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Cardiac Responses to Exercise with Age in Healthy Women

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Abstract To evaluate the cardiac responses during exercise across the age groups in healthy women. Cardiopulmonary indices and Borg scale were obtained at rest and during exercise in twenty-one young female university students and 23 healthy postmenopausal volunteers. Exercise workloads in the younger group were significantly higher than those in the older group at anaerobic threshold (85±13 vs 58±13 watts, respectively ; $p<0.001$) and at peak exercise (141±18 vs 93±17 watts, respectively ; $p<0.001$). Heart rates were not different between two groups at rest, but were significantly greater in the younger group than in the older group at anaerobic threshold (144±13 vs 124±11/min, respectively ; $p<0.001$) and at peak exercise (179±12 vs 157±14/min, respectively ; $p<0.001$). Oxygen uptake was significantly higher in younger subjects than in older subjects at anaerobic threshold (18.1±2.2 vs 15.0±2.3ml/kg/min, respectively, $p<0.001$) and at peak exercise (27.2±2.4 vs 21.1±4.0ml/kg/min, respectively ; $p<0.001$). However, oxygen pulses in the younger group were not significantly different from those in the older group at rest and during exercise. There were no difference in Borg scale between two groups at anaerobic threshold and at peak exercise.
Conclusions : These data suggest that the decline of physical working capacity in older women is contributed by the failure of increase in oxygen delivery which was mainly determined by the limited increase in exercise heart rate.

Key words : Age, Exercise, Heart rate, Oxygen uptake, Borg scale.

Introduction

An evidence obtained in isolated cardiac muscle tissues has indicated relatively little age-related changes in intrinsic cardiac muscle function[1-3]. It is documented that there is no major change in cardiac function at rest in normal aging people[1-4]. However, the cardiovascular response to exercise is altered with age. Although many investigators reported the age-associated decrease in the ability of physical work[1-6], none of the reports clearly identified the factors which limit ability to exercise in normal aging people.

In order to identify the factors to limit the exercise capacity in aging people, the present study observed the differences of cardiac responses to exercise between the younger and older groups. Furthermore, Borg scale, a scale for ratings of perceived exertion, was observed in relation to the objective findings in these two groups.

Methods

Subjects

The study consisted 21 younger females (20.7±0.9 years, 20-22 years) and 23 older females (58.6±5.4 years, 50-67 years), in whom cardio-pulmonary diseases were excluded by the physical examination, ECG, chest X-ray film and exercise ECG. Heights were 158±4.5cm in younger subjects and 151±5.2cm in older subjects. Weights were 51.1±4.9 kg, and 53.2±6.9kg, respectively. The younger group included university students and the older group included active healthy postmenopausal subjects who were the attendants of a health education program at the city hall. None of the subjects had ever been smokers. Before the study, each subject consented to the exercise test after a full explanation of the procedure.

Exercise testing

Subjects were exercise tested on an electric ergometer (Combi, Minato 232C) after the preliminary exercise test was done on the different day to allow the subjects to become familiar with the test. They abstained from food and coffee for at least 2 hours before the exercise. Subjects were studied with the initial work rate consisted of 2min of pedaling on an unloaded (0 watt) cycle ergometer, followed by the individualized ramp exercise to elicit a test duration of approximately 8 to 12min until symptoms limited the exercise[7-9]. Pulmonary gas exchange variables were measured using Minato Aeromonitor AE-280, which analyzed expired air by the breath-by-breath method. Gas exchange variables were consisted of minute ventilation (L/min, BTPS), oxygen uptake (ml/min/kg, STPD), carbon dioxide output (ml/min, STPD), the respiratory exchange ratio, and the oxygen pulse (oxygen uptake divided by heart rate, ml/beat). The anaerobic threshold was determined by two independent observers at the point of departure from linearity in the minute ventilation and carbon dioxide production responses for oxygen uptake, without minute ventilation/carbon dioxide production increasing, and with the abrupt increase in the respiratory exchange ratio. Peak oxygen uptake was determined by the average of the last 10 breaths. A standard 12-lead ECG and blood pressure were obtained at rest and throughout the exercise test and recovery period.

