Original Article

Hemodynamic Responses to an Isometric Handgrip Training Protocol

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Abstract

Background: **In the past, isometric exercises were proscribed for heart disease. However, recent evidence suggests that an isometric handgrip training (IHT) protocol – four sets of two minutes at 30% of maximum strength – produces favorable effects on the autonomic modulation and reduces resting systolic (SBP) and diastolic (DBP) blood pressure.**

Objective: **Aiming at obtaining support for broad clinical applicability, we quantified the main hemodynamic responses during an IHT session in patients from a supervised physical exercise program.**

Methods: **Forty-one patients (36 men) underwent the IHT with measurements of heart rate (HR) and BP before, during each of the two series performed with the left arm and one minute after completion. Measurements were obtained by an electrocardiogram signal in a digital Tango + oscillometric tensiometer, previously validated for physical exercise conditions.**

Results: **The IHT was appropriately carried out, with no clinical adverse reactions. There was a small increase in SBP and DBP levels, respectively, of 16 and 7 mmHg ($p < 0.05$) and an even smaller increase in HR - 3 bpm - ($p < 0.05$) when we compared the data obtained at 80 seconds of the last series with the pre-exercise ones. HR, SBP and DBP values had almost returned to baseline one minute post-exercise.**

Conclusions: **IHT was well tolerated by patients undergoing exercise programs, resulting in a transient and modest hemodynamic effect, without inducing rapid cardiac vagal inactivation, characteristic of dynamic and short exercises. (Arq Bras Cardiol 2011;97(5):413-419)**

Keywords: **Exercise; heart rate; cardiovascular diseases; rehabilitation.**

Introduction

The regular practice of physical exercise has been widely recommended for the general population[1] and particularly for those with heart disease[2], based on abundant epidemiological and clinical evidence[3]. Most of these data is primarily based on predominantly aerobic exercises; however, the scientific knowledge and interest in strength training with sports and clinical applications are increasing[4]. In fact, in many everyday situations, human beings need to perform movements that require significant amounts of strength and muscular power[5,6]. While in the past, predominantly static exercises were prohibited for most individuals with hypertension and heart disease, more recent institutional guidelines[4,7-10] have been promoting, to a greater or lesser extent, the progressive use of these exercises in clinical practice.

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The isometric or static muscle training has been widely used for training athletes and healthy individuals for decades. Throughout time, these exercises were progressively replaced by joint movement or dynamic exercises and are currently rarely used as part of the strength training of a cardiac rehabilitation session[8]. Nevertheless, it has been known for many years that an isometric handgrip exercise during cardiac catheterization induces hemodynamic and ventricular function responses[11], and it was around 1990, with the advent of modern non-invasive techniques for the study of vascular and autonomic functions that the interest in this kind of exercise was renewed, as a possibility that can favorably influence the pressure behavior of normotensive and even hypertensive individuals.

The hemodynamic behavior during isometric exercise has been the object of physiological studies since the mid-1970s[12-15]; however, in the last ten years, Canadian researchers have been using what was called the "Isometric Handgrip Training" (IHT)[16-22]. With few exceptions[19] the IHT involves obtaining a maximum value bilaterally for handgrip strength, followed by two 2-minute duration series for each hand, alternating sides of body, comprising a total of

8 minutes of effective isometric exercise and a total time, considering the intervals and the initial measurements of maximum strength, which must be repeated at each session, of approximately 12 to 13 minutes.

In 2010, Kelley and Kelley[24], in a meta-analysis on the subject, after identifying a few studies with adequate quality, observed reductions of 5 to 20 mmHg and 3 to 15 mmHg – around 10% –, respectively, for the systolic blood pressure (SBP) and diastolic blood pressure (DBP), after some weeks of intervention. A more recent randomized clinical trial[25] with 49 normotensive subjects found very similar reductions in blood pressure levels after IHT. Interestingly, in spite of several experiments that have been adequately carried out, doubts still remain about the mechanisms responsible for the decrease in resting blood pressure levels after IHT[21]. Some evidence suggests that, at least for some patients or normotensive individuals, there is a share of positive changes in vascular structure and/or function[26], with or without objective modifications in endothelium-dependent vasodilation[16,18], and of a better autonomic modulation[20].

For a more comprehensive clinical application of IHT, it seems appropriate to know, in more details, the magnitude of hemodynamic responses associated with this type of exertion within a clinical context. If the favorable effects of IHT are well documented, there is little information on the magnitude of the increase in heart rate (HR) and blood pressure (BP) with this type of isometric exercise in clinical situations, out of hemodynamic rooms or laboratories of physiology, involving patients that are commonly followed by cardiologists. Therefore, our main objective was to quantify the hemodynamic responses during an IHT session in patients from a supervised exercise program.

