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The Effect of Age on Selected Cardiovascular Responses to Static (Isometric) Exercise[1] (40518)

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Considerable effort has been devoted to the study of the cardiovascular responses to static exercise. In healthy subjects, sustained static exercise elicits an increase in heart rate (HR) and cardiac output (CO) which results in an increase of systolic and diastolic blood pressure (BP). Generally there is little change in peripheral resistance, but in some cases it does increase (1–3). These cardiovascular responses appear to depend on the tension developed by the muscle(s) involved relative to their maximal capability and are independent of the muscle mass or absolute tension developed (1). These responses seem to be neurally mediated by both cortical and peripheral components (4, 5). The latter is apparently due in part to a chemical factor which excites nerve endings in the muscle and elicits a reflex response (5).

While the effect of age on the cardiovascular responses to dynamic exercise has been studied, few studies have examined the effect of age on the responses to static or isometric exercise. McDermott and co-workers found no differences in HR and BP in response to a sustained static contraction between a group of 25- and 47-year-old subjects (6). However, Petrofsky and Lind found the HR responses to a sustained handgrip contraction decreased with increasing age in subjects up to 62 years of age. The older subjects had a higher resting systolic BP and this difference increased as BP rose in response to the static effort (7). Based on these findings, the purpose of the present study was to examine the cardiovascular responses to static exercise in normotensive subjects beyond 62 years of age.

Materials and methods. The subjects for this study were male volunteers selected from the Lexington community. All volunteers met the following criteria:

1. Resting systolic BP was no higher than 140 mm Hg.
2. Resting diastolic BP was no higher than 90 mm Hg.
3. There was no history of heart disease or any other cardiovascular disorder as determined by the volunteer's personal physician.
4. There was no medical disorder that required prescription medication on a continuing basis.
5. The volunteer did not participate in regular vigorous exercise.

Following a detailed explanation of the testing procedures, each subject gave written informed consent. Orientation sessions were conducted for each subject to minimize apprehension and to facilitate the collection of usable data.

At each testing session, the subject was seated in a dental chair in a room maintained at approximately 23°. A BP cuff was placed on the nonexercising (left) arm. The subject performed three brief (2 sec) maximal voluntary contractions (MVC) on a handgrip dynamometer with rest periods of 3 min between each contraction. This was followed by a 10-min recovery period, during the last 5 min of which control levels of BP and HR were determined. At the end of the recovery period, the subject maintained for 3 min a handgrip tension equal to 15 or 30% of the greatest of his MVCs. Handgrip tension was monitored visually on a Tektronix Oscilloscope Type 502A by the subject and was recorded on a Grass Polygraph Model 79D. The oscilloscope and handgrip device were mounted on a movable cart to minimize the use of muscles other than handgrip to maintain the required tension.

BP was recorded once each minute during the entire experiment. The pressure cuff was inflated automatically to approximately 200 mm Hg and then bled to approximately 20 mm Hg over a 45-sec period. Korotkoff

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sounds were detected by a microphone in the cuff and recorded on the polygraph. At 20 mm Hg, the balance of the air in the cuff was rapidly released to await the next inflation in approximately 15 sec. HR was determined from the recorded Korotkoff sounds.

In addition to the orientation session, each subject was tested twice at both the 15 and 30% MVC exercise level. At least 48 h elapsed between test sessions. The mean response value for each subject was calculated for each exercise level.

The subjects were divided into three age ranges: (a) 21–42 yr (mean 29 yr, $n = 10$); (b) 65–70 yr (mean 68 yr, $n = 11$); and (c) 73–91 yr (mean 81 yr, $n = 6$). The Student's 't' test was used to analyze the differences among the three groups for the parameters measured.

Results. As shown in Table I, with the exception of handgrip strength, the control values were not significantly different among the groups for the parameters indicated. The handgrip strength of Group 1 was significantly greater than those for Groups 2 and 3 ($P \leq 0.01$). There was no difference in this parameter between Groups 2 and 3.

At the 15% MVC exercise level there were no significant differences among the responses of the groups. However, at the 30% MVC level, significant differences of HR ($P \leq 0.01$) were found among all groups (Fig. 1). The HR of the youngest group increased 24.2% ± 4.9 compared to a 10.9% ± 1.1 increase in the middle group and a 5.2% ± 1.8 increase in the oldest group. In addition, the diastolic BP of Group 1 increased 32.2% ± 2.9 which was significantly higher ($P \leq 0.01$) than the 19.4% ± 3.0 increase seen in Group 3. The diastolic BP increases between Groups 1 and 2 and Groups 2 and 3, however, were not significantly different. The changes in systolic BP and mean arterial pressure (MAP) were not significantly different among any of the groups.

