



# Journal of Exercise Physiology **online** (JEP **online**)

Volume 8 Number 4 August 2005

## Systems Physiology: Cardiopulmonary

### Managing Editor

Tommy Boone, Ph.D.

### Editor-in-Chief

Robert Robergs, Ph.D.

### Review Board

Todd Astorino, Ph.D.

Julien Baker, Ph.D.

Tommy Boone, Ph.D.

Lance Dalleck, Ph.D.

Dan Drury, DPE.

Hermann Engels, Ph.D.

Eric Goulet, M.Sc.

Robert Gotshall, Ph.D.

Len Kravitz, Ph.D.

James Laskin, Ph.D.

Jon Linderman, Ph.D.

Derek Marks, Ph.D.

Cristine Mermier, Ph.D.

Daryl Parker, Ph.D.

Robert Robergs, Ph.D.

Brent Ruby, Ph.D.

Jason Siegler, Ph.D.

Greg Tardie, Ph.D.

Ben Zhou, Ph.D.

Official Research Journal  
of The American Society of  
Exercise Physiologists  
(ASEP)

ISSN 1097-9751

## GENDER DIFFERENCES IN CARDIOVASCULAR RESPONSE TO ISOMETRIC EXERCISE IN THE SEATED AND SUPINE POSITIONS

DON MELROSE

Human Performance Lab, Department of Kinesiology, Texas A&M  
University—Corpus Christi, Corpus Christi, TX 78412, USA

### ABSTRACT

**Donald R Melrose.** Gender Differences In Cardiovascular Response To Isometric Exercise In The Seated And Supine Positions. *JEPonline*. 2005;8(4):29-35. The purpose of this study was to 1) determine if the cardiovascular responses to isometric exercise differ between genders, and 2) determine if posture affects cardiovascular responses to isometric handgrip (IHG) exercise. Sixteen women and 15 men (age 22.6±4.2 yrs) performed two randomized (seated or supine) maximal IHG trials at 40 %MVC one week apart. Blood pressure (BP) and heart rate (HR) measurements were collected at rest (RT), the first minute of exercise (M1), prior to failure (PF), and at 30 s of recovery following failure (RC). Mean arterial pressure (MAP), pulse pressure (PP), and rate pressure product (RPP) were calculated from BP and HR data. Analyses showed significant time by gender interactions for diastolic blood pressure (DBP) and MAP. Males had significantly higher DBP than females at M1 (105.46±14.97 vs. 92.59±13.14 mmHg), PF (122.46±11.23 vs. 109.50±13.72 mmHg) and RC (85.83±4.11 vs. 73.46 ± 8.35 mmHg) and higher MAP measurements than females at M1 (120.32 ± 13.76 vs. 105.43 ± 13.76 mmHg), PF (136.44 ± 8.65 vs. 124.31 ± 13.34 mmHg), and RC (100.44 ± 8.21 vs. 87.67 ± 8.26 mmHg). DBP, MAP, and HR were significantly higher in the seated position than in the supine position for both genders. It was concluded that 1) men significantly increase MAP and DBP upon initiation of submaximal IHG exercise through recovery regardless of posture, 2) women have significantly lower blood pressure measurements than men during submaximal IHG exercise regardless of posture, and 3) posture has a significant affect on cardiovascular response during submaximal IHG exercise.

**Key Words:** Static Exercise, Blood Pressure, Pressor Response, Gender, Posture

## INTRODUCTION

The average isometric strength estimate is generally about thirty percent greater in men than in women in different muscle groups (1). Upon initiating isometric tension, increases in heart rate, systolic blood pressure, and diastolic blood pressure occur (2,3). Mitchell and associates (4) and Seals et al. (5) suggested that cardiovascular responses to isometric exercise are greater when larger muscle groups are involved. While heart rate responses to sustained submaximal static contractions tend not to be significantly different before, during, or after exercise, blood pressure responses to this exercise are significantly elevated before, during, and after exercise (6). Gender differences in cardiovascular responses to static exercise are believed to be due to differences in sympathetic-parasympathetic or adrenal interactions at the cardiac level (7,8).