Methods

Sample

We evaluated 53 (24%) of the patients who were regularly attending a supervised exercise program, selected by convenience due to time availability, acceptance to participate in data collection and also by the previous exclusion of those with chronic atrial fibrillation, external pacemaker rhythm, and frequent or complex extrasystole – i.e., the presence of more than five extrasystoles/min or in pairs or clusters. Technical difficulties with blood pressure measurement during exercise (e.g., arm circumference larger than that recommended by the cuff) or inability to perform the exercise properly led to the exclusion of 12 volunteers, determining a final number of 41 patients (36 men and 5 women) for analysis of final results. Eleven of the patients had been regularly submitted to IHT, as part of their supervised exercise session. Table 1 shows the physical characteristics, main clinical data and cardiovascular medications regularly used by the assessed patients.

Protocol

The study was carried out in a single visit. The patients signed a free and informed consent form, and remained sitting comfortably for about 5 minutes, during which the protocol to be followed was explained in details. The cuff was then positioned - Orkit K-adult size (Suntech, United States) – on the patient's right arm, following the manufacturer's recommendations, as well as a chest strap, under which three electrodes were placed in a position similar to that of the electrocardiographic CC5 leads and an initial measurement of HR, SBP and DBP was obtained.

Using the most common IHT protocol[19], patients then performed a maximal handgrip exertion with the right hand and after 10 seconds, they repeated it with the left hand in digital equipment suitable for IHT (Zone, USA). One minute after this measurement, patients were instructed to perform four successive series of two minutes each, exactly 1 minute apart, alternating hands, keeping an intensity corresponding to 30% of the maximum, more easily adjusted by the information continuously available on the equipment display[21]. Moreover, the examiner verbally encouraged the patient during the IHT to keep the recommended intensity. The device itself controls the duration of the exercises series and their intervals, through information clearly supplied by the display.

To eliminate any possibility of interference by the examiner on any differences or changes in hemodynamic variables, HR, SBP and DBP measurements were obtained using a digital Tango+ sphygmomanometer by the oscillometric method (Suntech, United States), using the detection of the RR interval of the electrocardiogram as reference, thus minimizing the influence of any noise or artifacts of the exercise, a basal value of 180 mmHg of inflation and a deflation rate of 5

Table 1 – Physical characteristics, main clinical data and regular use of medication (N = 41)*

Variable	Results
Age (years)	64.3 ± 8.7 (44-84)
Height (cm)	171.4 ± 7.9 (149.7-185.3)
Weight (kg)	78.6 ± 10.6 (58.5-97.3)
Body Mass Index (kg/m²)	26.7 ± 2.6 (22.3-31.6)
Known coronary artery disease (n)	28 (68%)
Acute myocardial infarction (n)	10 (24%)
Myocardial revascularization (n)	15 (37%)
Percutaneous coronary angioplasty (n)	12 (29%)
Systemic arterial hypertension (n)	22 (54%)
Diabetes mellitus (n)	9 (21%)
Dyslipidemia (n)	32 (78%)
Ex-smoker (n)	21 (51%)
Beta-blockers (n)	31 (76%)
Angiotensin antagonists (n)	15 (36%)
Vasodilators (n)	15 (36%)
Antilipemic drugs (n)	33 (80%)
Platelet antiaggregants (n)	29 (70%)

**Values are expressed as means ± SD (minimum and maximum) for age, height, body weight and body mass index and as n (percentage of the sample) for the other variables.*

mmHg/s. The values obtained were shown on the equipment display and duly recorded by the examiner, whereas the patients were unaware of the obtained values . The approximate time needed for each of the measurements was between 25 and 35 seconds.

This equipment is properly certified for blood pressure measurements, according to the technical standards of the country of manufacture, and has been used in other clinical studies[27-29]. Using the device's manual mode, measurements were made at rest, prior to determining the maximal handgrip strength, starting the inflation of the cuff at 20 and 80 seconds of the two maneuvers made with the left arm and also 1 minute after completion of the last maneuver. Data from a pilot analysis showed that after the HR pressure and values measured 1 minute after a single maximal handgrip contraction were virtually identical to resting values

Statistical Analysis

Physical characteristics and clinical data were described as means, standard deviations and minimum and maximum values or by percentage of frequency, as appropriate. For the hemodynamic variables, the type of distribution was initially confirmed using the D'Agostino & Pearson test and then ANOVAs for repeated measures were calculated, which were followed by Bonferroni's multiple comparison tests. Pearson's correlations were analyzed to assess the association between variables. The statistical significance was set at 5%. Statistical calculations and figures were carried out using Prism software version 5.04 (GraphPad, USA). The research project meets the requirements of resolution 196/96 of the Ministry of Health and the Declaration of Helsinki and was appropriately registered with CONEP-MS and institutionally approved by the Committee of Ethics in Research.

