Comparison of Systemic and Coronary Hemodynamics in the Normal Human Male and Female

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Coronary and systemic hemodynamics were compared in 15 normal men and 15 normal women. Systemic hemodynamics were very similar. The women had 26.5 per cent greater coronary flow and 19.6 per cent more oxygen consumption/100 Gm. of left ventricular myocardium. Their calculated coronary vascular resistance was 35 per cent less. Significant negative correlations between coronary flow and calculated heart weight, and between cardiac oxygen consumption and calculated heart weight, as well as between coronary flow and hematocrit probably explain the differences in part. Whether hormonal or anatomic differences are also significant is not known.

Although estimations of coronary blood flow in the human have been made since 1949, when the nitrous oxide method was adapted to this determination,1 and although a sizeable literature concerning the normal coronary flow is available,2# we have been unable to find any other series comparing coronary flow and systemic hemodynamics in the normal human male and female.

METHODS

In a series of 30 normal fasting subjects (15 male and 15 female) cardiac output was determined by the Fick principle and coronary blood flow by the nitrous oxide saturation method utilizing a blood-myocardial partition coefficient of 1.0.1 Six subjects were normal hospital patients and the others were cardiopulmonary laboratory personnel, nurses and medical students. Two subjects received pentobarbital 0.1 Gm. 1 hour before catheterization but the remainder had no premedication. In 13 of the 15 women duplicate studies of cardiac output and coronary flow were done 30 min. apart and since they were not different statistically, they were averaged in order to have a single figure with which to compare the other studies. Pressures were recorded by Statham strain gages and the direct writing Sanborn Poly-Viso. The Statham formula was used for calculation of cardiac work.

RESULTS

The results are presented in table 1. Although the average age of the women (26 years) was less than that of of men (30 years), there was sufficient overlap in the 2 groups so that the difference was not statistically significant (—15.4 per cent, p < 0.1). The surface area of the women was less than the men (-15.2 per cent, p < 0.001). The cardiac rate in the women exceeded that in the men by 7.3 per cent, but this was not a significant difference (p < 0.1). The mean systemic and pulmonary arterial blood pressures as well as the respiratory quotients were similar. Since the arterial hemoglobin of the women was less than that of the men (-13.4 per cent, p < 0.001) and their hematocrit reduced (-7.3 per cent, p < 0.001), the arterial oxygen content was also significantly less in the female (-13.7 per cent p < 0.001) as was the mixed venous oxygen content (-15.9 per cent p < 0.001) However, the arteriovenous oxygen and carbon dioxide differences were not significantly different even though the men had slightly greater differences than the women. The coronary sinus oxygen content was less in the

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women than in the men (-17.3 per cent, \( p < 0.05 \)) as is consistent with their lower hemoglobin and hematocrit. The arteriocoronary sinus oxygen difference was significantly less in the women than in the men (-12.8 per cent, \( p < 0.001 \)). Arterial, mixed venous and coronary sinus carbon dioxide contents were higher in the men \( (p < 0.001) \).

Coronary blood flow per 100 Gm. of left ventricular myocardium per minute was 26.5 per cent greater in women than in men \( (p < 0.001) \). The CMRO\(_2\) was 19.6 per cent

### Table 1.—Summary of Data

<table>
<thead>
<tr>
<th>Females</th>
<th>Males</th>
</tr>
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<tr>
<td>S.A. (M.²)</td>
<td>Cardiac rate</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>1.75</td>
<td>99</td>
</tr>
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<td>1.77</td>
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<td>1.53</td>
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<tr>
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</tr>
<tr>
<td>S.D. *</td>
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</tr>
<tr>
<td>S.E.M. †</td>
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*Standard deviation.
†Standard error mean.
Coronary sinus blood oxygen content in ml. per 100 ml. of blood.
Cardiac index, cardiac output in liters per minute per square meter body surface area.
Left ventricular work per square meter body surface area per minute.
Coronary blood flow in ml. per 100 Gm. of left ventricular myocardium per minute.
Ml. of oxygen used per 100 Gm. of myocardium per minute.
Coronary vascular resistance in arbitrary units (MAAP - CBP).
Index of efficiency (LVWI/CMRO₂).
greater \((p < 0.02)\) in the women and the \(\text{CMR}_2\) 12.5 per cent more \((p < 0.2)\). Cardiac respiratory quotients were essentially the same. Coronary vascular resistance was significantly less \((-35\) per cent, \(p < 0.01)\) and calculated cardiac efficiency was reduced \((-28\) per cent, \(p < 0.05)\) in the women as compared with the men.

**DISCUSSION**

Variation in the normal value for coronary blood flow as described in different laboratories has been discussed recently. American workers have published normal human figures of approximately 70 ml./100 Gm./min.,\(^1\)\(^7\) corresponding closely to figures of 78 ml./100 Gm. by French observers,\(^4\) and 69 ml./100 Gm. by the Japanese.\(^5\) These values agree very well with the figures presented here for normal men. Only 2 subjects from the above groups are stated to have been women, the sex of most subjects not having been given. The higher figures of 103° and 96° ml./100 Gm./min. are explained only partly by using the partition coefficient of 1.1 since it makes the now only 10 per cent higher.