Discussion. These results demonstrate that static handgrip contraction maintained at 30% MVC for 3 min evokes significant increases in BP and HR at all ages tested. However, the HR and diastolic BP response to the exercise declines as a function of increasing age. The HR and BP responses of the youngest group to 30% MVC in this study

TABLE I. Control Heart Rates, Blood Pressures and Handgrip Strengths in Male Subjects of Three Different Age Groups

	Group 1	Group 2	Group 3
N	10	11	6
Age-range (yr)	21–42	65–70	73–91
Age (yr)	29 ± 2.3*	68 ± 0.5*	81 ± 2.9*
Systolic BP (mm Hg)	118 ± 2.0	121 ± 3.6	122 ± 5.9
Diastolic BP (mm Hg)	78 ± 1.3	77 ± 2.1	71 ± 4.4
Arterial pressure (mm Hg)	92 ± 1.4	92 ± 2.5	88 ± 4.6
Heart rate (beats/min)	73 ± 2.1	71 ± 1.3	73 ± 4.1
Handgrip MVC (Kg)	55 ± 2.8	43 ± 1.8	41 ± 1.5

* MEAN ± SEM.

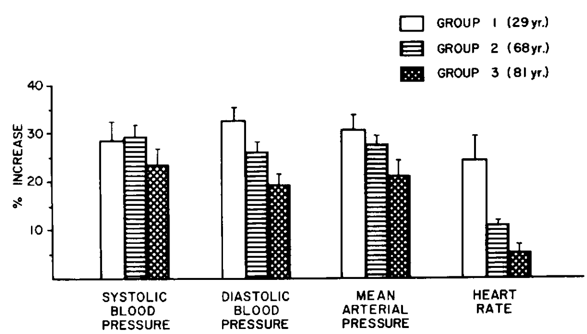

FIG. 1. Percent increases in heart rate and blood pressure in response to 3 min of static handgrip exercise at 30% MVC in male subjects of three different age groups.

are similar to those found by Martin and coworkers who used the same exercise regimen with subjects of comparable age (8). The HR response to the 30% MVC level of exercise is consistent with the findings of Petrofsky and Lind, who found an inverse relationship between age and the HR response to a handgrip contraction sustained to fatigue at 40% MVC (7, 9).

This relationship between age and HR response to sustained static exercise remains to be elucidated. Possible mechanisms include: (a) A reduced sensory input from the contracted muscle; (b) an alteration in the balance between sympathetic and parasympathetic nervous control of HR; and/or (c) an alteration in the transmitter–receptor interaction controlling HR.

It is well established that with increasing age there is a gradual reduction in maximal HR in response to rhythmic exercise. If the average HR response to 30% MVC for each group is normalized by dividing by the predicted maximal exercise HR as determined by Robinson (10), the resulting values are .47, .50, and .52 for Groups 1, 2, and 3 respectively. Therefore, the reduced HR response seen in older subjects may be related to the decline in maximal HR found as a function of increasing age.

The reduced diastolic BP response of our oldest group may be only a function of the reduced HR response seen in the older groups. Our older subjects are a very select group whose vascular compliance might be comparable to younger subjects since all three groups have the same control values. A reduced HR would allow more time for peripheral run-off following systole, which ultimately would be reflected in a reduced diastolic BP. There is a high correlation ($r = .76$) between the changes in HR and diastolic BP for all subjects at 30% MVC (Fig. 2).

The differences in the HR and diastolic BP responses among the groups might be related to the different handgrip strengths found among the groups. Previous studies have shown an inverse relationship between absolute isometric strength and relative isometric endurance (11, 12). One would then expect subjects with a lower MVC to have a greater endurance time at a given percent MVC than their stronger counterparts. Maintaining a given percent MVC for a set period of time might thus provide a proportionally greater stress on stronger subjects. Since Group 1 subjects had a stronger handgrip than those in Group 2 or Group 3, the data were analyzed from subjects from each group selected for the same mean level of strength. This analysis showed that the HR response still differed significantly between Groups 1 and 2 and Groups 1 and 3 ($P \leq .05$), and the diastolic BP response differed between Groups 1 and 3 ($P \leq 0.05$).

Summary. To determine the effect of age on some cardiovascular responses to static exercise, three groups of male subjects performed handgrip exercise bouts in which each maintained 15 or 30% of his MVC for 3 min. Mean ages for the three groups were 29, 68, and 81 yr. There were no significant differ-

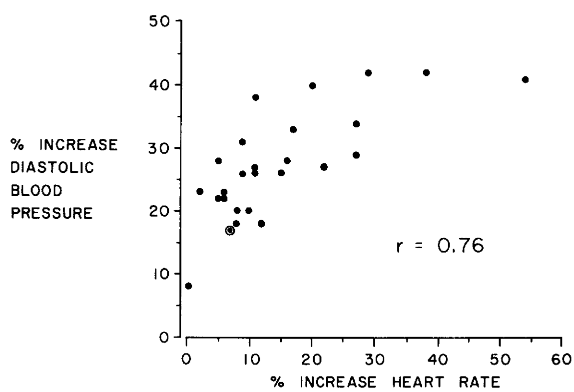

FIG. 2. Relationship between percent increases in heart rate and diastolic blood pressure in response to 3 min of static handgrip exercise at 30% MVC in male subjects.

ences among the control BPs or HRs of the three groups. At 15% MVC, there were no significant differences in the cardiovascular responses among the groups. At 30% MVC, however, the HR response of the youngest group was significantly greater than that of the middle group, which was significantly greater than the oldest group. Additionally, the diastolic BP response at 30% MVC was significantly greater in the youngest group than in the oldest. No other significant differences were shown at 30% MVC. The results indicate that as a function of increasing age, there is a decrease in the response of HR and diastolic BP to static handgrip exercise.

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