A NYONE with a stethoscope, a sphygmomanometer, and an open mind can readily satisfy himself that static effort or "isometrics" may raise the blood pressure to high levels. Yet, isometrics, as a form of exercise intended as a means of attaining physical fitness, has been urged on the population at large. A recognition of the fact that the obese, the infirm, and the aged are unlikely to commence jogging around the neighborhood before breakfast, apparently has recently led some advocates of isometrics (including physicians) to write in the open press urging the waddlers to turn instead to press-ups (push-ups) and pull-ups. Judging by current advertisements, the sale of a variety of devices for isometric exercises may have become brisk. In view of these trends, it is worth while to reiterate certain reported data concerning the physiologic responses to isometric exercise and to examine the case for and against this type of activity.

There are many kinds and degrees of static effort. Common examples are lifting, holding or carrying objects of all kinds, pushing furniture, and opening doors or windows that are difficult to move. Everyone is familiar with the tiring effects of holding or carrying large, awkwardly shaped objects. Working with the arms overhead is another common example since a good deal of static effort is needed to hold the arms in position, even before muscular activity or the weight of tools has been added.

Isometric training has been shown to improve the strength of a muscle group. To attain this improvement, the training stints must be undertaken at tensions of 50% or more of the muscle's maximal capacity. While the increase in efficiency of any physiologic function is a worthwhile goal, the only known improvement as a result of such training is in isometric strength. With isometric training there is strikingly little associated increase in aerobic capacity or cardiovascular efficiency and little contribution to fitness for sustained dynamic exercise.¹

There is clear evidence that any muscle group can maintain tensions of up to 10% or 15% of the maximal capacity (MVC) for a long time. At these low tensions, the heart rate and blood pressure increase by a few beats per minute and by some 5 to 15 mm Hg, respectively, to reach a steady state which continues for as long as the tension is maintained. The muscle blood flow also increases to a steady state, which clearly sets the stage for contractions that can be held for a long time.²⁻⁵ But contractions at such low tensions do not improve muscle strength, so we have to consider the events during higher...
tensions, when the cardiovascular effects are very different.

At skeletal muscle tensions of 20% MVC and higher, fatigue occurs rapidly. For example, at 20% MVC, the contraction can be held for only 10 to 12 minutes. At 30% MVC, the duration is about 5 minutes, while at 50% MVC, it is 1 to 2 minutes. Here, the blood flow in the muscle does not reach a steady state; nor does the heart rate or blood pressure. Instead, all these factors continue to increase until fatigue intervenes. The increase in heart rate is modest; at the point of fatigue it is uncommon to find values over 120 beats per minute, but both systolic and diastolic pressure increase dramatically and almost in parallel, and mean blood pressure at the point of fatigue is commonly 140 mm Hg or more (fig. 1). By contrast, in fatiguing rhythmic exercise (a treadmill test of progressive severity), the heart rate characteristically reaches maximum or near maximum values, while the mean blood pressure shows only slight changes.

In isometric exercise, the stroke volume does not increase and at higher tensions (for example, 50% MVC) it decreases, so that increased heart rate is the sole contributor to the increase in cardiac output. There is a mild

Figure 1

"Comparison of the heart rate and blood pressures (systolic, diastolic and estimated mean pressures) in response to a fatiguing, sustained hand-grip contraction at 30% MCV, and to an exhausting treadmill-walking test with stages of progressive severity shown as oxygen uptake/kg body weight/min. The results clearly show the dramatic rise of blood pressure, and the modest rise of heart rate during the sustained hand-grip, which contrast with the large rise in heart rate with little change in mean blood pressure during the fatiguing rhythmic exercise."

but widespread peripheral vasoconstriction in isometric work so that the increased cardiac output results in increased blood pressure. The only available evidence suggests that isometric work in older people does not raise cardiac output much, if at all; the large increase in blood pressure is due to a more intense peripheral vasoconstriction.\textsuperscript{2, 5} Whichever mechanism is invoked, isometric exercise is inevitably accompanied by an increase in mean blood pressure, which can only be called dramatic when it is remembered that at 50\% MVC, for example, it can reach 140 mm Hg or more in about 1 minute.

