National Journal of Physiology, Pharmacy and Pharmacology

RESEARCH ARTICLE

Study of evaluation of hemodynamic response during isometric handgrip exercise in young adult males

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Received: April 12, 2019; **Accepted:** May 01, 2019

ABSTRACT

Background: Isometric exercise is less extensively studied and compared to isotonic exercises, variable circulatory responses were observed by previous researchers to isometric exercise. **Aims and Objectives:** The present study aimed to analyze the changes in cardiocirculatory parameters during and after isometric exercise in young adult males. **Materials and Methods:** A total of 31 normotensive young healthy males (Mean age: 19.065 ± 0.92 years) were randomly selected in a cross-sectional study. Isometric handgrip (IHG) exercise at 30% of maximum voluntary contraction (MVC) was maintained by participants for 3 min or till fatigue. Hemodynamic factors such as blood pressure, heart rate, and peripheral oxygen saturation were recorded noninvasively at rest, 1st min of exercise, at 3rd min or till failure, and 2 min after completion of exercise. Mean arterial pressure, pulse pressure, and rate pressure product were calculated subsequently. Anthropometric variables were correlated with MVC. Repeated measure analysis of variance (ANOVA) was used to test level of significance for $P < 0.05$ at 95% confidence interval. **Results:** Exercise hemodynamic factors (at 1st min of exercise and at 3rd min or till failure) were significantly greater ($P < 0.05$) than values at rest. All the parameters return to resting level during the recovery period. **Conclusion:** IHG exercise can be a simple test to evaluate the left ventricular reserve and may be of value as a part of lifestyle intervention for the prevention of cardiovascular events.

KEY WORDS: Isometric Handgrip Exercise; Maximum Voluntary Contraction; Mean Arterial Pressure; Blood Pressure; Heart Rate

INTRODUCTION

Isometric exercise is though simple to perform, it is considered as complex exercise.[1] Isometric handgrip (IHG) is sensitive, specific and reproducible, simple, and non-invasive test for evaluation of sympathetic functions; however, cardiovascular responses have been variable in various studies.[1-5] IHG exercise has not been well studied and traditionally not been recommended as an alternative to dynamic exercise. Variable responses to isometric exercise have been demonstrated by various studies and difference exists in responses.[5] Hietanen,1984, suggested the level of isometric exercise at 30% of maximum voluntary contraction (MVC) to be held for 3 min to be studied because this level of exercise is more energy demanding which must be met by anaerobic metabolism so it can be performed only few minutes at a time.[6] In view of these facts, it is worthwhile to reiterate hemodynamic responses elicited by the IHG exercise performed at 30% of MVC. We tried to study cardiovascular response to isometric exercise at 30% of MVC and whether any difference exists in hemodynamic factors measured at rest, during, and after IHG exercise protocol.

Access this article online

Website: www.njppp.com

Quick Response code

DOI: 10.5455/njppp.2019.9.0415801052019

MATERIALS AND METHODS

Study Population

A cross-sectional study involved 31 young healthy adult males randomly selected from urban population. The study protocol was approved by the Institutional Ethics Committee.

After written informed consent, detailed history and physical examination following criteria were used to include participants in the study.

Inclusion Criteria

- Male
- 18–21 years of age
- No history of medical/surgical disorders, upper extremity abnormalities, or inflammatory joint disease
- Blood pressure (BP) <140/90 mmHg
- Non-smokers, non-tobacco chewer, and non-alcoholics
- Willing to cooperate
- Non-athlete/not involved in exercise training programs.

Sample size calculated to be 31 with power of 80% and alpha 0.05.

Data Collection

MVC of hand was obtained by the calibrated spring-type handgrip dynamometer (INCO AMBALA), with the dominant hand positioned below the plane in which the participants were seated and arms kept extended perpendicular to the floor. The hand was pronated 90° toward the midline of the body.[7] Participants were asked to exert maximal efforts and squeeze the bar of handgrip dynamometer as hard as possible, maintaining it for 2–3 s in sitting position.[8] Three trials with a gap of 2 min were measured[9] and out of three trials, single best response was taken as an estimate of MVC.

Body weight was measured with barefoot and light clothing on a weighing scale nearest to 0.1 kg. Height (to the nearest 0.5 cm) was measured by the stadiometer during inspiration standing upright, facing to the wall, looking front and heels touching to one another.

