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Sex Differences in Myocardial Oxygen and Glucose Metabolism

Linda R. Peterson, MD^{a,b}, Pablo F. Soto, MD^a, Pilar Herrero, MS^c, Kenneth B. Schechtman, PhD^d, Carmen Dence, MS^c, and Robert J. Gropler, MD^c

^aCardiovascular Division, Department of Medicine, Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

^bDivision of Geriatrics and Nutritional Sciences, Department of Medicine, Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

^cDepartment of Radiological Sciences, Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

^dDivision of Biostatistics, Washington University School of Medicine, St. Louis, Missouri

Abstract

Background—Both physiologic and pathophysiologic conditions affect the myocardium's substrate use and consequently, its structure, function, and adaptability. The effect of sex on myocardial oxygen, glucose, and fatty acid metabolism in humans is unknown.

Methods and Results—We studied 25 young subjects (13 women) using positron emission tomography quantifying myocardial blood flow, oxygen consumption (MVO₂), glucose and fatty acid extraction and metabolism. MVO₂ was higher in women compared with men (5.74±1.08 vs. 4.26±0.69 μmol•g⁻¹•min⁻¹, p<.005). Myocardial glucose extraction fraction, and utilization were lower in women compared with men (0.025±0.019 vs. 0.062±0.028, p<.001 and 133±96 vs. 287±164 nmol•g⁻¹•min⁻¹, p<.01). There were no sex differences in myocardial blood flow, fatty acid metabolism, plasma glucose, fatty acid, or insulin levels. Female sex was an independent predictor of increased MVO₂ (p=.01), decreased myocardial glucose extraction fraction and utilization (p<.005, and <.05, respectively). Insulin sensitivity was an independent predictor of increased myocardial glucose extraction fraction and utilization (p<.01, and p=.01).

Conclusions—Further studies are necessary to elucidate the mechanisms responsible for sex-associated differences in myocardial metabolism. However, the presence of such differences may provide a partial explanation for the observed sex-related differences in the prevalence and manifestation of a variety of cardiac disorders.

Keywords

sex; myocardial metabolism; glucose; myocardial oxygen consumption

Myocardial metabolism and cardiac function are inextricably linked: the myocardium metabolizes substrates in order to generate ATP, the hydrolysis of which allows for cardiac function. In the postnatal myocardium, metabolism of fatty acids provide most of the energy required; glucose, and to a lesser degree lactate, ketones, intracellular triglyceride, and glycogen also provide energy. However, the myocardium may switch its preference away from

Corresponding author: Linda R. Peterson, MD Washington University School of Medicine Campus Box 8086 660 S. Euclid Ave. St. Louis, MO 63110 Office: 314–362–4577 Facsimile: 314–362–9982 E-mail: lpeterso@im.wustl.edu

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free fatty acids and towards glucose depending on physiological or pathophysiological conditions and substrate availability.¹⁻⁵ The myocardium's choice of substrate affects its oxygen consumption, efficiency, and metabolic regulatory signals generated.⁶ Thus, the heart's ability to switch from using one substrate to another, impacts its ability to cope with different conditions. For example, in ischemia, β -oxidation of fatty acids is halted and glucose, the more oxygen-efficient substrate, is preferred.⁷ Consequently, conditions that detrimentally affect the myocardium's ability to use glucose may adversely alter the myocardium's ability to adapt to ischemia. E.g., humans with type I diabetes have an increased reliance on fatty acid metabolism, which may detrimentally affect the diabetic myocardium's ability to adapt to ischemia and survive.⁴

There are also data that show that sex affects myocardial metabolism in animal models, and skeletal muscle and liver substrate in humans under a variety of conditions.⁸⁻¹³ Whether sex affects myocardial metabolism in young, fasting humans is not clear; however, it is clear that there are sex-related differences in morbidity and mortality from various cardiovascular diseases and given the known link between metabolism and function, it is reasonable to theorize that there may be sex-related differences in myocardial metabolism playing a role.¹⁴ Although sex hormone levels and other differences between men and women are potential effectors or confounders of sex-related differences, the purpose of this study was to test the ground breaking hypothesis that sex, itself, is related to and affects myocardial substrate metabolism *in vivo*, in humans and in so doing lay the foundation for further investigation of sex-related differences in metabolism.

