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Research Article

Gender Effects on Direct vs Indirect Blood Pressure Measurements at Rest and During Biking -

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ABSTRACT

Purpose: This study tested gender effect on the systolic and diastolic Blood Pressures (BP) measured simultaneously by intra - arterial catheter and auscultation methods at rest, during two submaximal aerobic exercises and at peak bicycle exercise.

Methods: Comparisons were made between females and males: 18 males and 18 females age 23.6 ± 2.0 and 24.0 ± 2.0 years respectively, with work capacity of 14.5 ± 1.2 for males and 12.8 METs for females were recruited.

Results: At all conditions, heart rate were significantly ($p < 0.05$) higher in the females compared to the males group. At rest, correlations coefficients between direct and indirect BP measurements were high in female and males (0.91 and 0.92 respectively) for systolic BP and satisfactory for the diastolic BP (0.83 and 0.83 respectively). During exercises, at 60% and 70% efforts, correlations coefficients between direct and indirect BP measurements were high in females and males for systolic BP (0.92 and 0.90 respectively) and reasonable for the diastolic BP. At peak exercise no differences between males and females were noted in means achieved for systolic BP and diastolic BP.

Conclusions: The validity of an auscultation method in females and males at rest, submaximal aerobic exercise and peak aerobic exercises, are reliable for systolic BP, while auscultatory diastolic BP readings at rest and submaximal satisfactory. The significant higher rise in systolic BP in males compared to females reflects gender differences in levels of sympathetic and parasympathetic drive.

Keywords: Aerobic exercise; Auscultation; Intra - arterial blood pressure; Systolic blood pressure; Diastolic blood pressure.

ABBREVIATIONS

CM: Centimeter; Hz: Hertz; Mm: Millimeter; Sec: Second; SD: Standard Deviation; ANOVA: Analysis of Variance; mmHg: Millimeter of Mercury; BP: Blood Pressure, mmHg; BP: Blood Pressure, mmHg; MET: Metabolic Equivalent; mL: Milliliter; Kg: Kilogram; Min: Minute; ECG: Electrocardiograph

INTRODUCTION

Studies using the technique of 24-hour ambulatory Blood Pressure (BP) monitoring have shown that BP is higher in men compared to women at similar ages [1]. Previous work has shown a gender difference in BP response to exercise measured by auscultatory means. Men had significantly higher absolute systolic BP responses at rest, 50%, 75%, and 100% peak heart rate on all modalities [2,3]. Men had a higher systolic BP in spite of the fact that they had similar sympathetic nervous system response as indicated by urinary norepinephrine excretion [4].

Although the mechanisms responsible for the gender differences in BP control are not clear, there is significant evidence that testosterone, play an important role in gender - associated differences in BP regulation [1,5]. Previous studies comparing direct vs indirect of diastolic BP measurement have shown that in men at peak treadmill exercise and bicycle, the indirect method tends to bias low compared with direct one. Therefore, the indirect method is not valid for the assessment of diastolic pressure [6,7]. Unfortunately, some of the least accurate measurements (auscultatory) take place in the clinical environment where accuracy is most important [8]. Instead, invasive measurement is the only measurement of BP, which in theory could be highly accurate. Thus, the purpose of the present study was to investigate the gender effect on the intra - arterial and auscultator conventional sphygmomanometer methods at rest and during different aerobic workloads on a bicycle in normal young males and females.

METHODS

Subjects

36 well - trained subjects were recruited to participate in this study. They were divided into two evenly groups: 18 young adult males (23.4 ± 2.0 years) and 18 young adult females (24.1 ± 2.0 years). Males recorded maximal oxygen uptake of 50.4 ± 2.7, while females achieved 44.3 ± 1.9 mL·kg^{-1}·min^{-1}. All subjects were judged free from coronary artery disease by the clinical history, absence of major risk factors and by a normal exercise stress test up to maximal oxygen uptake. A written informed consent was obtained from each subject. The research was accomplished in accordance with the Helsinki declaration, approved by the Clinical Science Center Committee on Human Subjects. All subjects were in good health, physically active for at least 12 months with work capacity of 14.4 ± 1.2 for males and 12.7 ± 1.1 METs for females. None were members of competitive team. Findings from standard physical examination were normal in all subjects. Resting 12 - lead electrocardiogram revealed normal sinus rhythm in all.

