Original Research Article:

Gender differences in cardiac work of static exercise among healthy young population

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Abstract

Introduction: Sustained hand grip test is widely used to assess the cardiovascular functions. Cardiovascular responses to static exercise is found to increase as the intensity and duration of exercise increases. Several studies have assessed the heart rate and blood pressure response to exercise, however studies assessing the cardiac work in response to isometric exercise is scarce. Our objective in this study is to determine the cardiac work response to sustained isometric contraction and to find the gender difference in cardiac work and cardiovascular response to sustained isometric contraction.

Method: 42 healthy young participants between 18 and 30 years were recruited. Heart rate (HR), Cardiac output (CO) and left ventricular ejection time (LVET) was measured using impedance cardiography. Blood pressure was measured using an automated blood pressure device. Cardiovascular response to 40 % of maximal voluntary contraction for 90 seconds was assessed. Rate pressure product and triple product was derived from the parameters assessed.

Results: There was significant increase in cardiac work during isometric exercise. There was increase in HR, SBP and DBP during isometric exercise. There was no gender differences in cardiac work and cardiovascular responses to isometric exercise.

Conclusion: This study concludes that there is significant increase in cardiac work while performing isometric exercise. There is no gender differences in cardiovascular responses to isometric exercise.

Keywords: Isometric exercise; cardiac work; Sustained hand grip

Introduction

Cardiovascular responses to isometric or static exercise differ significantly from that of dynamic exercises (1). Isometric exercises (IE) involve an increase in tension of the muscle without a change in its length, for instance, activities such as grasping, holding, bracing or pushing involves isometric contraction of the flexor muscles of the hand (2). The cardiovascular responses to IE are higher when larger muscle groups are involved. Sustained handgrip test (SHG) is a form of IE which is widely used to assess the cardiovascular functions. Donald et al in the year 1967, demonstrated the heart rate (HR) and blood pressure (BP) response to SHG (3). Several studies have assessed the cardiovascular response to IE, there is an increase in cardiac output (CO) with the sole contribution of HR and not stroke volume. Increase in CO leads to the increase in BP (2,4,5). Cardiovascular responses to static exercises are largely proportionate to tension exerted relative to greatest possible tension in muscle group (%MVC) rather than absolute tension developed. The existence of anatomical, physiological and morphological difference between men and women affects the exercise performance and circulatory responses among them. Several studies have assessed the HR and BP response to IE in healthy individuals (5) and also in patients with heart failure (6), type 2 diabetes mellitus (7) and hypertension (8,9). Increase in CO in response to IE is found to be compromised in heart failure patients, hence SHG test is used as cardiac stress test in several studies. Even though HR and BP responses to IE were assessed by many researchers, studies assessing the cardiac work in response to IE is scarce in the literature. In this study, our primary objective was to determine the cardiac work in response to IE. Our secondary objective was to find the gender difference in cardiac work and cardiovascular response to IE.

Method:

2.1. Participants

The study complied with the ethical standards of the declaration of Helsinki. The institutional ethical committee approval was obtained before the commencement of the study. Written informed consent was obtained from participants after explaining the study procedure. 42 healthy young participants between 18 and 30 years were recruited. Participants with a history of cardiac and respiratory disorders, pregnant and lactating mothers and trained athletes were excluded. Participants were asked to come to Physiology laboratory in the early morning between 6 and 7 am after overnight fasting. Height was measured using a stadiometer (Holtain Ltd., Crymych, Britain) to the nearest 0.1cm. Weight was recorded to the nearest 0.1 kg using a weighing scale (Salter, Kent, England).

2.2 Cardiovascular parameters

HR and CO was measured using impedance cardiography (BoMed NCCOM3, BoMed Instruments, Irvine, California, USA). BP was measured using an automated blood pressure device (Welch Allyn, USA). Three basal measurements of HR, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), CO and left ventricular ejection time (LVET) were taken at the start of the experimental protocol and at the end of SHG.