The proposed mechanisms attempting to explain gender differences in cardiovascular responses to isometric exercise have been numerous and conflicting. Sanchez et al. (8) found differences in adrenergic patterns between genders in response to isometric exercise. Ettinger and associates (7) demonstrated attenuated increases in blood pressure and muscle sympathetic nerve activity compared with men. In data also derived from static exercise as well as temperature and psychological stressors, Jones et al. (9) found that gender did not influence sympathetic neural reactivity to stressors such as isometric handgrip exercise

Changes in posture often experienced during exercise or sporting activities have also been shown to elicit various circulatory adaptations (10). Sagiv et al. (11) and Borst et al. (12) both noted changes in cardiovascular regulation as a result of postural changes. Relatively fewer studies have investigated the cardiovascular adaptations to exercise performed when posture does not change during the time course of the exercise.

Given the contradictory findings from previous research, the purpose of this study was to 1) determine if the cardiovascular responses to isometric exercise differ between genders, and 2) to determine if posture affects cardiovascular responses to isometric exercise. It was hypothesized that cardiovascular responses to isometric exercise would differ between genders and that posture would affect cardiovascular responses similarly across genders.

## METHODS

### Subjects

Sixteen female and fifteen male volunteers participated as subjects. Before participating in the study, subjects were required to sign an institutional statement of informed consent that had been approved by the local institutional Committee for Research Involving Human Subjects.

### Procedures

Prior to the experimental trials each subject was screened to ensure normotensive blood pressure measurements (< 140/90 mmHg). Maximal isometric voluntary contractions (MVC's) for the handgrip were obtained using the participant's dominant hand in both the seated and supine positions. Maximal voluntary contractions (MVC) were determined from the subject's single best voluntary contraction of three trials. Within three days, subjects returned for testing. Subjects were tested in both the seated and supine positions. Seated and supine trials were alternated on subsequent visits approximately one week apart to prevent possible order effects. Subjects initially sat upright or lay quietly in the supine position for 15 min prior to the experimental trial to stabilize heart rate and blood pressure. Supine measurements were obtained with the subject laying on a horizontal surface with the arms extended parallel to the mid-line of the body. Seated measurements were obtained utilizing an erect posture. The arms were extended perpendicular to the floor with the hand positioned below

the surface in which the subject was seated. In both the seated and supine trials the subject's hand was pronated 90° toward the midline of the body. Subjects were instructed to maintain normal breathing patterns during all trials to avoid any influence from the Valsalva maneuver.

Isometric handgrip contractions were performed using an isometric handgrip apparatus interfaced with a load cell and force monitor (Prototype Design and Fabrication Company). The force monitor was coupled to a linear chart recorder. Initial MVC measurements were obtained with the chart recorder out of the subject's field of vision to aid the subject in focusing attention on the handgrip. Heart rate measurements were obtained throughout the test sessions using a Lifepak heart rate monitor (Physio-Control Lifepak 7). Blood pressure measurements were obtained at the brachial artery from the arm not being used for contraction (non-dominant arm). Systolic blood pressure was determined upon hearing the first of two or more Korotkoff sounds. Diastolic blood pressure was determined before the disappearance of Korotkoff sounds. Blood pressure and heart rate measurements were obtained following stabilization, at each minute of exercise, and 30 s following exercise termination. These values were used to calculate pulse pressure, mean arterial blood pressure, and rate pressure product.

Throughout all trials, subjects were instructed to refrain from muscular contractions other than those involved in the handgrip contraction. During trials, subjects maintained the 40 %MVC isometric handgrip contraction by observing their individual 40 %MVC on the chart recorder. Subjects maintained this intensity until failure. All subjects were able to complete two min of exercise, but none exceeded four min. During this period, blood pressure and heart rate measurements were obtained at each minute of exercise. When 40 % MVC could no longer be maintained within 10% of the subject's predetermined value, the test was terminated. Subjects were asked to remain in the designated position following test termination to permit recovery blood pressure and heart rate measurements to be obtained 30 s post-exercise. All blood pressure measurements were performed by an experienced lab technician.

