A DIFFERENT HEMODYNAMIC ADJUSTMENT IN YOUNG WOMEN COMPARED TO YOUNG MEN DURING EXERCISE IN HEAT

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INTRODUCTION

The cardiovascular response during exercise includes increases in heart rate, stroke volume, blood flow in exercising muscles, ventilation, oxygen consumption and arteriovenous oxygen difference in tissues. Heat stress changes these adjustments during exercise. High ambient temperature and/or elevated humidity challenge the circulatory adjustment. Evaporation needs sufficient skin blood flow. The redistribution of blood flow is different in the heat than under thermoneutral conditions. Increased demands for both muscle and skin blood flow during exercise in heat also affect cardiac function (1,2). Cardiac output must be augmented. Heart rate and/or stroke volume must increase. Stroke volume depends on the cardiac size, systolic function of cardiac muscle fibers and venous return to the heart. The autonomic nervous system modulates the adjustments in both peripheral and central circulation. Fluid shifts, hormonal changes and the endothelial regulation in blood vessels play a role in this adaptation.

It has been reported that women and men tolerate exercise in the heat similarly if the body size and differences in oxygen consumption capacity are excluded. Although, recent studies concerning the endothelial function of blood vessels reveal that the peripheral circulatory regulation may partly be different in women and men. There are an increasing number of female candidates for work that exposes them to heat and exercise. Therefore, it is very important to analyze the importance and nature of these possible differences. The aim of this study was to evaluate the circulatory and thermoregulatory responses in healthy young women and men during a standardized heat tolerance test.

MATERIAL AND METHODS

Eleven healthy women and 8 healthy man (Table 1) wearing a T-shirt (women only), shorts and shoes performed a 60-min exercise bout with bicycle ergometer in a climatic chamber set to 35°C with a relative humidity of 65% and air velocity of 0.3 $m \cdot s^{-1}$. The work rate was 110 W for men and 75 W for women. Water was consumed ad libitum. Heart rate (HR) and rectal temperature (T_{re}) were monitored continuously and recorded once a minute. Sweat production was estimated as the change in nude body weight, measured before and after the work, and corrected for fluid intake.

Systolic (SBP) and diastolic (DBP) blood pressures were measured every 10 min in the brachial artery with the conventional auscultation method of Riva-

Table 1. Physical characteristics of study groups.

	Women		Men	
	Mean (± SEM)	*Range*	*Mean (± SEM)*	*Range*
Age, years	24.1 (±1.1)	21 - 31	23.6 (±1.4)	18 - 29
Height, cm	163.8 (±2.0)	152 - 172	187.5 (±2.8)	172 - 196
Weight, kg	56.1 (±1.9)	43.7 - 68.9	76.5 (±4.1)	63 - 98
A_D, m^{-2}	1.60 (±0.03)	1.37 - 1.76	1.96 (±0.07)	1.75 - 2.31
Body fat, %	22.6 (±1.15)	16.2 - 31.6	13.1 (±0.72)	9.4 - 15.2
BMI	21.3 (±0.62)	18.9 - 25.3	23.2 (±0.58)	21.3 - 25.5
VO_2max, L/min*	2.53 (±0.14)	1.79 - 3.48	3.56 (±0.32)	2.63 - 5,4
VO_2ml/kg·min^{-1}*	45.0 (±2.4)	33.6 - 59.9	46.5 (±3.1)	35.6 - 63.5
HRmax, bpm	194 (±1.39)	188 - 205	193 (±1.6)	186 - 199

* evaluated by incremental exercise test

Rocci. The subjects' subjective sensations were also recorded. The criteria used to discontinue the exercise were sensations of exhaustion, dizziness, nausea, chest pain, unusual dyspnea, fall in SBP during the exercise, changes in ECG or a rise in $T_{re} > 39.5°C$.

Statistical analyses were carried out using non-paired t-tests. $P < 0.05$ was considered significant.

RESULTS

The results are presented in Table 2. During the rest before the heat exposure, there was no significant differences in HR, SBP, DBP or T_{re} between men and women. At the end of exercise, the mean T_{re} and HR did not differ between the groups. Respectively, there was no significant difference in DBP but SBP was significantly lower in women.

Four women stopped the test after 40 to 55 min of exercise. Major symptoms were dizziness, headache and nausea. Two of these women had a fall in SBP, and 2 had T_{re} over 39°C. Two other women had symptoms just before the scheduled 60 min; one of them had a fall in SBP and the other had $T_{re} > 39°C$. Three men terminated the exercise between 40 and 50 min. One man had a fall in SBP and suffered nausea. The other 2 men had feelings of exhaustion and loss of power in exercising muscles.

One woman had minor symptoms some days after the exercise, but she recovered fully.

DISCUSSION

The thermal response in men and women during exercise in the heat was similar. This result is consistent with reports from previous studies (3). During the exercise, HR increased in both study groups and was almost maximal at the

Table 2. The main results of circulatory and thermoregulatory measurements during a heat tolerance test.

	Women *Mean (±SEM)* *Range*	Men *Mean (±SEM)* *Range*	*P-value*
HR, rest (bpm)	86.6 (±4.3) 62- 105	78.6 (± 3.2) 64 - 89	0.156
HR, end of exercise (bpm)	170.6 (±5.5) 145 – 193	173.4 (±6.2) 148 - 197	0.743
SBP, rest (mmHg)	122.7 (±3.2) 108 - 138	133.4 (±3.6) 120 - 150	0.056
SBP, end of exercise (mmHg)	133.3 (± 7.6) 88 - 170	154.8 (±6.2) 130 - 178	0.039
DBP, rest (mmHg)	73.5 (±3.1) 60 - 90	76.5 (± 1.6) 70 - 80	0.414
DBP, end of exercise (mmHg)	61.8 (±3.8) 50 - 88	68.1 (±3.3) 55 - 80	0.224
T_{re}, rest (°C)	37.2 (±0.1) 36.4 - 37.6	37.1 (± 0.09) 36.8 - 37.4	0.403
T_{re}, end of exercise (°C)	38.5 (±0.16) 37.6 - 39.1	38.5 (± 0.17) (37.8 - 39.3)	0.819
Sweat produced (g)	500 (±40) 250 - 680	1205 (±232) 630 - 2990	0.019
Water deficit (%)	0.86 (±0.07) 0.4 - 1.13	1.52 (±0.29) 0.63 - 2.99	0.056

end of exercise. The significantly higher SBP in men may be due to greater body size and greater stroke volume. The body size has also some other effects on the heat tolerance (4). In women an endothelial regulation has some differences compared to men. A sex-hormone-related improvement in vasodilatory responses and differences in nitric oxide production in women has been reported (5). This may explain the tendency of decreasing blood pressure in women during exercise in the heat in spite of similar HR responses and smaller water deficit in women. The venous insufficiency is more common in women, and this may affect the cardiac capacity.

CONCLUSIONS

Our results indicate that the differences in heat tolerance between men and women are mainly due to circulatory capacity. The greater body size and stroke volume of men may help them to maintain blood pressure during exercise in the heat. On the other hand, this causes an extra demand on cardiac circulation. This may increase the risk of cardiac events in men during exercise in heat. In women, the protective effect of diminished arterial stiffness may expose them to syncopelike disorders. These differences must be taken into account in risk analyses of working in the hot environment.

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