Subjects were asked to grade "the sense of effort" required to breathe with a Borg category scale as described previously[5,6].

Statistics

All values are expressed as mean ± standard deviation. Analyses of variance were used for comparison of workload, heart rate, blood pressures, oxygen uptake, oxygen pulse, and Borg scale between younger and older female subjects. A p value <0.05 was considered significant.

Results

Cardiopulmonary indices and Borg scale at rest, at anaerobic threshold and peak exercise in the younger and older groups are shown in Table I. Exercise work loads (Fig. 1) were greater in the younger group than in the older group at anaerobic threshold ($p<0.001$) and at peak exercise ($p<0.001$). Heart rate (Fig. 2) was not different between two groups at rest, but was significantly higher in the younger group than in the older group at anaerobic threshold ($p<0.001$) and

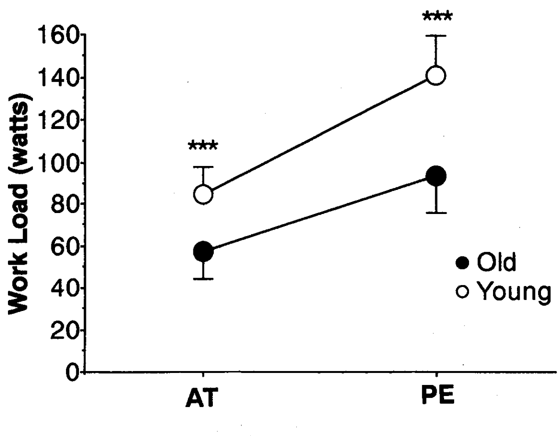

Fig 1. Age-related differences in the work load at anaerobic threshold (AT) and peak exercise (PE) in the younger and older groups. Exercise work load was significantly greater in the younger group than in the older group at anaerobic threshold and peak exercise. ***$p<0.001$

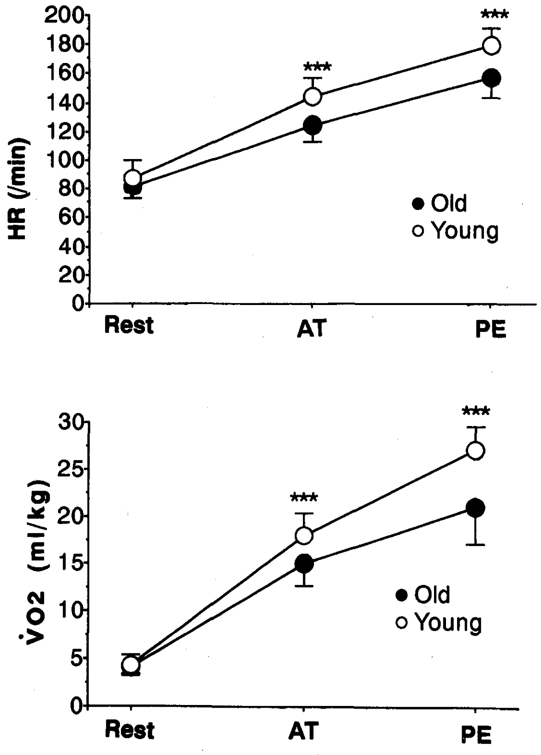

Fig. 2. Heart rate (HR). (upper panel) and oxygen uptake(VO2) (lower panel) at rest, anaerobic threshold(AT) and peak exercise (PE) in the younger and older groups. Heart rate and oxygen uptake were significantly greater in the younger group than in the older group at anaerobic threshold and peak exercise. ***$p<0.001$

at peak exercise ($p<0.001$). Compared to the younger group, the older group had significantly higher systolic blood pressures at rest ($p<0.001$), anaerobic threshold ($p<0.001$) and peak exercise ($p<0.001$), and diastolic blood pressure at rest ($p<0.001$), anaerobic threshold ($p<0.001$) and peak exercise ($p<0.05$). Oxygen uptake (Fig. 2) was not different between the two groups at rest, but was significantly higher in the younger group than in the older group at anaerobic threshold ($p<0.001$) and at peak exercise ($p<0.001$). Oxygen pulse in the younger group did not show any difference from that in the older group at rest and at all exercise levels (Table 1). Borg scale was not different between both groups at anaerobic threshold and at peak exercise (Table 1).