### Statistical Analyses

A repeated measures ANOVA was used to analyze data by time, gender, and position to determine if significant changes in variables occurred due to the experimental treatment. Statistical significance was accepted at  $p \leq 0.05$ . Post Hoc analyses of mean differences were performed using the Scheffe' test. Due to the varying duration of trial lengths among subjects, cardiovascular measurements were obtained at the following time increments: following the rest period prior to exercise, at the first minute of exercise, at failure, and following 30 s of recovery.

## RESULTS

Table 1 presents subject descriptive characteristics by gender.

**Table 1. Descriptive Statistics**

Variables	Females (n = 16)	Males (n = 15)
Age (yr)	23.4±5.2	21.8±2.9
Height (cm)	162.9±5.7	172.1±27.9
Weight (kg)	59.6±7.2	79.2±12.1
Body Fat (%)	18.7±3.6	9.5±3.4

\* Values are means±D.

Mean arterial pressure (MAP), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and rate pressure product (RPP) increased in parallel for both genders throughout all trials. Analysis showed no gender by position interactions.

Men had significantly greater values than women across experimental conditions for several cardiovascular measurements: MAP (112.25±19.27 vs. 101.17±19.07 mmHg), SBP (143.58±20.38 vs. 128.45±22.08 mmHg), and DBP (97.50±21.36 vs. 87.25±18.82 mmHg). When data for genders was combined, cardiovascular variables were significantly greater in the seated compared to supine

position: MAP ( $108.40 \pm 19.55$  vs.  $104.66 \pm 20.18$  mmHg), DBP ( $95.05 \pm 20.86$  vs.  $89.37 \pm 20.21$  mmHg), HR ( $82.82 \pm 19.01$  vs.  $78.75 \pm 19.54$  mmHg).

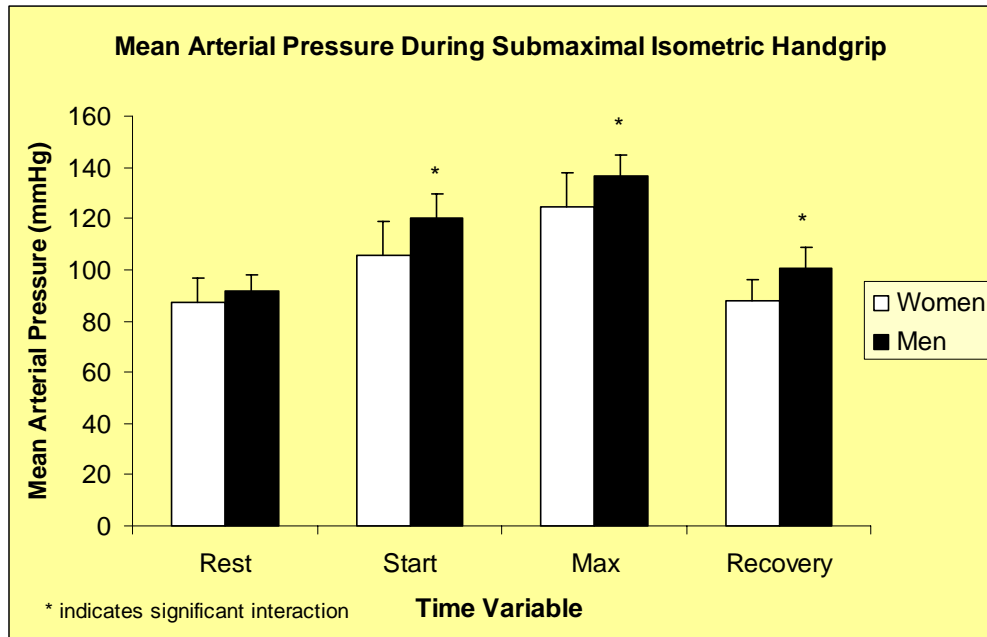


Figure 1. Mean changes in mean arterial blood pressure during IHG by gender.

