

# Effect of baseline status on cardiovascular responses post-isometric handgrip exercise.

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## Research Article

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# Abstract

## Background

Isometric handgrip (IHG) exercise causes changes in heart rate variability (HRV) and hemodynamic responses with individual differences. We test the hypothesis that baseline measurements affect post-exercise outcomes.

## Methods

In this cross-sectional study, 45 males aged 17 to 22 years were enrolled from SMS Medical College, Jaipur (India). Hemodynamic and HRV data were collected at baseline, during, and after 5 minutes of IHG exercise. The absolute and relative responses were compared before, during, and after the exercise using nonparametric tests. The relationship of baseline with outcomes was evaluated using Pearson's correlation.

## Results

The study showed a significant increase in the absolute values of hemodynamic parameters and LF/HF ratio during and after 5 minutes of IHG exercise compared to the baseline. However, a significant decrease and increase occurred in all the relative hemodynamic and most HRV parameters respectively after 5 minutes than during the IHG exercise. Hemodynamic parameters showed a significant correlation with baseline during and after 5 minutes of IHG exercise. Similarly, baseline affects all the HRV parameters during IHG exercise, but not after 5 minutes of IHG exercise.

## Conclusion

The present study concludes that initial baseline status should be considered while evaluating the post-IHG exercise responses.

## Introduction

The isometric handgrip (IHG) exercise is a relatively simple test that measures the hemodynamic response to a "pressor" stimulus. However, the response is a function of multiple factors, including sympathetic and parasympathetic output, negative feedback baroreceptor loop, local factors, cardiac function, and feedforward central commands. (1) Isometric handgrip exercise increases cardiac output due to increased metabolic demands on the body. Multiple hemodynamic parameters govern cardiac output. Abnormal changes in hemodynamic parameters during IHG may reflect the early stages of cardiovascular disease. (2) In addition, the role of IHG in the management of hypertension has been envisaged; the training for more than six weeks could reduce blood pressure and cause modulation of

cardiac autonomic function. (2)(4)(5)(6) Further, the isometric handgrip (IHG) test might have a role in the early detection of individuals prone to developing hypertension. (7) Isometric handgrip exercise causes changes in hemodynamic parameters and heart rate variability with individual differences. The present study aimed to delineate the effects of baseline measurement on post-exercise hemodynamic responses.

## Material And Methods

In this hospital-based cross-sectional study, 45 male students aged between 17 to 22 years enrolled from SMS Medical College, Jaipur (Rajasthan, India) after approval from Institutional Ethical Committee. The study evaluated the effect of baseline measurements on hemodynamic responses and heart rate variability after doing isometric handgrip exercise.

To evaluate the effect of baseline status, measurement of absolute responses was followed by calculation of relative responses (see section Data Analysis). The relationships between absolute and relative responses were evaluated using correlation.

## Protocol

The participants avoided tea, coffee, and food for at least 2 hours before data collection. Researchers did the recording between 09:00 AM and 12:00 PM to prevent the effect of diurnal variation. They clinically examined participants to rule out any morbidity. If the participant was found healthy, researchers collected hemodynamic and heart rate variability data in three phases as follows:

### Baseline

5 minutes duration before performing IHG exercise,

### Phase 1

5 minutes duration after completion of the IHG exercise, and

### Phase 2

Duration between 5 and 10 minutes after completing the IHG exercise.

## Isometric handgrip exercise

The participants were instructed to hold the hand dynamometer to provide a maximal voluntary contraction as a baseline. The tension was called maximal isometric tension ( $T_{max}$ ). After a rest of one minute, the participants compressed the dynamometer to 30% of the maximal effort ( $T_{max}$ ) for 5 minutes. Researchers measured the blood pressure, pulse rate, and ECG signals before, during, and after IHG exercise.

## Recording of hemodynamic parameters

Researchers measured systolic and diastolic blood pressure and pulse rate (PR) in the participant's non-tested arm in all the phases. An automated digital device was used to avoid a manual error. Further, researchers calculated pulse pressure (PP), mean arterial pressure (MAP), and rate pressure product (RPP).