Procedures and measurements

Subjects reported to the lab two times. During the first session, subjects were given a brief explanation on the experimental procedures and potential risks. Following that, subjects underwent a maximal oxygen uptake test performed on an electrical cycle ergometer. The initial load on the electrical cycle ergometer was 100 watts, which thereafter the load was increased by 25 watts each minute. Maximal tests were terminated according to the guidelines of the American College of Sports Medicine [9]. Subjects were given a verbal reminder not to drink coffee, smoke, or perform intensive physical activity 24 hours prior to testing.

During the second session, following warmup subjects were asked to perform two different workloads on an electrical break bicycle at their target heart rate training zone defined by the Karvonen equation [10]: 10 minutes at 60% and 10 minutes at 70% of their maximal work capacity. Following these submaximal loads, subjects were asked to paddle up to their peak heart rate. Heart rate and electrocardiogram were monitored continuously, using a Burdick Eclipse 400 3 - channel, 12 - lead ECG recorder system, and oscilloscope. Five-second recordings were obtained at rest and at peak exercises.

Measurements of direct and indirect blood pressures were taken simultaneously at rest (one measurement), each 5 minutes of each workload (two measurements) and at peak exercise (one measurement). The auscultatory BP was monitored using a standard sphygmomanometer cuff and mercury manometer mounted at eye level [11].

Auscultation was determined using a modified stethoscope with

60cm conduction tube connected to anesthesia diaphragm secure over the brachial artery of right arm with Velcro strap [7]. Systolic BP was defined as the first audible Korotkoff sound while diastolic BP was accepted either as 5th (disappearance) or phase 4th (muffling) if 5th phase was indeterminate [6]. The direct BP was taken from the brachial artery of the left arm. The anticubital surface was prepared with Betadine and alcohol and 1% Lindocaine. Local anesthetic was infiltrated over the brachial artery. A physician then inserted a 20 - gauge, $1^1/_4$” Jelco cathelon catheter percutaneously into the brachial artery two to three centimeters distal to the antecubital fossa. The indwelling 20 gauge brachial artery catheter was coupled with 20cm polyethylene that was maintained at right artery level. The transducer system showed a linear static calibration response that was flat to 25 Hz with a damping coefficient of 0.25. Arterial blood pressure was continuously recorded on the Gould recorder at a paper speed of $10mm·sec^{-1}$. The exact time of the indirect pressure was recorded and marked on the Gould recorder, taken at the same time using an electrical event marker. In addition, the intra-arterial system was calibrated prior to each modality of exercise performed by each patient. Systolic and diastolic pressures were calculated from the numerical average of consecutive arterial pulse pressure within a 5 second interval at the marked points described above [6,12].

Adipose fat assessment included measurement of total body weight (± 0.05 kg), skin fold thicknesses at eight sites (± 1 mm) using the Lange Caliper (chest, axilla, triceps, subscapular, abdomen, supra - ilium, front thigh, and circumferences at the shoulder). Anthropometric procedures followed the recommendations of Behnke and Wilmore [13].

Statistical methods

Data are reported as mean ± SD values. Two way ANOVA was performed for multiple comparisons, post-hoc analysis was performed by using the Tukey 2 multiple comparison. The bivariate correlation coefficient was utilized to evaluate the validity of the indirect measurement of BP as predictor of direct intra-arterial BP.