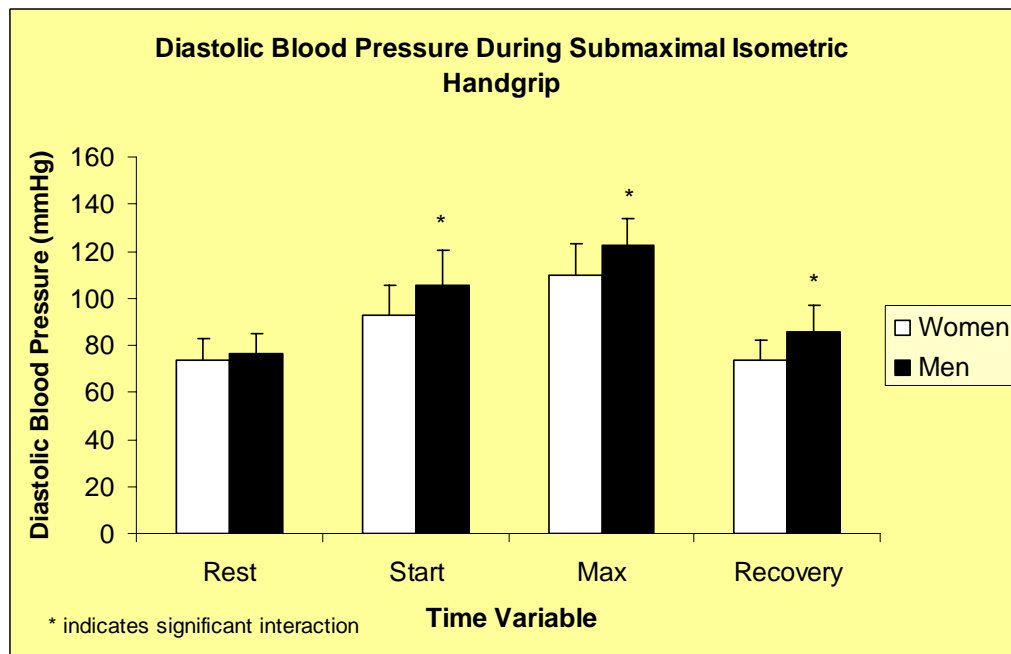


Figure 2. Mean changes in diastolic blood pressure during IHG by gender.

Significant time-by-gender interactions were found for the DBP and MAP variables. Men were found to have significantly greater MAP values than women (Figure 1) respectively across positions at the first min of exercise, prior to failure, and following 30 s of recovery. Men also had significantly greater DBP than women (Figure 2) across positions at the first minute of exercise, prior to failure, and following 30 seconds of recovery. There were no significant differences in DBP between men and women following the rest period prior to exercise. Mean arterial pressure, SBP, SBP, HR, and RPP

values increased significantly across time for women and men throughout the experimental treatment. Recovery values were significantly greater than resting values for each of these variables except rate pressure product and heart rate.

## DISCUSSION

While average blood pressure was greater for men across postural positions and throughout the isometric handgrip (IHG) trials, there were no significant differences in DBP and MAP between genders at rest in either position. Significant changes in the cardiovascular system began upon initiating the IHG trials. Previously, significant time by gender interactions in MAP and DBP response to isometric handgrip exercise has not been shown. Systolic blood pressure and HR were not found to be significantly greater in males during the first minute of exercise through recovery. These findings illustrate that there are gender differences in cardiovascular responses to isometric handgrip exercise.

Several investigations have measured cardiovascular response to isometric exercise between genders (7,8,9). Results in these investigations are inconsistent at best. Jones et al. (9) found that blood pressure responses to various forms of laboratory stressors, to include IHG, are not consistently influenced by gender. Sanchez, et al. (8) found that sustained isometric contractions showed similar blood pressure responses between genders. It was noted that the average systolic blood pressures were lower in women at rest and during sustained isometric contraction, but these differences were not significant. Ettinger et al. (7) did show attenuated increases in blood pressure in females. In each of these investigations subjects performed IHG's at 30% MVC whereas the present study utilized 40% MVC. Isometric exercise performed below 40 % MVC may not have been sufficient to evoke diastolic and mean arterial responses shown in males in the present study.