## Acquisition of heart rate variability

The ECG signals for heart rate variability (HRV) were recorded using RMS Polyrite D (version 1.0) after a supine rest for 15 minutes. The resting ECG was recorded at a sampling frequency of 256 Hz. The tachogram (RR-interval series) was constructed from ECG signals. Researchers calculated time and frequency domain measures using Kubois software. The time-domain measures include the standard deviation of all RR intervals (SDNN), the square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD), and pNN50, which is the percentage of consecutive RR intervals that differ by more than 50 milliseconds. The frequency-domain measures include total power, power in the high frequency (HF) band (0.15-0.40Hz), power in the low frequency (LF) band (0.04–0.15 Hz), and LF/HF ratio. (8)(9)(10)

## Data analysis:

The absolute readings were further processed to find out the relative readings. Let the baseline, phase 1, and phase 2 values of parameter X be represented by bX, X1, and X2, respectively. Then, the relative value of X1 is given by

$$\Delta X1 = X1 - bX$$

Similarly, the relative value of X2 is given by

$$\Delta X2 = X2 - bX$$

## Statistical analysis

Based on normality, the quantitative variables were expressed as mean (SD) or median (IQR). The comparison of absolute values of parameters during baseline (bX), phase1 (X1), and phase 2 (X2) were performed using the Friedman test. The relative values of parameters during phase 1 ( $\Delta X1$ ) and phase 2 ( $\Delta X2$ ) were compared using the Wilcoxon signed-rank test. Further, Pearson's coefficient measured the relationship between absolute and relative changes. The level of significance was considered at 5%. The JASP version 0.16.1.0 was used for statistical analysis (JASP Team) and MATLAB.(11)(12)

## Results

The study showed significant increase in the absolute SBP [W = 5.75 ;  $p < 0.001$ ], DBP [W = 8.62;  $p < 0.001$ ], HR [W = 8.52;  $p < 0.001$ ], MAP [W = 8.90;  $p < 0.001$ ] and RPP [W = 8.64;  $p < 0.001$ ] during phase 1 as compared to the baseline values. However, absolute PP [W = 3.33;  $p = 0.004$ ] showed significant decrease as compared to the baseline. Similarly, significant increase was observed in absolute SBP [W =

4.06;  $p < 0.001$ ], DBP [W = 4.061;  $p < 0.001$ ], HR [W = 5.39;  $p < 0.001$ ], MAP [W = 4.77;  $p < 0.001$ ] and RPP [W = 5.44;  $p < 0.001$ ] during phase 2 as compared to the baseline. During phase 2, absolute DBP [W = 4.56;  $p < 0.001$ ], HR [W = 3.13;  $p = 0.007$ ], MAP [W = 4.13;  $p < 0.001$ ] and RPP [W = 3.20;  $p = 0.006$ ] were significantly lowered as compared to phase 1. However, absolute PP2 showed significant increase as compared to phase 1 PP [W = 2.63;  $p = 0.03$ ] (Table 1) The comparison of absolute values of heart rate variability parameters showed no significant differences in SDNN, RMSSD, TP, and HF during phase 1 and phase 2 compared to the baseline. However, LF/HF ratio showed a significant increase in phase 1 and pN50 and LF/HF ratio showed significant increase in phase 2 compared to baseline. As compared to phase 1, RMSSD and pN50 showed a significant increase, while LF/HF ratio was decreased in phase 2. (Table 2)

Further, researchers compared relative cardiovascular responses and found a significant decrease in phase 2 compared to phase 1. (Table 3). Similarly, the relative change in all heart rate variability parameters, except LF/HF ratio, were higher during phase 2 as compared with phase 1. (Table 4)

To find the effect of baseline values on post-exercise responses, the authors calculated Pearson's correlation between absolute and relative responses. The study showed a significant effect of baseline values on the relative DBP, PP, and MAP in phases 1 and 2. However, baseline values had no significant impact on relative changes in SBP, HR, and RPP in phases 1 and 2. (Table 5). The relative values of all heart rate variability parameters in phase 1 were significantly correlated with baseline values. However, baseline values had no significant association with relative changes in phase 2 heart rate variability measures. (Table 6)

## Discussion

Isometric exercise is defined as a sustained muscular contraction with no joint movements. Conventionally, no work was done during the exercise. The oxygen consumption is moderate compared to isotonic exercise. The cardiovascular effects of static or isometric exercise primarily reflect the response to increased afterload or blood pressure. In contrast, the response to isotonic exercise is due to volume overload on the heart. (8) The high muscle tension and reduced blood flow produce a unique "pressor" reflex increase in systemic arterial pressure. (13) The reflex increases sympathetic activity in the heart and vessels and decreases parasympathetic activity, increasing BP, heart rate, and total peripheral resistance through arteriolar constriction. The sympathetic output varies in contracting and non-contracting skeletal muscle and is differentially controlled by a central command and the metaboreflex in healthy conditions. Further, studies on animals and humans showed the effect of cardiovascular diseases, such as diabetes, hypertension, and heart failure, on altered 'pressor' reflex function. (14) The hemodynamic response to isometric handgrip exercise results from a complex interaction of multiple factors, including sympathetic and parasympathetic output, norepinephrine uptake, baroreceptor loop, cardiac function, central commands, and age. (1)(15) Most studies showed the effect of IHG exercise on cardiovascular responses. The present study evaluated changes in absolute and relative responses compared to baseline measurements.

