AGE AND CONTROL OF VISCERAL BLOOD FLOW DURING WORK

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INTRODUCTION

Circulatory adjustments to prolonged work include a sympathetically-mediated redistribution of blood flow away from splanchnic and renal circulations. When exercise is performed in a warm environment, there is a dual demand for increased blood flow -- to working muscle and to the skin, the latter to facilitate convective heat transfer away from the body core. Because there is a limited ability for cardiac output to increase in light of a falling central filling pressure, renal (RBF) and splanchnic blood flows (SBF) decrease to augment perfusion of skin (and maintain perfusion of muscle) vascular beds (1).

It has been well documented that aging is associated with a reduced RBF at rest, decreasing progressively from the fourth through the ninth decades at a rate of 6-7 ml/min/year (2). The effect of age on baseline SBF has been studied less extensively, and neither circulation has been studied during work in older men. The purpose of the present studies was to compare the RBF and SBF responses of older (O; 65-75 years) and young (Y; 20-30 years) men during work in warm (30-36°C) environments. The results of two separate groups of experiments are reported here.

METHODS

Subjects. An attempt was made in subject recruitment to match groups of O and Y men with respect to VO2max, body size, and adiposity. Subjects for Experiment 1 comprised 6 men in each age group; for Experiment 2 there were 8 O and 4 Y men. In Experiment 1, a 15% difference in VO2max remained; in Exp. 2 there was no difference between groups.

Protocol - Exp. 1. This protocol consisted of 90 min rest, followed by a 90-min bout of cycle exercise @ 50% VO2max. Exercise was performed on a modified cycle ergometer which enabled subjects to pedal with the legs positioned horizontally in front of the hips. Ambient temperature was 30°C.

Protocol - Exp. 2. This protocol consisted of consecutive 20-min periods of rest, cycle exercise @ 40% VO2max, and exercise @ 65% VO2max. Ambient temperature was 36°C.

Measurements. Heart rate was monitored continuously and blood pressure was determined by brachial auscultation. Expired gas samples were collected for determination of V02. Constant infusion techniques were used to measure RBF (Exp. 1) and SBF (Exp. 2). A catheter placed in a radial vein was used for infusing para-aminohippurate (PAH) for the determination of RBF or indocyanine green (ICG) for the measurement of splanchnic blood flow. Another catheter was placed in an antecubital vein in the contralateral arm for venous sampling. In Exp. 1, urine was collected periodically so that clearance of PAH could be calculated. Other measurements included plasma norepinephrine (NE, HPLC) and aldosterone (ALDO, RIA) concentrations. In Exp. 2, cardiac output (Q) was also measured (CO2-rebreathing).

Data Analysis. In both experiments, comparisons between age groups were analyzed by a one-factor (age) analysis of variance (ANOVA) with repeated measures on day and time. When a significant main effect was determined, a least square means analysis was performed to determine differences between the age groups at individual time points. Significance was set at the $p<0.05$ level. All values are reported as means ± standard error of the mean (SEM).

RESULTS

Resting RBF was 25-30% lower in the O subjects ($p<0.05$). During exercise at 50% VO_2max, RBF decreased to a significantly greater extent in Y than O, but the resultant exercise RBF was similar. For the Y subjects, RBF decreased by 508 ml/min during exercise, corresponding to a reduction of 45%; for the O subjects, the exercise-induced RBF decrease was only 98 ml/min (12%). Renal vascular conductance (RVC) showed similar differences, indicating that the difference was not secondary to differences in blood pressure. There was no significant effect of age on plasma [NE] at any time, although the mean [NE] of the O group during exercise was 20-25% lower than that of the Y during exercise. When the decrease in RBF was plotted against either *HR* or plasma [NE], the data from both age groups fell along a single line. [ALDO] was similar between age groups at rest on each day, but exercise [ALDO] was significantly lower for the **O** compared to the Y.

In Exp. 2, neither Q nor SBF (Table 1) was significantly different between age groups at rest or during exercise (see Table). SBF declined progressively during exercise, comprising 25% of Q at rest, 10% @ 40%VO2max , and 6% at 65%VO2max. Splanchnic vascular conductance was likewise unaffected by age.

Table 1. Q and SBF responses of **Y** and **O** men at rest and during exercise (mean ± SEM).

Variable	Group	Rest	40%VO2max	65%VO2max
Q (l/min)	Y	4.09k0.34	8.54±0.65	10.76M.87
	O	4.07±0.24	8.99±0.36	11.05M.48
SBF (ml/min)	Y	986±81	853±73	592±68
	O	1060±115	873±98	649±74

CONCLUSIONS

In the present studies, groups of men differing in age by 40-45 years worked in hot environments to maximize the exercise-induced redistribution of blood flow away from renal and splanchnic circulations. **A** novel finding was that fit, healthy men over the age of 65 demonstrate a much smaller decrease in RBF during exercise. While the young men tested here decreased RBF by **45%** during exercise at 50%VO2max, the older men decreased RBF by only 12%, allowing for a redistribution of less than 100 ml/min to other regional circulations. This could be of important consequence for older patients with left ventricular dysfunction and thus a limited ability to increase cardiac output under conditions of exercise or thermal stress.

As for the underlying mechanism for this age difference, the smaller decrease in RBF and RVC does not appear to be secondary to an age-associated decrease in physical activity or functional capacity, since the **O** subjects were more physically active on a regular basis than the Y. Secondly, these data do not support the hypothesis of altered sympathetic control of RBF during exercise with aging. There is a close linear relationship between the change in RBF during exercise and various measures of whole-body SNS activity, including such indirect measures as HR (3,4) and plasma [NE] (5). This relationship is unaffected by changes in exercise intensity or duration, or superimposition of thermal stress (5-7). Our data suggest that it is likewise not affected by age. The smaller absolute decrease in RBF and RVC in the older group during exercise merely reflects a lower renal reserve capacity secondary to a lower resting RBF.

Finally, as shown by the data from Exp. 2, there seems to be no effect of chronological age on SBF or its control during dynamic work in the heat.

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