A striking point is that the mass of skeletal muscle involved is within an extreme range unimportant. The relevant factor is the fraction of the maximum isometric tension exerted by any muscle group. For example, a 30\% contraction of the small forearm muscles in a hand grip and a 30\% contraction of the large leg muscles pushing the knee up against an immovable force result in the same degree of pressor response, despite the fact that the absolute tensions involved are (for fit young men) about 20 kg for the forearm and 70 kg for the leg. Simultaneous contractions of two groups of muscles, at the same proportional tension, do not have an additive effect and the pressor response remains the same as if only one of the groups of muscles had contracted. Furthermore, the pressor response to static effort is the same when the individual is seated or when he is already engaged in mild or even hard rhythmic exercise, when the increases in heart rate and blood pressure are simply superimposed on the existing responses to the dynamic work. The pressor response to isometric contractions is therefore powerful, ubiquitous, and elicited alike from small or large groups of muscles, and when the individual is otherwise at rest or when he is already active.\textsuperscript{2-5}

Such increases of blood pressure may represent a potential risk for patients with aneurysms or incompetent valves. The effects for those with known or latent coronary insufficiency are in part probably illustrated by the occasional patient in whom angina pectoris is dramatically precipitated by working with arms extended or elevated. Because the heart is considered to tolerate an increased pressure load less well than an increased flow load, one could logically assume that isometric exercise is undesirable in patients with coronary artery disease or with borderline hemodynamic function. However, the phenomenon needs more extensive study, and practitioners will wish to consider its possible effects on cardiac patients. It is noteworthy that carefully monitored use of briefly sustained isometric forearm contraction appears promising as a simple means of imposing a graded pressure load during functional evaluation of patients with cardiovascular disease.\textsuperscript{6}

In addition to patients, the obese, the infirm, and the aged often have flabby, untrained muscles, which are less able, proportionately, to lift or support their body weight. Due partly to their weaker muscles and partly to the effects of gravity on relatively or actually greater limb or body weight, they would more likely have large increments in blood pressure than the younger or more physically fit when they practice isometric exercises. This is particularly so if those exercises are based on lifting the whole or part of the body weight (such as in press-ups or pull-ups). There is an ironic twist in that most of the recent popular articles urge the use of isometrics mainly in these groups of people, known to be more likely to have actual or potential weaknesses in their cardiovascular systems. If there is one kind of apparently innocuous exercise that might search out such weaknesses, it is isometrics. If there is one kind of exercise that does little to improve overall work performance or cardiovascular fitness, it is isometrics.

For younger and fit people, no problems are likely to arise in practicing isometric exercises. The cosmetic benefits for young and not-so-young men are legendary. There are other possible benefits which have not yet been fully explored or documented. For example, it is possible that for those who suffer transient postural dizziness, appropriate isometric exercise may help to mobilize their cardiovascular
responses, particularly by an increased blood pressure or by the mild generalized vasoconstriction in inactive tissues. The pilot who blacks out in high G maneuvers, simply because of a reduced hydrostatic cerebral blood pressure, might find isometrics of help. One could further conjecture that an athlete seeking power for his final sprint might benefit from an increased perfusion pressure by isometric hand exercise. But, until these and other investigations underway have been completed, it would be unwise to assume that such beneficial effects exist.

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References

1. MÜLLER EA: Physiological methods of increasing human physical work capacity. Ergonomics 8: 409, 1965
3. LIND AR, McNicol GW: Circulatory responses to sustained hand-grip contractions performed during other exercise, both rhythmic and static. J Physiol (London) 192: 595, 1967

First Angina — Isometrics?

Winston Churchill — December 27, 1941

He was in bed and looked worried.

"It was hot last night and I got up to open the window. It was very stiff. I had to use considerable force and I noticed all at once that I was short of breath. I had a dull pain over my heart. It went down my left arm. It didn't last very long, but it has never happened before. What is it? Is my heart all right? I thought of sending for you, but it passed off."—MORAN, C. McM. W., BARON: Churchill: The Struggle for Survival 1940-1965. Taken from the Diaries of Lord Moran. Boston, Houghton Mifflin Co., 1966, p. 17.
Cardiovascular Responses to Static Exercise (Isometrics, Anyone?)
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Circulation. 1970;41:173-176
doi: 10.1161/01.CIR.41.2.173

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