METHODS

Study subjects

Young, healthy, nonobese, sedentary subjects, 13 premenopausal women and 12 men, 20–44 years old, participated in this prospective study. All subjects completed a comprehensive medical evaluation, including a history, physical examination, electrocardiogram, routine blood tests, an oral glucose tolerance test, lipid profile, and a rest/stress echocardiogram. Those who had impaired fasting glucose, glucose tolerance, or diabetes during an oral glucose tolerance test, hypertension, a history of coronary artery or other cardiac disease, a history of smoking cigarettes within the last 12 months, or who had an abnormal rest/stress echo were excluded; those who performed routine aerobic exercise equal to or more than 30 minutes/day for more than 2 days a week were excluded from the study in order to minimize any potential confounding effect of aerobic training on myocardial metabolism since training has known effects on hemodynamics and cardiac structure. Subjects also underwent dual-energy X-ray absorptiometry using a Hologic Discovery QDR #70570 and software version 12.4 (Hologic Inc., Bedford, MA) for body composition measurement. Five women were taking contraception measure(s) (4 were taking oral and 1 was receiving intramuscular contraceptive agents). Serum progesterone and estradiol and estrone levels were measured and last menstrual dates were recorded in all the women for the determination of cycle phase. No data on any subject have been previously published. All participants signed the written informed consent form, which was approved by the Institutional Review Board, the General Clinical Research Center, and the Radioactive Drug Research Committee at the Washington University School of Medicine, St. Louis, MO.

Experimental procedure

Subjects were fasted overnight (12 hours) and studied the following a.m. (in order to avoid possible confounding effects of interindividual differences in postprandial absorption rates). The morning of the study an 18- or 20-gauge catheter was inserted into an antecubital vein for radiopharmaceutical infusion. All subjects underwent positron emission tomography (PET)

imaging at 8:00 a.m. to avoid circadian variations in hormones, myocardial metabolism, and function.¹⁵ All studies were performed on a conventional commercially available tomograph (Siemens ECAT 962 HR+, Siemens Medical Systems, Iselin, NJ). Blood pressure and heart rate were obtained throughout the study. PET was used to measure myocardial blood flow with ¹⁵O-water, MVO₂ with 1-¹¹C-acetate, myocardial glucose extraction fraction and utilization with 1-¹¹C-glucose, and fatty acid extraction fraction, utilization, and oxidation with 1-¹¹C-palmitate. During the study, venous blood samples were obtained at predetermined intervals to measure plasma substrate (glucose, fatty acids, and lactate) and insulin levels as well as radiolabeled metabolites, which are required for compartmental modeling of the kinetics of the metabolic tracers.¹⁶⁻¹⁸ Plasma substrate levels were determined from venous rather than arterial samples; however, because our subjects were in the resting state, differences in substrate concentrations between the 2 sample sites would be expected to be negligible. Radiolabeled metabolites were also determined using venous rather than arterial samples; we have used venous ¹¹CO₂ based on the results of previous studies and have showed that under resting conditions the differences in arterial and mixed venous ¹¹CO₂ levels was minimal and in post-hoc analyses did not contribute to a significant difference in MVO₂, myocardial fatty acid or glucose utilization.¹⁶⁻¹⁸