Similar to the present study, Laird et al. showed the effect of submaximal (25% maximal) IHG in 32 normal adolescents. They found significant increases in mean heart rate, systolic, diastolic, and mean blood pressures. (16) Aminoff et al. reported increased heart rate and blood pressure during sustained IHG were partly due to central command and partly due to activation of the afferent limb of reflex arc from contraction of muscles. At least a 15 mmHg increase in diastolic pressure was considered normal. (17) The present study enrolled only males within a narrow range of age to eliminate the effects of age on post-exercise responses. Cauwenberghs et al. observed a positive correlation of age with blood pressure and pulse pressure changes in 3 minutes of 40% maximal IHG. They showed significantly higher heart rate and diastolic BP after exercise in males compared to females. (2) In addition, Goulopoulou et al. showed greater mean arterial pressure responses in adults compared to children ( $p < 0.05$ ) after doing IHG. However, heart rate variability measures were not significantly different in adults and children ( $p > 0.05$ ). (18) The causes of post-exercise response might be multifactorial. In a study by Watanabe et al., thirty-nine healthy subjects performed a 1-minute IHG exercise at 50% of maximal voluntary contraction followed by a 4-minute post-exercise muscle ischemia period to selectively maintain activation of the muscle metaboreflex. Researchers hypothesized an inverse correlation between changes in cardiac output (CO) and total peripheral vascular resistance (TPR) during IHG [ $r = -0.751$ ;  $p = 0.01$ ] but showed CO and TPR were positively correlated with corresponding responses during post-exercise muscle ischemia [ $r = 0.568$  and  $0.512$ , respectively,  $p = 0.01$ ](19) Clark et al. evaluated the effect of omega-3 polyunsaturated fatty acids consumption on cardiovascular responses at the onset of IHG exercise. Fourteen young and fifteen old subjects ingested 4 g of fish oil daily for 12 weeks. Participants performed 15 second bouts of IHG at 10%, 30%, 50% and 70% maximal voluntary contraction. The systolic and diastolic blood pressure and heart rate were recorded before and after the intervention. Researchers found that fish oil supplementation attenuates MAP and DBP increases at the onset of IHG exercise in young and older subjects [change from baseline during 70% MVC handgrip pre-and post-intervention: young  $\Delta$ MAP =  $14 \pm 2$  mmHg versus  $10 \pm 2$  mmHg, older  $\Delta$ MAP =  $14 \pm 3$  mmHg versus  $11 \pm 2$  mmHg; young  $\Delta$ DBP =  $12 \pm 1$  mmHg versus  $7 \pm 2$  mmHg, older  $\Delta$ DBP =  $12 \pm 1$  mmHg versus  $7 \pm 1$  mmHg;  $p < 0.05$ ]. (20) Chaney et al. calculated the predictor variables for systolic BP response [age, gender, resting systolic BP, and maximal treadmill systolic BP, yielded 70% predictability] and diastolic BP response [handgrip strength, resting diastolic BP, treadmill HR, systolic BP, and diastolic PB allowed 66% prediction]. (21)

The present study evaluated the effects of IHG exercise on heart rate variability parameters. Kluess et al., in a study on 34 participants (age,  $20 \pm 1$  year), compared heart rate variability parameters during spontaneous breathing, venous-occluded exercise (60% maximal voluntary contraction, 0.5 Hz), and immediate postexercise arterial occlusion. Similar to the present study, researchers found increased LFnu ( $+9.39 \pm 16.83\%$ ) and MAP ( $+25.40 \pm 17.55$  mm Hg) after exercise. On the contrary, mean R-R interval ( $-230.73 \pm 125.79$  msec) and SDNN ( $-38.54 \pm 36.02$  msec) showed decrease ( $P < 0.05$ ). During forearm arterial occlusion, SDNN ( $-17.89 \pm 64.41$  msec) and LFnu ( $9.89 \pm 21.01\%$ ) showed recovery ( $P < 0.05$ )(22). Farah et al. did a systematic review and meta-analysis of seven randomized controlled trials with 86 participants. Mean difference (MD) and 95% confidence interval (95% CI) were calculated using an inverse variance method with a random-effects model. The results showed no significant effects of IHG