Results

The 11 individuals who were experienced and had been regularly undergoing IHT training during the supervised exercise program sessions had resting blood pressure levels slightly higher than those who had no previous experience in the technique, although there was no difference in nature and magnitude of the acute responses to IHT. Moreover, in preliminary analyses, there was no evidence of any difference that could be attributed to any subgroup, whether by gender, medical condition, either by use or nonuse of medications with negative chronotropic action. Therefore, we chose to consider the data from all 41 patients together, without differentiating by regular participation in IHT or any of these potential intervening variables.

In agreement with the diversity of clinical condition and body size, the results of maximal handgrip strength varied between 24 and 136 (in equipment units), with means that were almost identical between the right and left hands, respectively, 78.4 ± 23 and 77.5 ± 22, and a mean difference for each individual of 10% of the measurement - minimum 0 and maximum 21. The degree of accuracy in the maintenance of 30% of maximal handgrip strength for each hand during the two minutes of each series ranged between 90% and 100%, with an average of 97% in 164 maneuvers (41 patients x 4 maneuvers).

None of the individuals had any clinical abnormalities or inappropriate symptoms during or immediately after IHT, with excellent tolerance to the 8-minute exercise protocol. As it usually occurs during IHT, patients noticed mild to moderate fatigue and/or a "burning" sensation in the flexor muscles of the fingers, caused by blood hypoperfusion associated to probable arterial occlusion resulting from the isometric contraction at 30% of maximal voluntary force. The results show that the patients were normotensive at rest - 115/69 mmHg on average (standard error, respectively, 11 and 10 mmHg) - and had an appropriate HR - 64 bpm - before starting the IHT.

As it might theoretically be expected, some of the hemodynamic responses were increased with the continuation of isometric exertion, being somewhat more pronounced in the second minute of the series when compared to the first minute, ending the exertion with significant differences in relation to measurements at rest, in relation to SBP and DBP (mean ± standard error of mean) – delta increment = 16 ± 10 and 7 ± 6 mmHg, respectively – ($p < 0.05$) and minimal difference for HR, which increased only 3 ± 4 bpm ($p < 0.05$). There were no differences in the responses of HR and BP between the two series ($p > 0.05$). The hemodynamic values obtained 1 minute after IHT completion are numerically between the pre-exertion and the final exertion measurements for SBP and DBP ($p < 0.05$), whereas HR had already returned to pre-exercise values ($p > 0.05$). The values of resting HR and delta HR - maximum minus rest – did not correlate ($r = -0.19$, $p = 0.24$).

An additional analysis was performed by comparing the results obtained between the 31 patients who were taking beta-blockers and 10 that were not using these drugs. The values at rest were virtually identical, except for a somewhat lower HR in patients receiving beta-blockers – 69 ± 3.0 (mean and standard error of mean) *versus* 62 ± 2.6 bpm ($p = 0.14$). The hemodynamic responses, either in absolute terms or as variations between resting and maximum values, did not differ with IHT ($p > 0.05$) between patients with and without beta-blockers, including the variation between resting HR and maximum HR values – 1.4 ± 1.4 *versus* 3.3 ± 1.5 bpm ($p = 0.46$).

Discussion

The present clinical study has some strong points, including the relatively large, clinically well-characterized sample, consisting of patients with great familiarity with the location and laboratory facilities and also with the examiners, which minimized the possibility of emotional or anticipatory influence on the measurements that were obtained. The use of digital equipment specific for IHT made it possible for the isometric exertion intensities to be precisely individualized and controlled – thanks to the existence of a continuous visual feedback – throughout the test, as shown by the average percentage of 97%. Moreover, there was an accurate and sophisticated control of hemodynamic variable measurements, eliminating any potential interference or biases on the part of the examiners through the use of equipment with examiner-independent readings. In turn, there are some limitations that deserve further consideration.