The possible explanation as to why men experienced greater DBP and MAP at the onset of exercise is difficult to clarify because of the many possible mechanisms. Such changes would indicate an increase in sympathetic flow. Mean arterial pressure increases suggest men undergo significant changes in either cardiac output or total peripheral resistance at the onset of isometric exercise whereas women do not. Increases in diastolic pressure suggest a lesser decrease in arterial pressure during diastole as the aorta supplies blood to the systemic vascular beds. There are many possible explanations for such responses. According to Sanchez et al. (8) increases in sympathetic flow increase the levels of circulating catecholamines. This study investigated changes in blood pressure and catecholamine response to isometric handgrip exercise at 30% MVC. No differences in catecholamine concentrations were found between genders at rest, but concentrations of norepinephrine, epinephrine, and dopamine were greater in men at the first minute of exercise. Of these three catecholamines, epinephrine concentration specifically was significantly greater in men at the first minute of exercise. If the concentration were high enough this could account for the significant increase in MAP and DBP in men in the current study.

In women, norepinephrine and epinephrine concentrations were unaffected throughout IHG trials. The cardiovascular effects of high levels of circulating catecholamines parallel the direct effects of sympathetic activation (13). Epinephrine and norepinephrine can activate the cardiac  $\beta$ -adrenergic receptors to increase heart rate and myocardial contractility and can activate vascular alpha-receptors to cause vasoconstriction. Vascular  $\beta$ -receptors are more sensitive to epinephrine than are vascular alpha-receptors. Low levels of circulating epinephrine can cause vasodilatation whereas higher levels cause alpha-receptor mediated vasoconstriction. Ettinger and associates (7) measured gender differences in blood pressure and muscle sympathetic neural activity (MSNA) in response to very low intensity (non-ischemic) static exercise. They concluded that this type of static exercise

produced less sympathetic neural outflow in women due to an attenuated metaboreflex in women. Claustre et al. (14) suggested adrenergic gender differences may originate from differences in the central mechanisms eliciting sympathetic activation.

On the other hand, gender differences in adrenergic response may be due to gender specific hormones (15). An analysis of twelve gender comparison investigations, revealed two consistencies: men have greater SBP and catecholamine response to acute stress (16). This analysis didn't focus on responses to IHG exercise; however it does show a precedence of greater cardiovascular reactivity to stressors in men. The study of gender differences during isometric exercise has few definitive conclusions, which make it difficult to identify a precise mechanism(s) to explain gender differences in cardiovascular response to isometric exercise. Jones et al. (9) believes this due to several factors; 1) there are data indicating men are not more reactive to stress than women, 2) investigators have not always properly documented that the level of stress used was equivalent in the men and women, and 3) sympathetic neural adjustments to stress may not be accurately reflected by cardiovascular and humoral responses.

The present data show a significant increase in HR, MAP, DBP, and rate pressure product (RPP) across genders in response to isometric work performed in the seated position as compared to the supine position. Body position may be responsible for differences in blood pressure during isometric exercise (11). In the upright position postural muscle tension may increase intra-thoracic and intra-abdominal pressures thereby contributing to increases in blood pressure. Disturbances in the pressure-flow relationship of the venous system as well as increases in systemic venous resistance are typically attributed to the effect of gravity. As a result of isometric exercise in an upright position, increased blood pooling occurs in the lower extremities thereby reducing the preload to the left ventricle. In the upright position gravity decreases the body's central blood volume and cardiac output. This occurrence causes difficulties in increasing or maintaining an adequate stroke volume (17,18). To maintain adequate cardiac output in an upright position, heart rate must increase (11). The increase in RPP reflects increased myocardial oxygen uptake and coronary blood flow (19).

## CONCLUSIONS

In conclusion, the current investigation shows that; 1) cardiovascular and hemodynamic responses to submaximal levels of isometric handgrip exercise do differ by gender specifically at the onset of exercise and 2) posture does affect cardiovascular responses to isometric exercise. Factors responsible for differences in cardiovascular response due to gender appear to be numerous and in need of further study to definitively elucidate specific mechanisms.