Discussion

Exercise cardiac responses according to the age

It has been generally accepted that a diminution in exercise cardiac function is a manifestation of the aging process. In normal persons, there were no major age-associated changes in resting cardiac function[1,3]. The cardiac responses during exercise have been controversial in the elderly[13,14]. Rodeheffer et al[14]. reported that aging does not limit cardiac output in healthy subjects at rest and during exercise, but reduce the maximal heart rate, altering the mechanism of the

Table 1. Cardiopulmonary indices and Borg scale at rest, anaerobic threshold and peak exercise in younger and older groups.

	Younger group			Older group		
	Rest	AT	PE	Rest	AT	PE
Ex work load(watts)	–	85±13	141±18	–	58±13**	93±17**
Heart rate (/min)	88±13	144±13	179±12	82±9	124±11**	157±14**
Systolic BP (mmHg)	104±9	146±17	162±18	140±24**	189±25**	211±25**
Diastolic BP (mmHg)	77±10	74±17	87±25	90±13**	103±21**	106±30*
O2 pulse (ml/beat)	2.6±1.0	6.5±1.1	7.8±1.1	2.7±0.4	6.4±0.7	7.1±0.9
O2 uptake (ml/kg/min)	4.3±1.1	18.1±2.2	27.2±2.4	4.1±0.7	15.0±2.3**	21.1±4.0**
Borg scale	–	14.2±1.7	18.2±1.3	–	13.8±2.3	17.6±1.7

AT=anaerobic threshold, BP=blood pressure, EX=exercise, PE=peak exercise
* = $p<0.05$, **=$p<0.001$ younger group vs older group

cardiovascular response to the effects of β-adrenergic stimulation. A larger left ventricular end-diastolic volume more than compensates for the lower left ventricular ejection fraction in older individuals. They concluded that there was a shift with advancing age from a catecholamine-mediated increase in heart rate and reduction in end-systolic volume to a greater reliance on the Frank-Starling mechanism. The study of Ogawa et al[13]. indicate that stroke volume , heart rate, and arteriovenous oxygen difference at maximal exercise all contribute to the decline in maximal oxygen consumption with age. However, the difference between the younger and the older groups was not present for stroke volume adjusted for the weight of fat-free mass in both sedentary men and women, which is consistent with our results. It has been documented that β-receptor responses decrease with increasing age[6,15,16]. In the current study, the decline of oxygen uptake during exercise in older individuals was observed with the decrease of the heart rate without the change of the oxygen pulse, which would explain that the limited exercise capacity in the older group was attributed by the limited increase of heart rate rather than stroke volume. The failure of increase in exercise heart rate in the older group can be explained by age-related diminution in the cardiovascular response to β-adrenergic stimulation.

Borg scale

As a method to quantify the subjective symptoms, Borg scale has been used to estimate the rating of exercise[5,6]. Borg scales in younger group at anaerobic threshold and at peak exercise were not different from those in the older group. Borg scale might be applied to younger and older subjects as an equal standardization of rating of exercise, as well as heart rate and oxygen uptake. Borg scale seems to be a good index to evaluate the rating of perceived exertion in each individual.

Study limitation

Difficulties in the study of aging have been matters of discussion for many years. All of us have a preconception that cardiovascular function as well as many other bodily functions decreases substantially during the latter portion of the life span of an individual. Part of this bias is certainly related to the fact that cardiovascular disease is prevalent in our population and its prevalence and severity increase with age. It is often difficult to dissociate aging from disease. Although the population in this study are healthy volunteers, the study never avoid this bias.

Conclusion

Physical exercise capacity is different from one individual to the another individual or from the young to the old. In the present study, oxygen uptake and heart rate were greater in younger women than in older women, which support that younger women tolerate more physical work load than older women. Since oxygen uptake is mainly determined by heart rate, the limited increase of the heart rate seems to be a major determinant of exercise capacity in older women.

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