Patient selection was not random and included cases with different clinical conditions, which, on the one hand could generate greater variability in results, which did not occur;

on the other hand, it can contribute to increase the external validity of the study. The blood pressure measurement was performed noninvasively, as it would not be practical to use an intra-arterial measurement device; however, the equipment used for measurements is considered valid for exercise situations and allowed the elimination of any possible influence of reading error on the part of the examiner. As only one cuff size was available – adequate for a 27 to 40-cm arm circumference – it was not possible to include some of the thinner or smaller patients or those who were larger or more obese; however, there is no theoretical reason to suppose that the modest hemodynamic responses verified during the IHT would be different in patients with arm circumferences that were smaller or greater than the limits of 27 and 40 cm of the cuff.

No other IHT forms were tested, but only the protocol most commonly used for training and clinical research; however, very recent data point to similar reductions in BP magnitude using different combinations of intervals and percentages of maximal handgrip strength[21, 22]. Although this study used relatively expensive equipment and not readily available in the Brazilian market for IHT performance, other studies have obtained similarly favorable results on resting SBP and DBP in subjects trained with much simpler equipment or materials and even using springs or balls[25]. This question seems relevant if the IHT becomes more widely used as a form of exercise therapy in the treatment of arterial hypertension.

In agreement with the experience in the literature and our own experience of more than one year applying IHT to more than one hundred patients – approximately more than seven thousand sessions – there was no evidence of clinical adverse reactions with IHT, with the procedure being well tolerated and accepted by patients, including the elderly. Knowing that the handgrip strength tends to decrease with aging in patients of both sexes[30,31], it is quite appropriate that the IHT involves the objective measurement of maximal strength bilaterally in each patient, thus effectively allowing training load equalization at a percentage of 30% of the maximal individual strength.

The hemodynamic responses to isometric handgrip exertion have been studied by some authors in the past[32], but without the primary goal of supporting a clinical application such as IHT. Recent physiological studies, with the quantification of some of the cardiorespiratory responses to predominantly static exercises using small and different muscle groups and with different percentages of maximal voluntary strength, have contributed to a better understanding of the mechanisms associated with IHT and similar exercises[14,15,33-37]. Nevertheless, when these physiological data, respecting the methodological differences and small samples involved, are compared with our results, one can identify a