Image analyses

PET image analysis for the quantification of myocardial blood flow (in mL•g⁻¹•min⁻¹), MVO₂ (in μmol•g⁻¹•min⁻¹), glucose and fatty acid metabolism was performed using well-validated techniques.¹⁶⁻¹⁹ In brief, myocardial glucose or fatty acid extraction fraction is the fraction of glucose or fatty acid extracted by the myocardium. Myocardial glucose utilization and fatty acid utilization (in nmol•g⁻¹•min⁻¹) represent the total amount of glucose or fatty acid utilized per minute by the myocardium. Myocardial fatty acid oxidation (in nmol•g⁻¹•min⁻¹) represents the total amount of fatty acid oxidized by the myocardium. For the purposes of calculating myocardial efficiency, MVO₂ was converted to its volume equivalent using the conversion factor 0.0224 mL/μmol O₂, then to its energy equivalent using the conversion factor 2.059 kg•m/mL oxygen consumed, and finally to SI units (J•g⁻¹•min⁻¹) by multiplying by *g*, the gravitational constant (9.81 m/sec²).

Echocardiography—During the PET study, all subjects had a complete 2-D and Doppler echocardiographic examination using a Sequoia-C256® (Acuson-Siemens, Mountain View, CA) immediately after the imaging for MVO₂. Left ventricular (LV) end-diastolic and end-systolic volumes were determined using the method of discs. LV mass was determined using the area-length method, and LV mass index = LV mass/body surface area according to the recommendations of Americanp.8) Society of Echocardiography.²⁰ Relative wall thickness was calculated as (2 × posterior wall thickness at end-diastole)/LV diastolic dimension. LV ejection fraction was calculated online using the modified Simpson's method. Cardiac output (mL•min⁻¹) = the time-velocity integral of the LV outflow × LV outflow tract area. LV minute work per gram of myocardium (LVMW_g) = mean arterial pressure × cardiac output × 0.0000136 × *g* / LV mass. The number 0.0000136 represents a conversion factor from units of pressure and volume (mm Hg•mL) to work (kg•m) (2) and *g* represents the gravitational constant for the purposes of converting to SI units (J•g⁻¹•min⁻¹). LV efficiency was calculated as the ratio (LVMW_g / MVO₂) × 100%. Subjects also underwent tissue Doppler imaging in order to quantify the longitudinal, early, peak diastolic myocardial relaxation velocity (Em) and the longitudinal, peak systolic shortening velocity (Sm) for the assessment of preload-independent systolic and diastolic function, respectively.²¹ Em and Sm values measured from the septal and lateral walls were averaged to obtain one Em and Sm value per subject.

Plasma analyses—Plasma glucose concentration was determined by using the Cobas Mira analyzer (Roche Diagnostics, Indianapolis, IN). Insulin was measured by radioimmunoassay

(Linco Research Co., St. Charles, MO). Free fatty acid concentrations were measured by using an enzymatic colorimetric method (NEFA C kit, WAKO Chemicals USA, Inc., Richmond, VA). Lactate was measured using a photospectrometry kit (Sigma Chemicals, St. Louis, MO). Estrogen levels were measured using liquid chromatography tandem mass spectrometry (Mayo, Rochester, MN); progesterone levels were measured by chemiluminescence enzyme immunoassay (Advia redipack, Bayer Corporation).

Insulin resistance—Insulin sensitivity was quantified by the homeostasis model assessment, or “HOMA,” as described previously.²² Specifically, HOMA is calculated as $[(\text{fasting insulin (in } \mu\text{U/mL})}] \times [\text{fasting glucose (mM)}]/22.5$.

Statistical analysis—Statistical calculations were performed using SAS version 8.2. Data are shown as the mean $\pm$ standard deviation. Differences between the continuous variables were determined using student t-tests as the data were normally distributed. Chi-square tests were used to determine the differences in categorical variables between the 2 groups. Pearson correlation coefficients were used to determine the relationship between continuous variables. In order to be tested in the multivariate model, we required that an independent variable be significantly related to the outcome variable at a significance level of $p \leq .10$. A type III sum of squares was used to calculate the independent predictors of the predetermined outcome variables that had a significant relationship with sex, (i.e., MVO_2 , myocardial glucose extraction fraction, glucose uptake, and utilization). A p value of $<.05$ was considered statistically significant.