2.3 Isometric exercise

The participant was asked to sit comfortably and baseline HR, BP, CO and ventricular ejection time was recorded. The participant was asked to apply sustained force of 40% of maximal voluntary contraction (MVC) for 90 seconds on a hand grip dynamometer. This has been done to ensure compliance by a majority of subjects since typical endurance at 50% MVC is for 90 seconds (10). Changes in HR, BP, CO and ventricular ejection time were recorded at the end of IE.

2.4 Derived indices

From the parameters obtained, rate pressure product (RPP) [HR x SBP] and triple product (TP) [CO (SV x HR) x SBP] were calculated to determine the cardiac work. Delta changes in HR, SBP, DBP, CO, DP and TP were calculated. Left Ventricular Ejection Time Index (LVETI) was calculated as LVETI = LVET+ 1.7* HR (5).

2.5. Statistical Analysis

All values were presented as Mean ± SD. Paired t-test was done to determine statistical significance between resting values and post-exercise values. Independent t-test used to assess gender differences in cardiovascular responses. SPSS version 17.0 was used for data analysis.

3. Results

Table 1 shows the characteristics of the participants and resting values of cardiovascular parameters. The participants were between 18 and 30 years of age. There were 21 participants in both genders. All the participants were apparently healthy and are of normal BMI. HR, BP and CO were within normal range.

Table 2 shows the effect of IE on the cardiovascular parameters. On performing IE, there was significant increase in HR, SBP and DBP. RPP and TP which is considered as the surrogate for the cardiac work was also significantly increased post exercise. There was significant decrease in LVET at the end of the IE. LVETI was significantly prolonged at the end of the exercise. There was only mild increase in CO.

Table 3 shows the gender differences between the cardiovascular parameters pre and post-exercise. Resting HR was significantly higher in females and resting SBP was significantly higher in males. There were no gender differences in other resting cardiovascular parameters. Even though there was increase in cardiovascular parameters in both the groups, there was no significant difference in delta change of these parameters.

4. Discussion

There was a significant increase in HR, SBP and DBP at the end of IE. These responses are similar to the responses obtained in several studies which showed that HR, SBP, DBP and left ventricular contractility of the heart significantly increased in response to IE (8,11,12). Studies assessing the effect of IE on cardiovascular parameters by catheterization techniques and also noninvasive methods (13) showed similar results. Previous studies have reported an increase in BP after IE in healthy young population (14), adolescents (15), normotensive and hypertensive patients (8,9) and also older population (16,17). In our study, we selected to administer 40% of MVC for 90 seconds to maintain the uniformity of duration of IE. There was a 21% increase in mean HR, 13 % increase in SBP and 17% increase in DBP. Similar results were seen in studies that assessed the HR and BP responses to IE. Studies comparing static and rhythmic exercise showed that the BP responses were pronounced in static exercise than rhythmic exercise (18). Rapid withdrawal of parasympathetic activity initially and increase in sympathetic activity in later phase causes an increase in HR and BP during IE (19). Central command and exercise pressor reflex contribute to the increase in sympathetic activity to IE Central command theory proposes a direct action of the motor cortex on the medullary centers and spinal neuronal circuits that cause the changes in cardiovascular functions during exercise (20,21). Exercise pressor reflex due to muscle contraction that stimulates afferent nerve endings within the skeletal muscle causes an increase in arterial pressure (21) and these neural responses are modulated by the arterial baroreceptors (22).

In our study, there was shortening of LVET at the end of IE. This response was also seen in several studies which assessed the left ventricular function on performing IE. LVETI was calculated to correct the effect of HR on LVET (5). There was a significant prolongation of LVETI post-exercise which was in agreement with studies by Martin et al (23) and Laird et al (15). This could be due to an acute increase in afterload independent of changes in HR and stroke volume (5). In the present study, there was 37 % increase in RPP and 18% increase in TP due to IE. RPP and TP are considered as the surrogates for cardiac work which have positive correlation with the myocardial blood blow and myocardial oxygen consumption.

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In the present study, the increase in HR and BP due to IE were higher in males than females, however there was no significant gender difference in delta change of cardiovascular parameters. These responses were higher among males due to pronounced pressor responses among males than females. Studies assessing the gender differences in cardiovascular parameters reported similar results (11,24–27).