Body mass index (BMI) was calculated as follows: BMI = (Weight in kg ÷ [Height in m]^2)

Body surface area (BSA) was calculated as per Mosteller's formula (1987):

$$\text{BSA (m}^2\text{)} = ([\text{Height (cm)} \times \text{Weight (kg)}] \div 3600)\ 1/2$$

IHG Strength Exercise

Participants seated upright at rest for 15 min.[7] IHG exercise was performed with calibrated spring-type handgrip dynamometer by applying force of 30% of MVC with dominant arm for 3 min or till failure.[10] Failure was considered when exercise was not possible due to perceived muscle fatigue.[6] Participants were instructed to breathe normally and to inform when they were no longer able to continue IHG exercise.[11]

Recording of Hemodynamic Parameters

Cardiovascular parameters were recorded before (at rest), during (at 1st min of exercise), and at the end of IHG exercise (at 3rd min of exercise or at the time of failure) and 2 min after completion of exercise.

BP to nearest 2 mmHg was recorded with mercury sphygmomanometer (Diamond Co.) and adult size cuff in non-exercising arm, at brachial artery. Pulse oximeter sensor at fingertip was used to measure peripheral oxygen saturation (SpO_2) and pulse rate (PR).

Mean arterial pressure (MAP), pulse pressure (PP), and rate pressure product (RPP) were calculated as follows:

PP = Systolic blood pressure (SBP) − diastolic blood pressure (DBP)

$$\text{MAP} = \text{DBP} + 1/3\ \text{PP}$$
$$\text{RPP} = \text{PR} \times \text{SBP}$$

Data were reported as mean ± standard deviation. Repeated measured analysis of variance (ANOVA) with *post hoc* analysis was done with IBM SPSS (v23). Pearson correlation coefficient (r) was calculated to find the correlation between MVC and anthropometric parameters. probability (P) value of <0.05 was considered statistically significant at 95% confidence interval.

RESULTS

Data were approximately normally distributed. The general characteristics of the participants are shown in Table 1. Body weight, BSA, and BMI positively correlated with MVC [Table 1].

During IHG exercise trial at 30% of MVC, a significant progressive increase in measurements of SBP, DBP, PP, MAP, heart rate (HR), and RPP was observed. Partial pressure of oxygen measured as SpO_2 remained unaffected during and after IHG exercise. Immediately at the end of 1st min of exercise, the mean value of SBP, DBP, MAP, HR, and RPP was increased significantly ($P < 0.01$) when compared to the values at rest as shown in Table 2. No significant ($P > 0.05$) difference was observed in mean value of PP at the end of 1st min of exercise compared to the resting value.

By the end of 3rd min of exercise or termination of IHG exercise, mean value of SBP, DBP, MAP, HR, and RPP was significantly increased when compared to the values at rest and at the end of 1st min of exercise. While PP was significantly ($P < 0.05$) increased at 3rd min of exercise compared to 1st min of exercise but not different from resting. There were no significant ($P > 0.05$) differences in any of the cardiovascular parameters between initial rest and during the recovery period, i.e., 2 min after exercise [Table 2].

Hemodynamic responses are shown graphically in Figures 1 and 2.

DISCUSSION

The present study focused on cardiovascular response to isometric exercise in male participants. The results revealed a significant positive correlation of weight, BSA, and BMI with MVC. The level of isometric exercise in our study was set at 30% of MVC. We found a significant increase in HR, SBP, DBP, MAP, PP, as well as RPP at 1st min of exercise and increase continued further at 3rd min of exercise till fatigue. All the parameters which were increased during exercise returned to resting level after 2 min post-exercise. SpO_2 remained same during the entire duration of exercise and also during 2 min after exercise.

Table 1: General characteristics of the study population and their correlation with MVC (*n*=31)

Variables	Mean±SD	Range	Pearson correlation coefficient (r)
Age (years)	19.065±0.9286	18-21	−0.196
Height (cm)	171.122±6.598	160.02-190.5	0.184
Weight (kg)	64.032±10.397	45-89	0.44*
BMI (kg/m^2)	21.774±3.363	17-31	0.391*
BSA (m^2)	1.739±0.156	1.41-2.12	0.441*
MVC (kg)	33.419±8.2291	17-45	1
30% of MVC (kg)	10.023±2.4754	5-13.5	1

SD: Standard deviation, BMI: Body mass index, MVC: Maximum voluntary contraction, BSA: Body surface area; *correlation is significant at the 0.05 level.