RESULTS

Baseline characteristics and echocardiographic measurements

Baseline characteristics of the subjects are shown in Table 1. There were no statistical differences between the men and women with respect to age, body mass index, or cholesterol levels. Cardiac structure, function, and hemodynamic data at the time of PET imaging are shown in Table 2. Systolic, but not diastolic, blood pressure was higher in the men. LV mass was higher in the men than the women, and LV mass index trended toward being higher in the men; relative wall thickness, though, was not different between the groups. There were no statistical differences in systolic function as measured by Sm , ejection fraction, or cardiac work, between the men and women. Diastolic function, as measured using the tissue Doppler-derived Em , was borderline higher in the men.

Plasma substrate and hormone levels

Between men and women, there were no statistical differences in plasma glucose (4.94 ± 0.33 vs. 4.85 ± 0.36 $\mu\text{mol/mL}$, $p=.51$), fatty acid, or lactate levels (739 ± 273 vs. 637 ± 162 nmol/mL , $p=.27$) at the time of the PET study (Table 3). The men had higher triglyceride levels (Table 1, $p<.05$). The difference between plasma insulin levels or insulin sensitivity between the men and women was not significant although there was a trend towards the men having a lower fasting insulin level (3.9 ± 2.1 vs. 5.7 ± 2.8 $\mu\text{mol/mL}$, $p=.07$) and consequently trending towards being more insulin sensitive per HOMA (Table 1). Of the women, 5 were in the luteal, 6 were in the follicular, and 1 was in the menstrual phase, and the menstrual phase status of 1 was not known. The levels of estradiol and progesterone for the women in the follicular phase were ≤ 56 pg/mL and ≤ 2.3 ng/mL , respectively, and the mean levels of estrogen and progesterone for the women in the luteal phase were 118 ± 23 pg/mL and 11.8 ± 7.4 ng/mL . There was no relationship between these hormone levels and MVO_2 , or myocardial glucose extraction fraction or utilization.

Myocardial blood flow, MVO₂, and efficiency

Values for myocardial blood flow and MVO₂ are shown in Table 3 and Figure 1. Myocardial blood flow did not differ between the 2 groups, but MVO₂ was significantly higher in the women than the men ($p < .005$). Post-hoc analysis excluding the women who were taking any type of hormonal contraception still showed that women had a significantly higher MVO₂ ($p < .05$). In the univariate analyses comparing the predetermined continuous variables with MVO₂, only age ($r = -.48, p < .05$), and HOMA ($r = .43, p < .05$) were found to be significantly correlated with MVO₂. In the multivariate analysis only age and female sex were independent predictors of increased MVO₂ ($p < .05, p = .01$, respectively). In this model, age and sex predicted 54% of the variability of MVO₂. Efficiency trended higher in men ($p = .07$) but was not significantly related to sex or the other predetermined variables in a univariate analysis or multivariate model.

Myocardial glucose metabolism

As shown in Figure 2, myocardial glucose extraction fraction was significantly higher in the men than the women (0.062 ± 0.028 vs. 0.025 ± 0.019). Myocardial glucose utilization was also significantly higher in the men when compared with women (287 ± 164 vs. 133 ± 96 nmol $\cdot$ g⁻¹ $\cdot$ min⁻¹). Post-hoc analysis excluding the subjects who were taking any type of hormonal contraception still showed that women had a significantly lower myocardial glucose extraction fraction compared with the men ($p < .05$). Among the predetermined, continuous, independent variables (body mass index, age, relative wall thickness, mean arterial pressure, and HOMA) that were tested for their level of association with the myocardial glucose extraction fraction and metabolism measures, only HOMA was significantly related to myocardial glucose extraction fraction ($r = -.60, p < .005$) and utilization ($r = -.58, p < .005$). In the multivariate analysis sex and HOMA were both independent predictors of myocardial glucose extraction fraction ($p < .005, p < .01$, respectively), and the model predicted 56% of the variability in myocardial glucose extraction fraction. Similarly, sex and HOMA were independent predictors of myocardial glucose utilization ($p < .05, p = .01$, respectively). The multivariate models incorporating sex and HOMA predicted 50 and 45% of the variation in myocardial glucose utilization.