RESULTS

All subjects completed the efforts without difficulty or abnormal symptoms, dysrhythmias or electrocardiographic abnormalities. Mean descriptive data are presented in table 1. Females, weight, height, fat, heart rate and work capacity were significantly ($p < 0.05$) lower than that of men. Table 2 reveals that across all conditions heart rate was significantly higher in the females compared to males. Table 3 reveals that at rest, correlations coefficients between direct and indirect BP measurements were high in both groups for systolic BP. Correlations coefficients for diastolic BP variable were reasonable. Table 3 (at rest), also presents the mean ± SD of systolic and diastolic pressures measured simultaneously by auscultation and intra-arterial methods. It discloses that no significant differences were noted between the direct and the indirect methods for systolic and diastolic BP. However, males compared to females, had significant ($p < 0.05$) higher values for systolic and diastolic BP during both methods. In addition, auscultatory values were significantly ($p < 0.05$) higher than the values measured for the direct method. Table 4 expresses values for 60% and 70% of their work capacity. Correlations coefficients between direct and indirect BP measurements were sensible in both groups for systolic and diastolic BPs. In addition, table 4 demonstrate that males compared to females, had significant ($p < 0.05$) higher values for systolic and diastolic BP of both methods. Furthermore, auscultatory values were significantly ($p < 0.05$) higher than the values measured for the direct method. Means of systolic and diastolic pressures measured simultaneously by auscultation and intra - arterial methods at peak exercise are presented in table 5. It reveals no differences between males and females with regard to differences in means achieved for systolic BP and diastolic BP. However, significant ($p < 0.05$) higher values were seen for the auscultatory method compared to the intra-arterial for diastolic BP measurements in both groups.Discussion

The present study demonstrated that in males and females, at rest and during dynamic exercises, systolic BP values reached by the intra - arterial method correlated highly with the auscultatory recordings. Yet, at peak exercise, low correlations between the indirect method and the direct method were observed for males in diastolic BP, with lower correlations in the females. Throughout the study, mean values of systolic and diastolic were always higher in the auscultatory method compared to the intra - arterial one, and in the males compared to the females.

The reported data may be useful in interpreting more accurately the significance of abnormal systolic BP responses to exercise in statistical terms stratified by gender [14]. BP is determined by a complex interplay between cardiac output, which is related to left

Table 1: Descriptive data of the females and males (values are mean ± SD).

Variable	Females	Males
N	18	18
Age (years)	23.4 ± 2.0	24.1 ± 2.0
Weight (kg)	71.3 ± 1.7	58.4 ± 1.3[a]
Height (cm)	180.2 ± 2.0	171.4 ± 2.1[a]
Fat (%)	9.9 ± 1.6	12.6 ± 2.7[a]
Heart rate ($beats·min^{-1}$)	67.7 ± 6.3	72.4 ± 6.7[a]
Work capacity (METs)	14.4 ± 1.2	12.7 ± 1.1[a]

[a] = significant differences ($p < 0.05$) between females and males; N = sample size.

Table 2: Heart rate responses across conditions (means ± SD).

Condition	Males	Females
Rest	64 ± 5	72 ± 6[a]
68% OF MAX	120 ± 4	126 ± 5[a]
70% OF MAX	134 ± 7	142 ± 8[a]
MAXIMAL WORK	190 ± 5	197 ± 6[a]

[a] = significant differences ($p < 0.05$) between females and males.

Table 3: Descriptive statistics and correlations of systolic and diastolic pressures measured simultaneously by auscultation and intra - arterial methods at rest.

Sex	Effort	Variable	Method	Mean ± SD	Sig.
F	Rest	Systolic	Direct	103 ± 7	r = 0.91[a]
			Indirect	110 ± 8	
		Diastolic	Direct	70 ± 3	r = 0.84[a]
			Indirect	76 ± 3	
M	Rest	Systolic	Direct	116 ± 7	r = 0.92
			Indirect	122 ± 8	
		Diastolic	Direct	78 ± 4	r = 0.83
			Indirect	82 ± 3	

[a] = significant differences ($p < 0.05$) between females and males; r = correlation coefficient.

Table 4: Descriptive statistics (mean ± SD) of systolic and diastolic pressures measured simultaneously by auscultation and intra-arterial methods during exercise.