---

**Address for Correspondence:** Don Melrose Ph.D. CSCS. Texas A&M University-Corpus Christi, Department of Kinesiology, 6300 Ocean Drive, Corpus Christi, TX 78412. Phone: 361-825-2811; FAX: 361361-825-6076; Email: [dmelrose@falcon.tamucc.edu](mailto:dmelrose@falcon.tamucc.edu)

---

## REFERENCES

1. Petrofsky J, Phillips C. The physiology of static exercise. **Med Sci Sports Exerc** 1986;14:1-44.
2. Lind A, Taylor S, Humphreys P, Kenelly B, Donald K. The circulatory effects of sustained voluntary muscle contraction. **Clin Sci** 1964;27:229-244.
3. Humphreys P, Lind A. The blood flow through active and inactive muscles of the forearm during sustained handgrip contractions. **J Physiol London** 1963;166:120-135.

4. Mitchell J, Payne F, Saltin B, Schibye B. The role of muscle mass in the cardiovascular response to static contractions. *J Physiol London* 1980;309:45-54.
5. Seals D, Washburn R, Hanson P, Painter P, Nagle F. Increased cardiovascular response to static contraction of larger muscle groups. *J Appl Physiol* 1983;54(2):434-437.
6. Petrofsky J, Burse R, Lind A. Comparison of physiological responses of women and men to isometric exercise. *J Appl Physiol* 1975;38(5):863-868.
7. Ettinger S, Silber D, Collins B, Gray K, Sutliff G, Whisler S, McClain J, Smith M, Yang Q, Sinoway L. Influences of gender on sympathetic nerve responses to static exercise. *J Appl Physiol* 1996;80:245-251.
8. Sanchez J, Pequignot J, Peyrin L, Monod H. Sex differences in the sympatho-adrenal response to isometric exercise. *Eur J Appl Physiol* 1980;45:147-154.
9. Jones P, Spraul M, Matt K, Seals D, Skinner J, Ravussin E. Gender does not influence sympathetic neural reactivity to stress in healthy humans. *Am J Physiol* 1996;270:H350-H357.
10. Sprangers R, Wesseling K, Imholz A, Wieling W. Initial blood pressure fall on stand up and exercise explained by changes in total peripheral resistance. *J Appl Physiol* 1991;70(2):523-530.
11. Sagiv M, Rotstein A, Watkins J, Climor L, Ben-Sira D. Effect of body position on the afterload response during sustained exercise. *J Sports Med Phys Fitness* 1992;32:170-174.
12. Borst C, Wieling W, Van Brederode J, Hond A, De Rijk L, Dunning A. Mechanisms of initial heart rate response to postural change. *Am J Physiol* 1982;243:H676-H681.
13. Mohrman D, Heller L. *Cardiovascular Physiology 4th edition*. New York: McGraw-Hill, 1997.
14. Claustre J, Peyrin L, Fitoussi R, Mornex R. Sex differences in the adrenergic responses to hypoglycemic stress in humans. *Psychopharmacology* 1980;67:147-153.
15. Wiechman B, Borowitz J. Effects of steroid hormones and diethylstilbestrol on adrenomedullary catecholamine secretion. *Pharmacology* 1979;18:195-210.
16. Stoney C, Davis M, Matthews K. Sex differences in physiological responses to stress and in coronary heart disease: a causal link? *Psychophysiology* 1987;24:127-131.
17. Ehsani A, Heath G, Hagberg J, Schechtman K. Noninvasive assessment of change in left ventricular function induced by graded isometric exercise in healthy subjects. *Chest* 1981;80:51-55.
18. Ganong W. *Review of Medical Physiology* Los Altos: Lange Medical Publications. 1979.
19. McArdle W, Katch F, Katch V. *Exercise Physiology: Energy, Nutrition, and Human Performance*. Baltimore: Lippincott Williams and Wilkins, 2000.