exercise on heart rate variability parameters [4 trials to SDNN: MD = - 1.44 ms and 95% CI = - 8.02, 5.14 ms; RMSSD: MD = - 1.48 ms and 95% CI = - 9.41, 6.45 ms; pNN50: MD = 0.85% and 95% CI = - 1.10, 2.81%; 7 trials to LF: -0.17 nu. and 95% CI = - 6.32, 5.98 nu.; HF: MD = 0.17 nu. and 95% CI = - 5.97, 6.30 nu.; and LF/HF: MD = 0.13 and 95% CI = - 0.34, 0.59]. (23) Kurita et al. studied the effect of IHG on frequency domain heart rate variability in healthy and coronary artery disease patients. The authors found no significant differences in low-frequency (LF) spectra and LF/HF ratios during handgrip exercise, but HF spectra significantly increased from  $10.1 \pm 4.5$  to  $12.2 \pm 7.0$  ms ( $p < 0.05$ ) in normal subjects. However, LF and LF/HF spectra showed significant ( $p < 0.05$  and  $0.01$ , respectively) increase in the CAD subjects, while HF spectra were not significantly changed by handgrip exercise. (24)

The present study found that initial baseline status affects cardiovascular responses after IHG exercise. In a meta-analysis of seven randomized controlled trials, Yin et al. found the effect of isometric handgrip (IHG) training on resting BP and heart rate. They analyzed the association between IHG training and participants with different initial BP status. The participants in training groups showed significantly decrease in SBP [MD= -8.33, 95% CI: -11.19 to -5.46;  $P < 0.01$ ] and DBP (MD=-3.93, 95% CI: -6.14 to -1.72;  $P < 0.01$ ) compared to control group. In subgroup analysis, SBP, DBP, and HR significantly decreased in prehypertensive subjects ( $P < 0.01$ ). However, medicated hypertensive subgroup showed a significant reduction in SBP and DBP ( $P < 0.01$ ). (25) Although researchers compared post-exercise outcomes in various studies, the intensities (that is, percentage of maximum voluntary contraction) used in different studies had not shown standardized protocols. The effect of exercise intensity was evaluated by Kluess et al. using repeated measures ANOVAs and found the effect of intensity of IHG on blood pressure and heart rate variability measures. Researchers found that the mean R-R interval responded to exercise in an intensity-dependent manner. However, SDNN decreased with IHG but did not correlate with exercise intensity. (26)

The present study evaluated the acute effects of IHG exercise on cardiovascular responses. Many studies suggested IHG training as an intervention for hypertension. On the contrary, Moldoven et al. found the impact of IHG training for 8–10 weeks on resting arterial blood pressure and heart rate variability in an investigation. However, blood pressure and heart rate variability parameters had no significant effects [ $p > 0.05$ ]. (23) In a few instances, post-exercise dizziness and hypotension were observed. In a meta-analysis of 30 trials, Farinatti et al. proposed no role of autonomic dysfunction during post resistance exercise hypotension. (27) Considering multiple factors in post IHG exercise cardiovascular responses. The present study outlines the importance of initial baseline status in the development of post-exercise cardio-dynamics.

## Conclusion

The present study concludes that initial baseline status should be considered while evaluating the post IHG exercise responses. The study showed a significant effect of baseline measurements on post IHG exercise diastolic blood pressure, pulse pressure and mean arterial pressure, and the heart rate variability parameters.

**Limitations of the study:** The study enrolled only males within 17 to 22 years to limit the effects of gender and age. Many studies evaluating cardiovascular responses post-IHG exercise use different protocols; more research is required in the future with studies using similar intensities of maximum voluntary contraction.

## Declarations

- **Source of financial support in the form of grants:** NA
- **Registration number in case of Clinical Trials:** NA
- **Contribution of Authors:** Equal contribution was made by all the authors in their respective domains.
- **Competing Interest** – There is no competing interest among authors
- **Research Quality and Ethics Statement-** The present study was in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975, as revised in 2000. The approval of the Institutional Ethical Committee, SMS Medical College, Jaipur was through letter no 3433/MC/EC/2017 dated 7 Oct 2017.

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## Tables

Tables 1-6 are in the supplementary files section.

## Supplementary Files

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