although inter-arm pressures were determined serially, as opposed to the simultaneous method of the present study, and no documentation as to handedness was provided, the absolute inter-arm pressure difference (δP) they reported was 5·6 ± 5·4 mmHg, a value not dissimilar to that obtained in the present study.

Another relevant result of the present study was the finding that even among the young adult normotensive and otherwise apparently healthy group of subjects herein studied, there were about 15% of subjects that had at least one measured inter-arm pressure difference ≥10 mmHg. A similar percentage (15·5%) was reported for average inter-arm differences among a general Chinese population in the age range 35–44 years

Table 4 Systolic DOM-NDOM signed pressure differences (ΔP).

	ΔP > 2 mmHg DOM > NDOM	ΔP < −2 mmHg NDOM > DOM	ΔP between ±2 mmHg DOM = NDOM
Left-hander measurements (*n* = 102)	35 (34·3)	27 (26·5)	40 (39·2)
Right-hander measurements (*n* = 168)	59 (35·1)	46 (27·4)	63 (37·5)
Combined measurements (*n* = 270)	94 (34·8)	73 (27·0)	103 (38·2)

Entries are the number and (percentage) of systolic blood pressure measurements greater or less or not different between dominant (DOM) and non-dominant (NDOM) arms calculated as ΔP = DOM − NDOM. The minimum difference between arms considered as different was 2 mmHg. For measurements with a non-zero inter-arm pressure difference, the percentage of cases in which DOM exceeded NDOM tended to be greater than the percentage of cases in which NDOM exceeded DOM.

(Sun *et al.*, 2018). Contrastingly, using simultaneous measurements, only 3·7% of 806 adults in a general Korean population were found to have an inter-arm SBP difference ≥10 mmHg (Song *et al.*, 2016). However, the analysis of these workers was based on average differences of three paired-measurements, not on the number of measurements that exceeded the 10-mmHg threshold or the number of patients for which at least one measurement exceeded the threshold. Clinical blood pressure determinations are usually made on the basis of a single measurement (Kranenburg *et al.*, 2017), so that the averaging process would tend to diminish the number of subjects having average SBP ≥ 10 mmHg. Such averaging effects have been demonstrated by comparing single simultaneous bilateral measurements versus the average of these two measurements (Kleefstra *et al.*, 2007). Although about 15% of young adults herein evaluated had one or more SBP measurements ≥10 mmHg, it is useful to view this percentage in comparison to those with co-present cardiovascular disease. In a study utilizing single sequential measurements that included 5293 patients (age 60 ± 10 years) with manifest vascular disease, it was reported (Kranenburg *et al.*, 2017) that 34% of patients had a $\delta P \geq 10$ mmHg. In that same study a similar percentage was reported for 2051 patients without manifest vascular disease.

In conclusion, based on the inclusion of a substantial percentage of left-handers and the use of simultaneously determined bilateral pressures, the present findings indicate no significant impact of handedness on inter-arm SBP differences in the young adult healthy population herein studied. An unsuspected but potentially useful secondary outcome was the finding that about 15% of this subject group had at least one measured inter-arm SBP difference that was ≥10 mmHg a fact that may have future relevance.

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Conflict of interest

The author declares no conflict of interest of any kind.

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