Cardiovascular Response to Exercise in Women

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There are physiological and morphological gender differences in humans. It is likely that certain gender-specific factors such as differences in some hormonal levels, menstrual cycle variability, and physical characteristics (primarily cardiac size and function) may influence the cardiovascular response to exercise in women.

The most consistent gender difference in cardiovascular responses during submaximal exercise and at peak effort is the lower stroke volume (SV) of women and the smaller increase in SV from rest to exercise. It has been proposed that the smaller SV response during exercise in women is due mainly to a smaller cardiac size, particularly left ventricular (LV) volume and mass (5,11). Additionally, the difference in cardiac size has also been assumed to account for a majority of the difference in maximal oxygen uptake ($\dot{V}O_{2max}$) during exercise in genders, which is usually reported to be higher in men than in women, whether it is expressed in absolute value or relative to body mass (11). $\dot{V}O_{2max}$ is the best objective measure of fitness and is a widely used index of the integrity of cardiovascular function (21).

Previous studies demonstrated that in normal men during upright exercise, SV was augmented through both an increase in LV end-diastolic volume and a decrease in LV end-systolic volume, resulting in an increase in LV ejection fraction (8,19,22). However, it has also been suggested that LV ejection fraction did not increase and even decreased from rest to peak exercise in women (1,6,7). These results may indicate that gender is an important factor determining the central hemodynamic response to exercise in normal humans. This notion was supported by the findings that during treadmill exercise, stroke index (SV normalized by body surface area) was lower in women than in men and did not increase from rest to peak exercise in women (9,10). In contrast, Sullivan et al. (23) observed no differences in cardiac index, stroke index, and LV end-diastolic and end-systolic volume indexes in the time course or magnitude of changes with respect to oxygen uptake ($\dot{V}O_2$), expressed as percentage of $\dot{V}O_{2max}$ in men and women.

Our unpublished data on HR responses to exercise in untrained and highly trained young individuals is consistent with the findings of Sullivan et al. (23). In accordance with all previous studies, we found that HR increased progressively during submaximal exercise and reached a maximal value (HR_{max}) at peak exercise effort in all subjects. The increase in HR was greatest in untrained women and smallest in highly trained men at the same absolute work rate, which was expressed as $\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$), whereas highly trained women had a smaller increase in HR than untrained men. However, HR_{max} was not different between genders. Interestingly, when we compared the HR responses at the same relative work rate, namely, the percentage of $\dot{V}O_{2max}$ (%), we found no difference among groups (Fig. 1). Results from our study and that of Sullivan et al. may suggest that cardiovascular control during dynamic exercise is similar in men and women, no matter whether they are trained or untrained.

One of the key principles in exercise physiology in humans is the remarkably constant relationship between the increase in $\dot{V}O_2$ and the corresponding increase in cardiac output (14). In general, about 6 L of cardiac output are required for every liter of $\dot{V}O_2$ above rest, regardless of age, gender, or fitness level (20). In numerous studies from our laboratory, we observed that the line relating the increase in $\dot{V}O_2$ to the corresponding increase in cardiac output during exercise was entirely overlapped, and the slope of the line was exactly the same between men and women as well as between untrained and highly trained individuals (Fig. 2). This observation confirms that cardiovascular control during exercise is constant in normal individuals, independent of age, gender, and physical condition.

Indeed, in the late 1970s, Wilmore (25) found that there were rather substantial physiological and morphological gender differences between the average male and the average female; however, these differences seemed to be reduced considerably when comparisons were made between the highly trained male and female athletes who were competing in the same event or sport. Later, Zwiren et al. (26) investigated cardiovascular responses to submaximal bicycle ergometry exercise in equally trained men and women and found that the magnitude of gender-related differences in cardiovascular responses during exercise appears to be

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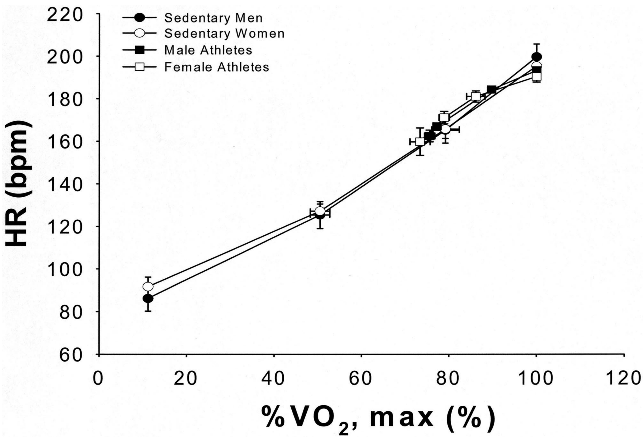

FIGURE 1—Comparisons of HR responses during submaximal and maximal exercise in sedentary men and women and during submaximal exercise in highly trained male and female athletes at the same relative work rate, expressed as the percentage of maximal oxygen uptake ($\dot{V}O_{2max}$), which represents a matter of cardiovascular control during exercise in normal humans.