Correlation with weight, BSA, and BMI in our study was similar to the finding by Chatterjee and Chowdhuri, who showed the right and left handgrip strength positively correlated with weight, height, and BSA in Indian population.[12] In contrast, Dhananjaya *et al*. found a negative correlation of handgrip strength with BMI.[13] Recording of hemodynamic parameters began after 1st min of exercise, as this much time may be required to have immediate and significant effect of IHG exercise.[14] Our study found a significant increase in HR and BP during IHC at 30% of MVC. Donald *et al*. agreed that contraction >15% of MVC known to cause progressive hemodynamic changes to the point of fatigue.[15] Lind *et al*. and Ewing *et al*. demonstrated that the extent of cardiovascular acceleration was directly related to the extent of exertion.[14,16] The increase in the HR as well as BP known as pressure response to isometric contraction is powerful, ubiquitous[17] while pressure response in dynamic exercise is lower as vasodilatation[14] induced by metabolites in large muscle group increases the systemic conductance.[6] Pressure response is a net result of central command and peripheral mechanism. Mitchell *et al*. have shown that central and peripheral nervous inputs playing a role in the cardiovascular adjustment to static exercise.[18] Peripheral mechanism is due to muscle chemoreflex (Feedback System) formed by chemosensitive afferent nerve fibers present in the exercising muscles. Afferent impulses from the exercising muscles reach to spinal cord and ascend in the spinothalamic tract to the medullary cardiovascular centers. Mark *et al*., Saito *et al*., and Seals *et al*. stated that for determining the pressure response after 2–3 min of isometric exercise, the muscle chemoreflex plays a critical role.[19-21] Over a period of time the metabolites accumulated in the active muscle, there is muscle chemoreflex[18] dependent increase in sympathetic nerve activity. According to Asmussen *et al*., the rapid increase in the heart rate immediately after the beginning of exercise is due to activation of mechanoreceptors (Type III afferents) while during the progress of static exercise, slow increase in heart

Table 2: Cardiovascular parameters during isometric exercise in the study population (*n*=31) (values are mean±SD)

Variables	Resting	Measurements along isometric exercise		2 min after exercise	*F* Value	*P* Value
		At 1st min of exercise	At 3rd min/termination of exercise			
SBP (mmHg)	113.42±8.13	136.45±16.92*	157.29±21.54*^	113.87±8.82^	125.41	0.000
DBP (mmHg)	78.25±7.07	101.48±12.17*	113.29±12.78*^	81.41±6.85*^	155.60	0.000
PP (mmHg)	37.64±13.81	34.96±14.34	44.00±18.21^	32.45±8.09	5.34	0.005
MAP (mmHg)	90.80±7.56	113.13±12.19*	127.95±13.78*^	92.23±6.53^	177.33	0.000
HR (per min)	83.61±11.44	97.03±12.93*	105.38±14.83*^	87.67±12.03*^	48.51	0.000
RPP (bpm x mmHg)	9484.97±1501.15	13267.39±2596.94*	16668.39±3870.49*^	10012.9±1796.33^	90.88	0.000
SpO_2 (%)	97.71±0.86	97.8±0.74	97.51±1.31	97.48±1.99	0.49	0.61

SpO_2: Peripheral oxygen saturation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, HR: Heart rate, RPP: Rate pressure product, PP: Pulse pressure; *$P < 0.05$ comparing with resting measurements, ^$P < 0.05$ comparing with 1st min of exercise

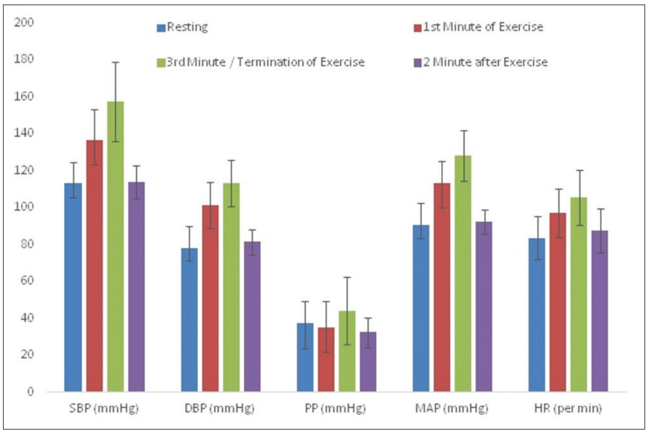

Figure 1: Comparison of systolic blood pressure, diastolic blood pressure, pulse pressure, mean arterial pressure, and heart rate in different phases of exercise

