Editorial

The Effects of Rest in Bed and of Exercise on Cardiovascular Function

A MAJOR CONTRIBUTION to the understanding of the relationship of physical activity to cardiovascular function has been published as a supplement to the November Circulation, entitled "Response to Exercise After Bed Rest and After Training." by Saltin, Blomqvist, Mitchell, Johnson, Wil- denthal, and Chapman. Cardiac output at work intensities that elicit maximal oxygen intake varied from 14.8 L/min after rest in bed to 22.8 L/min at the end of an intensive conditioning program which followed rest in bed. The maximal oxygen intake paralleled changes in cardiac output closely, increasing from 2.43 L/min after bed rest to 3.86 L/min at the end of the training program.

In 1926, Hill stated that maximal oxygen intake is reached when oxygen intake per unit time has attained "its maximum and remains constant owing to the limitations of the circulatory and respiratory systems." Saltin and Mitchell, Wil- denthal, and Chapman have documented part of this statement over a wide range of fitness and have made the key observation that the range of the arteriovenous difference at maximal oxygen intake at the several stages of fitness is narrow, thus making it clear that the principal determinant of maximal oxygen intake is the cardiac output. Hill, in his original analysis of the maximal oxygen intake, included the respiratory system as a limiting factor, but examination of the problem with modern methods has ruled out pulmonary function as an important limiting factor in the absence of chronic pulmonary disease. Saltin and his colleagues have shown an increase in the diffusion capacity, measured with carbon monoxide, which is related to the quantity of blood in the pulmonary capillaries which increases after training.

In 1926, Bock and his collaborators at the Harvard Fatigue Laboratory studied Clar- ence DeMar, the well-known marathon runner, and several relatively sedentary men by means of the CO₂-rebreathing technique for measuring cardiac output. The conclusions reached were that the well-conditioned man performs submaximal work with a higher cardiac output and a larger stroke volume than his sedentary contemporary.

Similar results were obtained by Christensen using the acetylene procedure. Keys and Friedell provided a cross-section study confirming the large stroke volume of athletes. Subsequent studies were in general agreement regarding stroke volume but failed in some investigations to confirm the increased cardiac output during submaximal work in the conditioned athlete.

But the doubts that remained were based on questions of technique and confusion concerning experimental design. Saltin and his colleagues found an increased stroke volume, but no difference in cardiac output, when the values after training were compared to those found in the control period. After rest in bed, three subjects showed no change in cardiac output during upright submaximal work while in two it was decreased; and during submaximal supine work, the cardiac output was reduced in all. The authors drew the interesting conclusion that the effects of rest in bed could not be attributed entirely to impairment of peripheral circulatory control.

Data from two other studies which followed cardiac output during a period of intensive physical training have been pooled to show that the improvement in cardiovascular function to be expected from a conditioning program is related to the initial level of maximal oxygen intake, expressed as milliliters per kilogram of body weight per minute. The data suggest that the upper limit of
cardiovascular performance which can be attained by training young men is described by a maximal oxygen intake of roughly 65 ml/kg/min. Elite cross-country skiers and distance runners have maximal oxygen intakes of 75 to 85 ml/kg/min. Another difference between the men trained for a short period and the champion athletes is the stroke volume, which is substantially larger in the athletes. It seems unlikely that physical training alone can account for the observed differences. But since the currently available data are confined to short-term training (9 months or less), systematic studies over a period of years will have to be done to settle the point.

Cumming has recently discussed physical fitness and pointed out some of the unanswered questions which remain regarding the relationship of cardiovascular fitness to health. Saltin and his co-workers have documented modification of physical activity as a powerful tool, which the physician can use to achieve substantial alterations in the functional capacity of the cardiovascular system. It remains to be demonstrated that specific levels of cardiovascular fitness are related to cardiovascular health.

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References
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