Myocardial fatty acid metabolism

Measurements of myocardial fatty acid extraction fraction, utilization, and oxidation are shown in Table 3. In contrast to measurements of myocardial glucose metabolism, measures of myocardial fatty acid uptake and metabolism were similar between the groups.

DISCUSSION

The results of the current study are the first to demonstrate that sex differences in myocardial glucose utilization and MVO₂ exist, with the hearts of young, healthy, nonobese women using less glucose and more oxygen than the hearts of age-matched men at rest. This cannot be explained by differences in myocardial blood flow, insulin sensitivity, hemodynamics, myocardial work, or the plasma substrate environment.

These findings expand upon our knowledge of sex-related differences in metabolism derived from studies of animal myocardium and from studies of other organs, in vivo, in humans. For example, results of studies in a transgenic mouse model demonstrated greater myocardial glycogen preservation, and studies in diabetic rat models demonstrated sex differences in myocardial metabolism, with female rats exhibiting less myocardial glucose and more fatty acid metabolism than males (although there were no sex-differences in metabolism in the nondiabetic controls).^{12,13} Studies of whole body and liver metabolism in humans also demonstrated the existence of sex-related differences in basal whole body lipolytic rates, fatty

acid uptake, and very low density lipoprotein secretion rates and in skeletal muscle carbohydrate metabolism during and after exercise or after fasting.^{8-11,23-25}

Differences in hormonal stimulation may play a role in the mechanism of sex-related differences in myocardial metabolism since animal studies have shown that estrogen decreases glucose oxidation, gluconeogenesis, and glycogenolysis, and increases fatty acid oxidation in liver and skeletal muscle.²⁶⁻²⁹ Myocardial glucose utilization may be decreased by estrogen because it is known to upregulate nitric oxide synthases, which cause a reduction in AMPK-stimulated GLUT-4 translocation to the cell surface, thereby inhibiting myocardial glucose uptake.³⁰⁻³² However, the lack of a direct relationship between hormone levels and metabolic measures in our study and results from other studies of hormone effects suggest that the relationship between sex hormones and their effects is more complicated than a simple direct relationship between estradiol level and its putative effects. For example, studies of vascular function in both animal models and humans demonstrate sexually dimorphic responses to the same levels of estradiol.^{33,34} Thus, the exact molecular basis of the sex-related differences in myocardial glucose metabolic profiles that we have demonstrated in this study, is not yet clearly defined but is likely to be a complicated interaction involving genomic differences, sex hormones, hormone receptors, and metabolites.

Our finding of increased MVO_2 in the young women, despite no statistical difference in cardiac work (and hence a trend toward less efficiency), may be due to an effect of estrogen since there is data from animal studies that shows that uncoupling proteins may be upregulated by estrogen, which could lead to increased oxygen consumption.³⁵ It should be noted, however, that in our study, the relationship defined as efficiency, only reflects *external* cardiac work performed per MVO_2 ; also, the slightly higher mean cardiac work in the women may account for some, though likely not all, of the increase in MVO_2 . Some of the difference in MVO_2 between the sexes may result from differences in glucose oxidation (we have only measured myocardial glucose utilization in the current study – not oxidation), differences in metabolism of endogenous substrates (e.g., glycogen and triglyceride) that our current PET technique can not measure, and/or differences in metabolism of other exogenous substrates (e.g., ketones, amino acids). Further studies are needed to evaluate the possibility that sex-related differences in uncoupling proteins and/or their regulation impact MVO_2 in humans and how oxidation of substrates other than exogenous fatty acids impact sex-related differences in myocardial metabolism.