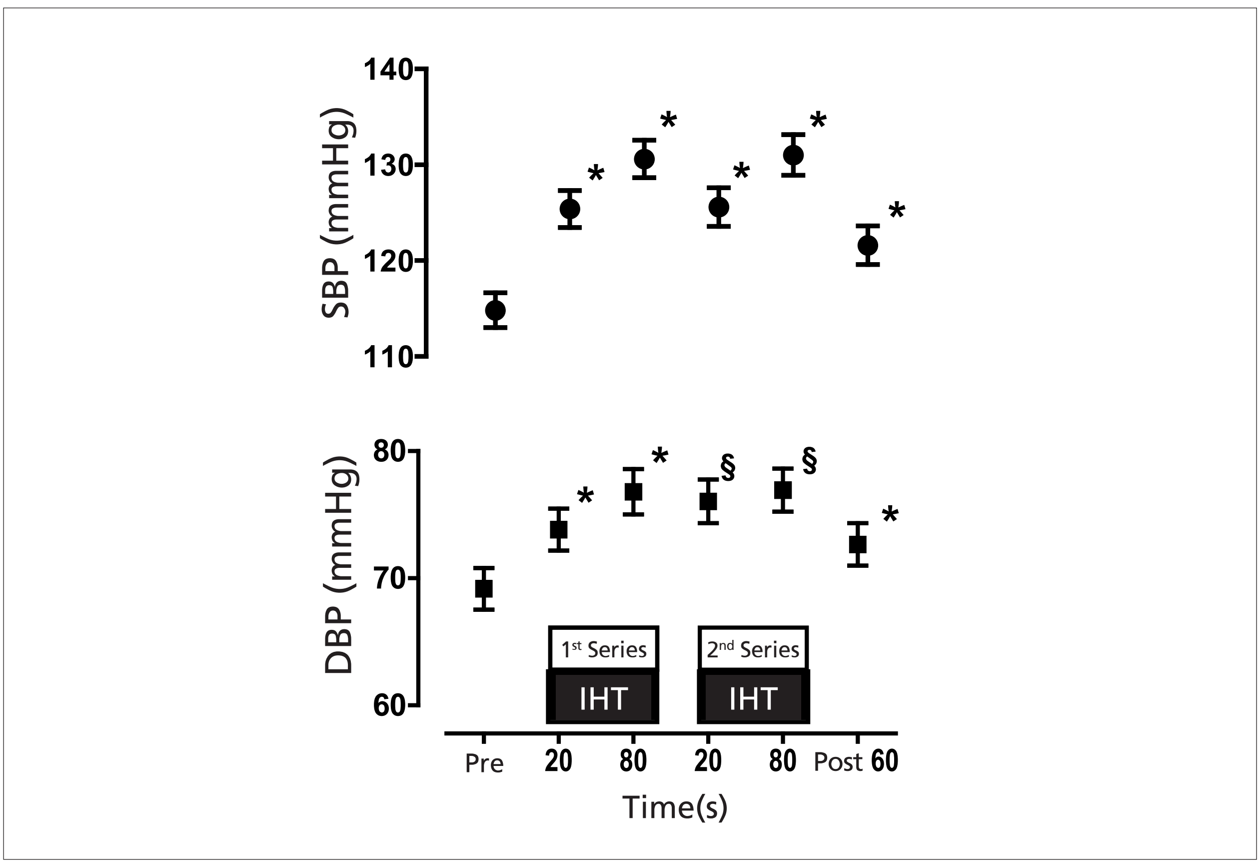

Figure 1 – *Blood pressure responses to isometric handgrip training in 41 patients from a supervised exercise program. IHT – isometric handgrip training; SBP – systolic blood pressure; DBP – diastolic blood pressure; *values different from the initial measurement (Pre) and from the immediately previous measurement; § values different from the initial measurement (Pre) and undistinguishable from the immediately previous measurement.*

reasonable similarity, that is, a minimal hemodynamic effect, especially when the fatigue of the muscle group is not attained, which, in the case of handgrip tends to occur as soon as after 3 minutes[13].

Considering that all patients tested were undergoing regular supervised exercise programs, any differences that might occur in these hemodynamic responses between trained and untrained individuals cannot be assessed, nor was the purpose of the present study.

Although hemodynamic responses were observed as a result of IHT performed in this study, the small magnitude of the differences between the resting conditions and the end of the exercise suggests a minimal or likely negligible clinical significance, representing less than the variation observed during a walk or even a fast riding exercise without load[38].

This aspect is clinically interesting, as previous studies with the latter protocol have demonstrated that the rapid movement of the legs or arms[39] and even the bending of wrists[40] is capable of inducing a rapid and sharp increase in heart rate and also the SBP[41] and that this response can be completely abolished by selective pharmacological blockade with atropine[42], characterizing the mechanism of vagal inactivation as responsible for the response.

From the physiological point of view, with an isometric muscle contraction of 30% of the maximal strength there is no major vagal inactivation and thus, virtually no HR changes. As there should not be an increase in venous return, as there is a mechanical compression of venous vessels by muscle contraction at 30% of maximal intensity in the forearm that is performing the handgrip, the cardiac output must remain very close to the resting value[32]. Thus, the slightest variation in SBP and DBP levels should reflect primarily the small increase in peripheral vascular resistance caused by occlusion of the arterial vessels in the region of muscle contraction, without a significant change in cardiac output. Apparently, the little relevance of the results can be found in subgroups of patients, as objectively tested and confirmed in the comparison made between those with and without regular use of beta blockers.

Additionally, it is worth mentioning that the SBP, DBP and HR values obtained after only 1 minute of recovery were already very similar to those at rest, especially for HR, which showed exactly the same results. These data are literally in accordance with the findings of McGowan et al.[17] and are somewhat less striking than those found by Helfant et al.[11], which probably occurred because the latter have obtained the data during cardiac catheterization in the supine position and using handgrip for 3 minutes.

Conclusions

This study corroborates the clinical impression that the IHT, as performed in this study, a is well-tolerated procedure and cause no adverse signs or symptoms that induces transient and modest hemodynamic responses in patients attending supervised exercise and/or cardiac rehabilitation programs and who have adequately controlled resting blood pressure levels. We expect that this study will contribute to an increased use of IHT in the therapeutic management of patients with cardiovascular diseases in our country.

Future guidelines of the Brazilian Society of Cardiology (SBC) on the subject of physical exercise might include this type of training as potentially helpful in reducing blood pressure levels and producing favorable vascular and autonomic changes, as it has been well documented in the current medical literature[19, 21, 22,24,43].

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Potential Conflict of Interest

Dr. Claudio Gil Soares de Araújo - Potential conflict of interest: Provision of one of the devices used in the study at a special price (Tango SunTech, USA).

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