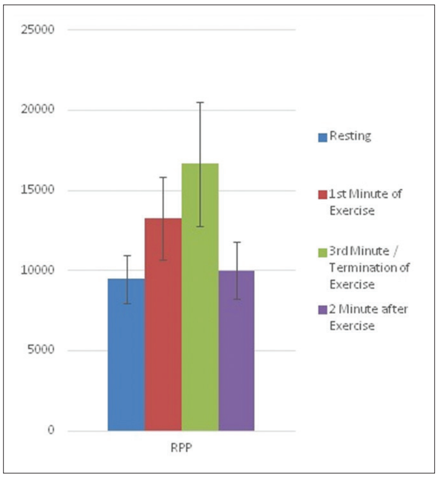

Figure 2: Comparison of rate pressure product in different phases of exercise

rate was due to chemoreceptor (Type IV afferents) signals.[22] Central command (Feedforward controller of cardiovascular system) arises from higher centers (e.g., insular cortex). Shepherd *et al*. stated that during isometric exercise, the heart rate increases through parasympathetic (vagal) inhibition through this central command[23] while Mitchell *et al*. and Seals and Enoka told that the higher heart rate response not due to central command rather due to increase sympathetic activity.[24,25] Freyschuss suggested withdrawal of vagal inhibition increased heart rate.[26] A study by Lind *et al*. stated that isometric contraction elicited marked increase in systolic and diastolic BP while HR increase is less pronounced compared to dynamic exercise.[27] Nutter *et al*. postulated that during IHG exercise, increase in arterial pressure is mediated through an increase in cardiac output due to concurrent increase in heart rate.[28] Sakakibara and Honda also stated that during handgrip exercise increased cardiac output resulted in elevated arterial BP.[29] During heavy static exercise, systolic and diastolic both BPs increase continuously due to increased peripheral resistance secondarily due to increased intramuscular pressure.[6] Asmussen *et al*. and Hietanen explained that the MAP is a function of cardiac output and total peripheral resistance (TPR). MAP = k *Q × TPR. Where, k is a constant, Q = HR × stroke volume. This explains increase in MAP due to increases in heart rate. Significant increase in MAP during static exercise involving small muscles is due to corticomedullary reflex-induced tachycardia and consequent increase in cardiac output.[6,22] The RPP, the index of cardiac stress, and predictor of myocardial oxygen consumption at rest and during isometric exercise is indicator of ventricular function.[30] During exercise, the increased SBP and HR adjust the myocardial oxygen consumption supply by increasing RPP according to the RPP = SBP × HR formula. The peak value of RPP due to pressure overload indicates the better coronary perfusion to meet increased myocardial oxygen demand during IHG exercise.[31,32] Post-exercise fall was seen due to vasodilatation resulting due to accumulation of the metabolites due to decreased blood supply to the exercising muscles

Our study was done on male subjects, females were excluded as Ettinger *et al*. demonstrated that muscle sympathetic nerve activity (MSNA) responses which play a primary role in pressure response to static handgrip exercise were greater during the menstrual phase (days 1–4) compared with the follicular phase (days 10–12) in premenopausal women. Furthermore, during the follicular phase, attenuated responses were observed.[33] The study can be extrapolated to different postures as well as to different disease population like in diabetics to explore the utility of isometric exercise.[34,35] Rating of perceived exertion (RPE) using Borg scale 6–20 was not recorded per minute of exercise. Higher RPE was previously associated with high pressure response due to increased MSNA which may be limiting the findings.

CONCLUSION

Thus, IHG exercise leads to marked increased in heart rate and blood pressure parameters during exercise which returns to basal level almost immediately after exercise. Thus, IHG exercise can be a simple test to evaluate the left ventricular reserve and may be of value as a part of lifestyle advice for maintaining BP within desirable range and prevent risk of cardiovascular events.

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How to cite this article: Champaneri VI, Kathrotia RG. Study of evaluation of hemodynamic response during isometric handgrip exercise in young adult males. Natl J Physiol Pharm Pharmacol 2019;9(6):566-570.

Source of Support: Nil, **Conflict of Interest:** None declared.