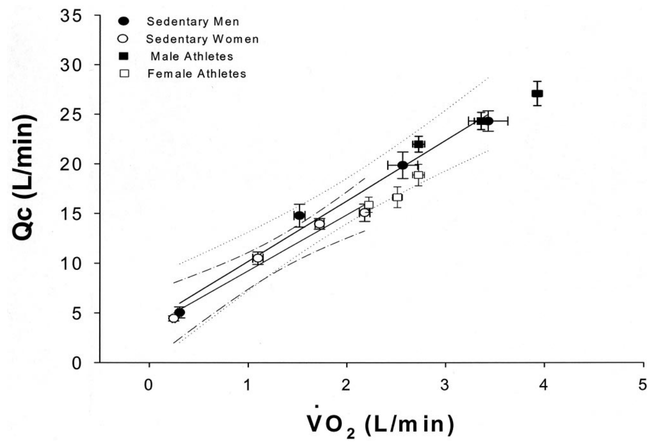

FIGURE 2—Relationship between the increase in oxygen uptake ($\dot{V}O_2$) and the corresponding increase in cardiac output ($\dot{Q}c$) during submaximal and maximal exercise in sedentary men and women, during submaximal exercise in highly trained male and female athletes. Data from six sedentary men and six sedentary women at rest, during two submaximal steady-state work rates and an incremental test to maximal. Athlete data from 39 (27 men and 12 women, aged 18–31 yr) competitive collegiate athletes performing three steady-state work rates up to 10 mph for women and 12 mph for men. All studies done on the same treadmill, using the same acetylene rebreathing system for cardiac output, and Polar HR monitor. Regression lines drawn through data from sedentary men and women only.

smaller than previously thought. They thereby concluded that gender difference in certain cardiovascular responses to submaximal exercise was a consequence of different levels of physical condition of men and women. Similarly, O'Toole (17) reported that the overall response of the cardiovascular system to exercise was similar in men and women. In 1990s, Pivarnik and Sherman (18) also found that gender differences appear to be negligible when comparing aerobically trained men and women. Mitchell et al. (15) demonstrated that the overall response to acute and chronic exercise in women appears to be similar to the response in men. In addition, it has been shown that although highly trained women runners have much higher $\dot{V}O_{2max}$ and submaximal as well as maximal SV, but lower HR than those untrained women of comparable age, they have similar cardiovascular endurance capacity compared to highly trained men (24).

It is well known that $\dot{V}O_{2max}$ decreases with advancing age (14,21). A lower SV, HR, and arteriovenous oxygen difference across the body at maximal exercise all contribute to the age-related decline in $\dot{V}O_{2max}$, not only in the untrained individuals but also in the endurance exercise–trained men and women (16). Fleg et al. (4), found that age and gender each had a significant impact on the cardiac response to exhaustive upright cycle exercise. It was demonstrated by Hossack and Bruce (9) that the normal range of maximal values for $\dot{V}O_2$, HR, cardiac index, and stroke index during treadmill exercise testing decreased with age in both genders, but men showed a significantly greater reduction than women. On the other hand, FitzGerald et al. (3) reported that the absolute ($mL \cdot kg^{-1} \cdot min^{-1}$ per year) rate of decline in $\dot{V}O_{2max}$ with increasing age was greatest in highly trained women, next greatest in active women, and lowest in sedentary women; however, when expressed as percentage or relative decrease from mean levels at approximately 25 yr of age, the rate of decline in $\dot{V}O_{2max}$ was similar in the three groups. Similar to the previous findings in untrained women (2,12,13), it was found that menopausal status did not affect cardiovascular fitness in masters women runners (24).

In summary, it seems to us that gender does not affect significantly cardiovascular responses to exercise in both untrained and highly trained individuals. For any task requiring a given absolute oxygen uptake, women are working at a higher percentage of their exercise capacity than men. This would result in a higher HR, greater stress, and a quicker onset of fatigue during the exercise. If allowed to work at a similar percentage of their maximal exercise capacity, men and women would have similar cardiovascular responses. Though cardiovascular endurance capacity declines with advancing age without obvious gender differences, the menopausal status does not seem to influence cardiovascular fitness in sedentary women and in masters women athletes.

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