The differences demonstrated in coronary blood flow between these men and women would appear to be biologically as well as statistically significant. The subjects were deliberately selected to be healthy young individuals under the full normal stimulus of the sex hormones on the thesis that during this period existing sex differences might be greatest. However, the possibility should be considered that the differences may not be related to sex but some associated characteristics. The partition coefficients of \(\text{N}_2\) between blood and normal living human male and female heart muscle are unknown but are assumed to be the same. This constitutes a basic assumption and derives its only justification from repeated use. It has been shown experimentally that coronary flow tends to increase as the cardiac rate increases,\(^8\) but the flow per cardiac cycle was 20 per cent greater in the women \((p < 0.001)\) than in the men. The women have 26 per cent more coronary flow per kilogram meter of left ventricular work index \((p < 0.01)\) than the men. Furthermore the women have 16.6 per cent more oxygen available to each 100 Gm. of myocardium/min. \((p < 0.05)\) and 17.6 per cent more hemoglobin \((p < 0.01)\). Whether heart weight be estimated as related to body surface (index of efficiency \(a:\) in table 1) or to body weight, the female heart is calculated to be less efficient than the male.

It is possible that the increase in coronary blood flow is the physiologic counterpart of the previously demonstrated anatomic difference in the thickness of the intima of the coronary vessels in infants in the 2 sexes.\(^8\)\(^9\) Comparable data concerning intimal thickness of coronary vessels of adults has not been found but the circumference of the coronary arteries in relation to heart weight has been shown to be greater in the adult human female as compared with the male.\(^11\) The increase in coronary blood flow per unit weight of the heart may be related to the known decreased incidence of coronary occlusion and atherosclerotic coronary artery disease in women. It must be conceded from purely statistical considerations based on the pathologic studies of Korean war dead\(^12\) that many of our \"normal\" males probably have some coronary atherosclerosis. This seems an unlikely explanation of the difference, however, since the flows in the men are uniformly low, not low in sporadic cases as would be expected if it were due to disease of isolated members of the group. Furthermore, coronary flow is reported to be normal in patients with angina pectoris who presumably have extensive coronary atherosclerosis.\(^15\) Consideration must also be given to a body of information concerning the effect of sex hormones on tissue respiration which indicates that testosterone depresses oxygen consumption.\(^14\)\(^15\)

An inverse relation has been shown between heart weight and myocardial oxygen consumption in the dog heart lung prepara-
Coronary hemodynamics in human male and female

Intact, unanesthetized dogs showed a similar relation between myocardial oxygen consumption and left ventricular weight \( r = -0.56 \) and between left ventricular coronary blood flow and left ventricular weight \( r = -0.68 \). If the data from the men and women are pooled and the heart weight assumed to be a predictable fraction of the body weight (0.43 per cent for men; 0.40 per cent for women), similar correlations may be calculated for this series. The relation of coronary flow per unit weight of left ventricle and total heart weight is then significant \( r = -0.66, p < 0.001 \), as is the relation between heart weight and cardiac metabolic rate for oxygen \( r = -0.55, p < 0.01 \). The relation between body surface area and left ventricular coronary blood flow per unit weight \( r = -0.57, p < 0.001 \) and between body surface area and left ventricular myocardial oxygen consumption per unit weight \( r = -0.44, p < 0.02 \) are not quite so close, but still highly significant. Furthermore, the relation between hematocrit and coronary flow in the pooled group is significant \( r = -0.49, p < 0.01 \), but that between hematocrit and myocardial oxygen consumption is not \( r = 0.26, p > 0.1 \). The differences in coronary flow and myocardial metabolism between the two groups may be due, in part at least, to non-specific factors such as the larger body size of the males as compared to the females. The fact that the hematocrit is related inversely to coronary blood flow seems all the more credible since myocardial oxygen consumption was not related significantly to the hematocrit. That the difference in hematocrit is not the sole explanation for the differences in hemodynamics is apparent from the preceding calculations which show that the female heart is exposed to more oxyhemoglobin per grams of myocardium per minute than the male.

Summary

Coronary blood flow, determined by the nitrous oxide method, and cardiac output determined by the Fick principle are reported for 15 normal young women and 15 normal young men. Coronary blood flow was found to be 26.5 per cent greater per 100 Gm. of left ventricle/min. and coronary vascular resistance 35 per cent less in the women than in the men. Factors are discussed which must be considered in relation to this difference.

Summary in Interlingua

Le fluxo de sanguine coronari, determinate per le methodo a oxydo nitrose, e le rendimento cardiae, determinate per medio del principio de Fick, es reportate pro 15 normal juvene adultos feminin e 15 normal juvene adultos mascul. Esseva trovate que le fluxo de sanguine coronari esseva 26,5 pro cento per 100 g de ventriculo sinistre per minuta plus grande in le femininas que in le masculos. Le resistentia coronario-vascular esseva 35 pro cento plus basse in le femininas. Es discute le factores que debe esser predite in consideration con respecto a iste differentia.

REFERENCES


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