5. Conclusion

We conclude that there was significant increase in cardiac work during IE assessed by impedance cardiography. There was also a significant increase in HR, SBP and DBP in response to IE. There were no significant gender differences in increase in HR, BP and cardiac work parameters.

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Table 1: Subject Characteristics

Parameters	Mean ± SD
Age (years)	23 ± 4
Height (cms)	162.2 ± 10.1
Weight (Kg)	57.6 ± 10.4
BMI (Kg/m^2)	21.8 ± 3
Resting cardiovascular parameters	
Heart rate (HR) bpm	69.7 ± 9
Systolic blood pressure (SBP) mmHg	102 ± 8.5
Diastolic blood pressure (DBP) mmHg	67.4 ± 6.5
Cardiac output (CO) L/min	4.5 ± 1.1
Rate Pressure Product (RPP)	7098.3 ± 1018.1
Triple Product (TP)	460.6 ± 111.2

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Table 2: Pre and Post Exercise Response to IE

Parameters	Pre exercise	Post exercise
HR	69.7 ± 9.0	83.7 ± 12.6 *
SBP	102.0 ± 8.5	115.3 ± 14.1*
DBP	67.0 ± 6.5	77.9 ± 8.9*
CO	4.5 ± 1.1	4.7 ± 1.2
RPP	7098.3 ± 1018.1	9661.0 ± 1905.8 *
TP	460.6 ± 111.2	538.9 ± 142.0 *
LVET	284.6 ± 20.8	277.5 ± 19.8 *
LVETI	403.1 ± 16.6	419.8 ± 19.6 *

HR – Heart rate, SBP – Systolic Blood Pressure, DBP – Diastolic Blood Pressure, CO - Cardiac Output, RPP – Rate Pressure Product (RPP = HR * SBP), TP – Triple Product (TP = HR*SBP*CO), LVET – Left Ventricular Ejection Time, LVETI – Left Ventricular Ejection Time Index (LVETI = LVET+ 1.7* HR)

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Table 3: Gender Differences in cardiovascular response to IE

	Male (n = 21)			Female (n = 21)		
Parameters	**Resting**	**Post Exercise**	**Delta change**	**Resting**	**Post Exercise**	**Delta change**
HR	66.4 ± 8.6	81.2 ± 11.0	14.8 ± 9.3	73 ± 8.4 *	86.1 ± 13.9	13.1 ± 10.3
SBP	105.9 ± 8.1	122.6 ± 13.7	16.7 ± 13.6	98.0 ± 7.0 *	108.1 ± 10.4	10.0 ± 9.4
DBP	67.5 ± 6.7	81.6 ± 10.2	14.0 ± 12.6	66.6 ± 6.4	74.2 ± 5.4	7.7 ± 8.3
CO	4.3 ± 0.6	4.5 ± 0.76	0.15 ± 0.51	4.7 ± 1.4	4.9 ± 1.5	0.17 ± 0.94
RPP	7028.2 ± 1008.9	9987.7 ± 1918.8	2959.4 ± 1935.9	7168.3 ± 1047.7	9334.3 ± 1881.4	2166.0 ± 1468.9
TPP	456. 7 ± 71.87	548.6 ± 116.7	91.9 ± 84.8	464.51 ± 141.99	529.3 ± 165.8	64.8 ± 102.6
LVET	285.1 ± 17.2	272.9 ± 22.8	-12.23 ± 21.27	284.0 ± 24.2	282.1 ± 15.3	- 1.9 ± 23.3
LVETI	398.1 ± 9.7	411.0 ± 428.5	12.9 ± 12.1	408.1 ± 20.4	428.5 ± 21.1	20.4 ± 28.6

HR – Heart rate, SBP – Systolic Blood Pressure, DBP – Diastolic Blood Pressure, CO - Cardiac Output, RPP – Rate

Pressure Product (RPP = HR * SBP), TP – Triple Product (TP = HR*SBP*CO), LVET – Left Ventricular Ejection Time, LVETI – Left Ventricular Ejection Time Index (LVETI = LVET+ 1.7* HR),

*Independent t test was done to compare resting values and delta values between two groups. P<0.05 was considered as significant.

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