Sex	Effort	Variable	Method	Mean ± SD	Sig.
F	Bicycle 60%	Systolic	Direct	151.2 ± 6.3	r = 0.92[a,b]
			Indirect	159.9 ± 7.7	[a]
		Diastolic	Direct	71.5 ± 3.7	r = 0.71[a,b]
			Indirect	76.8 ± 3.0	[a]
M	Bicycle 60%	Systolic	Direct	161.8 ± 4.2	r = 0.90[b]
			Indirect	166.4 ± 4.1	
		Diastolic	Direct	76.9 ± 2.6	r = 0.68[b]
			Indirect	80.6 ± 3.1	
FEMALES	Bicycle 70%	Systolic	Direct	160.2 ± 6.2	r = 0.92[a,b]
			Indirect	167.7 ± 6.9	[a]
		Diastolic	Direct	75.8 ± 2.7	r = 0.66[b]
			Indirect	81.1 ± 3.1	
MALES	Bicycle 70%	Systolic	Direct	172.0 ± 6.9	r = 0.93[b]
			Indirect	180.4 ± 7.1	
		Diastolic	Direct	74 ± 3.1	r = 0.71[b]
			Indirect	80 ± 3.5	

[a] = significant differences ($p < 0.05$) between females and males; [b] = significant differences between direct and indirect BP measurements; r = correlation coefficient; F = female; M = male.

Table 5: Descriptive statistics (mean ± SD) of systolic and diastolic pressures measured simultaneously by auscultation and intra - arterial methods at peak exercise.

Gender	Effort	Variable	Method	Mean ± Sd	*P* - Value
Females	Maximal	Systolic	Direct	184.7 ± 7.4	r = 0.90
			Indirect	189.4 ± 8.9	
		Diastolic	Direct	75.7 ± 2.7	b, r = 0.49
			Indirect	82.3 ± 3.5	
Males	Maximal	Systolic	Direct	189.4 ± 9.1	r = 0.92
			Indirect	196.9 ± 8.8	
		Diastolic	Direct	77.7 ± 3.4	b, r = 0.57
			Indirect	85.3 ± 4.1	

b = significant differences between direct and indirect BP measurements.
r = correlation coefficient.

ventricular systolic function, and peripheral vascular resistance. During exercise in the present study, although heart rates were significantly lower in the male group, results indicate a significantly higher rise in systolic BP in males than females. Studies [15] have shown that a rise in systolic BP during exercise is mainly due to increase in cardiac output and reflects the level of sympathetic and parasympathetic drive. Increase in cardiac output is a function of increase in heart rate via the baroreflex, which is the most prominent short - term compensator during arterial pressure challenges and stroke volume due to increased venous return. This compensatory mechanism results in an alteration of cardiac output and peripheral resistance through the cardiac and peripheral limb of the baroreflex, respectively. This baroreflex - mediated response of heart rate to changes in arterial blood pressure indicates the capacity of reflex cardiac autonomic modulation [16,17], due to increase in sympathetic activity and a decrease in parasympathetic activity [18]. Other studies have observed that men show greater sympathetic activity, and higher baroreflex responsiveness than females [17].

The average adult male heart rate is lower from that of adult women differences largely accounted for by the smaller heart in females than males. Thus, female pumps less blood with each beat, and therefore has to beat at a faster rate to match the larger male heart's output. Exercise is associated with an increase in sympathetic tone and skeletal blood flow but a decrease in total peripheral resistance [19]. With exercise, a rise in systolic blood pressure is expected, whereas the change in diastolic blood pressure can vary 10-mmHg increase or decrease [19].