The results of our study are seemingly in contrast to those from another PET study that suggested that there were no sex differences in myocardial metabolism between men and women during a hyperinsulinemic/euglycemic clamp; however, this study did not examine the fasted, resting state.³⁶ The differences between the results of our study and the previous study may be due to the myocardial glucose uptake-enhancing effect of exogenous insulin infusion overwhelming sex-related differences in myocardial glucose uptake.

Myocardial fatty acid uptake, utilization, and oxidation were not statistically different between the women and men in this study; this may be due to differences in oxidation of other substrates exogenous to (e.g., lactate and pyruvate) or endogenous to (e.g., intramyocellular triglyceride) the heart that may also be significantly involved in the overall contribution to MVO_2 , so that a precisely inverse relationship between glucose and fatty acid utilization is not apparent.³⁷

Study limitations

1) This study was performed in a select group of young, healthy subjects and thus our findings may not apply to all men and women. For example, relatively small number of nonwhite men limits this study's ability to make strong conclusions as to a possible interaction between sex and race and the dependent variables. 2) This study was not designed to analyze the effect of sex on myocardial metabolism in subjects with ischemia or other cardiac conditions (such as

the postprandial state); thus our theory that the sex-related differences in myocardial metabolism that we report here have implications on metabolism and outcomes in ischemia needs to be tested in future studies. 3) Also, although the women were in different phases of their menstrual cycle, some metabolism studies of some organs such as liver have not shown an effect of menstrual cycle.³⁸ 4) We are not able to measure endogenous myocardial glycogen or triglyceride metabolism, so that we cannot detect the degree to which metabolism of these substrates may contribute to the differences in myocardial metabolism shown in this study. 5) Of note, although the cardiac work measurements in the study subjects are relatively low, the subjects were healthy and at rest and hence had low mean arterial pressure and cardiac output. The stroke volume indexed to body surface area in both the men and women (42 ± 9 mL/m² and 37 ± 5 mL/m², respectively) were within normal limits.³⁹

Clinical implications

Although speculative, it is tempting to contemplate the implications of these gender differences in MVO₂ and glucose metabolism. Sex differences in myocardial glucose and oxygen metabolism in young, healthy, nonobese humans may play a role in sex-related outcome differences in cardiovascular disease given the intrinsic interaction between myocardial substrate preference, metabolism, cardiac function, and adaptability to various conditions.⁶ For example, our observed sex differences in myocardial metabolism may detrimentally affect outcome in young women affected by myocardial ischemia – a condition associated with a decline in β -oxidation of fatty acids, and an increased reliance on glucose metabolism. This could potentially explain, at least in part, why young women (although much less likely to suffer a myocardial infarction) have a much higher mortality from myocardial infarction than men – a difference that is not fully accounted for by differences in medical history, clinical severity of infarction, or early management.¹⁴ To be certain, differences other than myocardial substrate metabolism likely play a role in this discrepancy in cardiovascular outcomes; however, the significant associations between sex and oxygen and glucose metabolism shown in the current study provide a new paradigm for future investigations of sex-related cardiovascular outcome differences and may help refine future research in metabolic manipulation of the myocardium as it pertains to men and women. The degree to which non-hormone related genetic differences, sex hormones, and adipokines may affect myocardial substrate utilization in men and women with cardiac pathophysiologic conditions deserves further investigation.

Conclusions—Sex is an independent predictor of MVO₂ and myocardial glucose metabolism in young, healthy, nonobese humans at rest, with women having a higher MVO₂, and lower myocardial glucose extraction fraction and utilization than men. The current study increases the complexity of our understanding of myocardial metabolism and its regulation, which are altered by substrate availability, cardiac work, pathophysiologic conditions, and physiologic conditions, such as aging, and now sex. Future studies are needed to determine if sex-related differences in myocardial metabolism contribute to known sex-related outcome differences in cardiovascular diseases.