The method of obtaining the most accurate reading at rest and during aerobic exercise BP is invasively through an arterial line [6]. Measurement of arterial pressure by conventional Sphygmomanometer is subject to error, including faults in the instrumentation and the use of an occluding cuff of incorrect size. Perhaps the five most common errors with the measurement of BP by means of auscultation are:

- Using the wrong size cuff;
- Applying the cuff incorrectly;
- Not positioning the stethoscope directly above the artery incorrect placement will result in too low of a systolic and too high of a diastolic pressure measurement;
- Uncertainty in interpreting the Korotkoff sounds during systole and diastole, may be due to intensity and distinction [7,20];
- Variations in blood pressure during the respiratory cycle, which has an inherent difference between auscultation BP, which is determined at one distinct point in the respiratory cycle and direct BP over several respiratory cycles [21].

Thus, the reliability of the sphygmomanometer method in recording arterial pressure during exercise is frequently questioned, although some investigators [22] have found that systolic BP in the brachial artery correlates highly with left ventricular pressure. These BP measurements may be used as an indicator of the force opposing the left ventricle ejection [23].

In the present study, mean systolic BP measured by means of auscultation in both groups, were higher across all conditions measured compared to those readings of the intra-arterial. The high correlations for systolic BP between the direct and indirect methods in the present study, during the aerobic tests is due to the effect of exercise in rendering Korotkoff sounds louder and more distinctly, thus, enabling the reading of systolic BP by auscultation close to the point at which sounds begin, and blood starts to flow through the obstructed artery. This finding may suggest that when measuring left ventricular contractility during aerobic exercise by the end systolic volume-pressure ratio, the validity of the systolic BP defined by the auscultatory method will correctly represent the intra - arterial systolic BP value. In the present study, at rest it was found in males and females that the intra-arterial diastolic pressure was lower than that measured by the indirect method with acceptable correlation. This result is in agreement with the reported values previously [24] in which auscultatory diastolic BP was 4 mmHg higher than that measured by the intra - arterial method.

Submaximal (60 and 70% work capacity) aerobic exercise dilates muscular arteries and reduces arterial pressure augmentation [25], an effect that will ultimately enhance ventricular - vascular coupling and reduce the pressure load on the left ventricle. The sympathoadrenal and renin - angiotensin systems play an important role in BP control and regulation of cardiovascular function during exercise [26]. In the present study, diastolic BP correlations between the two methods during the submaximal aerobic exercises were acceptable in females and males. The discrepancies in the correlations between the intra - arterial and auscultation during the submaximal aerobic exercises and the results at peak exercise is due to the lower artifact motion during the submaximal exercises thus, do not diminishes and mask the auscultatory Korotkoff-sounds, making detection of the proper Korotkoff-sounds during exercise easier. Furthermore, at peak exercise, in both groups, the presence of inaudible Korotkoff-sounds may further explain the published discrepancies between auscultatory and intra-arterial BP measurements during exercise [27]. These problems (particularly the latter) may be further aggravated during exercise because of the problems of ambient noise and motion artifact. Problems with motion and noise artifact have prevented reliable quantification of arterial pressure during exercise. These results are in agreement with previous studies during dynamic and isometric exercises demonstrating low diastolic correlation between the two methods [6,13].

CONCLUSIONS

The validity of an auscultation method in females and males at rest, submaximal aerobic exercise and peak aerobic exercises, are reliable for systolic BP, while auscultatory diastolic BP readings at rest and submaximal are acceptable, at peak dynamic exercises it is not trustworthy for the definition of diastolic BP. The significant higher rise in BP in males compared to females is mainly due to increase in a higher cardiac output in males and reflects gender differences in levels of sympathetic and parasympathetic drive.

NOVELTY AND SIGNIFICANCE

This study includes updates on gender differences in measuring blood pressure, during aerobic exercise. This study is justified by several new scientific contributions to the problem of gender effects. Specifically, we extended the understanding on the gender differences in the indirect measurement interpretation. In recent years, there has been increasing interest in methods for blood pressure monitoring. However, guidance in this area has been largely based on research among males. The significant higher rise in systolic blood pressure in males compared to females is mainly due to a higher cardiac output in males reflecting gender differences in levels of sympathetic and parasympathetic drive.

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