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List of abbreviations

MVO₂, myocardial oxygen consumption; PET, positron emission tomography; LV, left ventricular; HOMA, homeostasis model assessment.

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Figure 1.
Sex-related myocardial oxygen consumption (MVO₂) differences

Figure 2.

Left graph, MGEF = myocardial glucose extraction fraction; right, MGU = myocardial glucose utilization.

Myocardial glucose extraction fraction and utilization: sex differences

Table 1

Baseline Characteristics

	Men	Women	<i>P</i> value
N	12	13	
Age (yrs)	28 ± 7	26 ± 4	.37
Race (% Caucasian)	83	46	.10
Height (cm)	182 ± 6	163 ± 4	<.0001
Weight (kg)	79 ± 7	64 ± 5	<.0001
Body mass index (kg/m ²)	23.7 ± 2.6	24.4 ± 2.8	.54
Body surface area (m²)	1.97 ± 0.12	1.66 ± 0.09	<.0001
Fat free mass (kg)	66 ± 5	44 ± 2	<.0001
% Body fat	16 ± 6	33 ± 6	<.0001
Total Cholesterol (mg/dL)	164 ± 21	157 ± 31	.53
Low-density lipoprotein (mg/dL)	96 ± 18	85 ± 27	.25
High-density lipoprotein (mg/dL)	51 ± 12	59 ± 12	.08
Triglycerides (mg/dL)	89 ± 29	65 ± 27	<.05
HOMA (μU/mL)	0.84 ± .45	1.24 ± .62	.08

HOMA = homeostasis model assessment for insulin resistance.

Table 2
Hemodynamics, Cardiac Structure and Function During PET Imaging

	Men	Women	P value
Hemodynamics			
SBP (mm Hg)	119 ± 8	106 ± 13	<.01
DBP (mm Hg)	66 ± 6	66 ± 9	.99
MAP (mm Hg)	83 ± 6	79 ± 9	.20
Heart rate (bpm)	55 ± 10	63 ± 11	.06
Rate-pressure product (mm Hg*bpm)	6523 ± 1281	6650 ± 1277	.81
Cardiac structure			
LV mass (g)	172 ± 33	127 ± 15	<.0005
LV mass index (g/m ²)	87 ± 16	77 ± 9	.05
Relative wall thickness	0.41 ± 0.09	0.37 ± 0.05	.13
Ejection fraction	60 ± 4	61 ± 6	.56
Cardiac systolic function and efficiency			
Sm (cm/s)	8.4 ± 1.0	8.4 ± 1.2	.90
Cardiac output (L/min)	4.4 ± 0.8	3.8 ± 0.8	.10
Cardiac minute work (J•g ⁻¹ •min ⁻¹)	0.29 ± .09	0.32 ± .08	.36
Efficiency (%)	14.6 ± 3.4	12.4 ± 2.3	.07
Cardiac diastolic function			
Em (cm/s)	17.3 ± 2.4	15.4 ± 2.4	.05

SBP = systolic blood pressure, DBP = diastolic blood pressure, MAP = mean arterial pressure, LV = left ventricular, Em = mitral annular velocity during diastole, Sm = mitral annular velocity during systole

Table 3**MBF and Fatty Acid Metabolism**

	Men	Women	p value
MBF (mL•g ⁻¹ •min ⁻¹)	0.99 ± 0.19	1.13 ± .27	.16
Plasma free fatty acid level (nmol/mL)	590 ± 213	692 ± 251	.29
Myocardial fatty acid extraction fraction	0.393 ± 0.072	0.349 ± 0.089	.18
Myocardial fatty acid utilization (nmol•g ⁻¹ •min ⁻¹)	222 ± 93	249 ± 77	.44
Myocardial fatty acid oxidation (nmol•g ⁻¹ •min ⁻¹)	197 ± 71	200 ± 67	.93