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Research Article

Left Ventricular Response at Peak All-Out Anaerobic and Peak Oxygen Uptake Bouts with Aging

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Abstract

Background: All-out anaerobic and peak oxygen uptake exercises may be dangerous for the older population, due to hypoxia and inappropriate blood pressure response.

Objectives: This study compared and evaluated left ventricular function at peak all-out anaerobic and peak oxygen uptake efforts in 15 well trained older (60 ± 1 yrs.) all males, once performing the Wingate Anaerobic Test and once peak oxygen uptake.

Methods: Subjects were studied by echocardiography on a cycle ergometer.

Results: Anaerobic bout compared to aerobic exercise showed significant ($p < 0.05$) lower values for cardiac output (10 ± 1 vs 18 ± 2 L ▪ min^{-1}), end diastolic volume, heart rate (156 ± 7 vs 182 ± 9), ejection fraction (60 ± 6 vs 78 ± 8%) as well as left ventricular end diastolic volume and stroke volume. While, significant ($p < 0.05$) higher values were seen for total peripheral resistance (97 ± 8 vs 52 ± 8 dynes ▪ s^{-1} ▪ cm^{-5})/10) end systolic volume and load.

Conclusions: Although no abnormalities were noted in all subjects, data suggests, that at peak both exercises, in the older subjects, force opposing left ventricular ejection during the anaerobic bout was not reduced enough to facilitate ejection. This may be attributed to functional changes with aging in the myocardium and high total peripheral resistance, leading to reduced left ventricular function and blunted inotropic and chronotropic responses to catecholamine. Therefore, all-out anaerobic-type effort should not be given to an older subject due to the great hazardous potential.

***Keywords:** Cardiac Output; Arrhythmia; Echocardiograph; Contractility; Total Peripheral Resistance*

Introduction

Anaerobic effort compared to aerobic bout is characterized by exposing the subjects to a very high degree of sudden strenuous all-out exercise and lactic acid levels which in turn, limiting muscle contraction [1]. It has been assumed that this type of activity is potentially dangerous for the older population, due to hypoxia and a seemingly inappropriate blood pressure response [2]. This has the effect of placing a large load on the left ventricular which might have significant effects on left ventricular systolic function.

Previous study [2], in young subjects, demonstrated, following warm-up, reduced left ventricular function and contractility without ECG abnormalities due to increase after-load.

Age-related deterioration in cardiovascular function is usually attributed to structural and functional changes in the myocardium and associated blood vessels [3], leading to impairment of left ventricular function, increased after-load and blunted inotropic and chronotropic responses to catecholamine [4]. The Wingate Anaerobic Test exposes the subjects to a very high degree of sudden strenuous all-out exercise, and thus, may alter left ventricular function [5]. Therefore, the present study was designed to examine the effect of all-out anaerobic exercise stress on left ventricular function in young and older adult males.

Methods

Subjects

Fifteen well trained healthy older men (60 ± 1 yrs.), volunteered for this study. Subjects were in good health, aerobically active for at least 12 months 3 times ▪ wk^{-1}. They were judged free from coronary artery disease by the clinical history, absence of major risk factors and by a normal exercise test up to $V0_2$ peak. A written informed consent was obtained from each subject, which was approved by the Clinical Science Center Committee on Human Subjects.

Procedure and measurements

Subjects reported 3 times to the laboratory. Sessions were spaced by intervals of at least 48h and on average by intervals of no more than 1 wk. The first session was devoted to accustoming the subjects to the study's procedures. During the 2nd and third sessions, subjects were tied by torso-straps to the wall while cycling. This was done to minimize movement of the upper body and to facilitate auscultation of blood pressure and echocardiographic measurements at peak exercise [6]. Oxygen uptake was determined breath by breath utilizing the Medical Graphics (St. Paul, MN) metabolic cart. The metabolic cart was calibrated before each test with known primary standard quality gases. A 12-leads ECG and heart rate were continuously monitored at rest, during exercise and recovery. Five-second recordings were obtained at rest and at peak exercise. After warm up, subjects cranked against an initial workload of 75W that was increased by 25W every minute until the subject could no longer continue at the predetermined pace.

During the 3rd session, following warm-up, subjects performed the 30 seconds all-out Wingate Anaerobic Test, utilizing a weight-adjusted Monark cycle-ergometer Model 864. The subject was seated on the ergometer with their feet fastened to the pedals by means of racing-type toe-clips, and seat height was adjusted. In addition, subjects were tied by torso-straps to the wall while cycling, in order to minimize movement of the upper body and to facilitate auscultation of blood pressure and echocardiographic measurements at peak exercise [6]. The anaerobic test consisted of 30 seconds supramaximal pedaling against a resistance determined relative to the subject's body mass at 40g ▪ kg^{-1} body weight [7]. Subjects commenced cranking as fast as they could against the ergometer's inertial resistance only. The full, predetermined resistance load was applied within 3 - 4 seconds once the inertial resistance had been overcome. Pedal revolution count started at that instant by means of an electro-mechanical counter and subjects maintained an all-out effort throughout the test. Strong verbal encouragement was given to ensure maximal effort. The test was performed at the same time of the day in order to avoid anything connected to

A 25μ fingertip blood sample was taken at rest and during the 2nd minute post exercise for the determination of lactic acid concentration at peak anaerobic effort. The sample was immediately transferred to a micro-tube containing 100μ of 7% perchloric acid. The tubes were centrifuged after standing for at least 1 hour. Twenty microliter aliquots of the supernatant were subsequently used for lactic acid analysis on the Analox LM3 analyzer (Analox Instruments, England; Reagent Kit No. GMRD-071).

Echocardiographic data processing

2-D, echocardiographic and M-mode images were performed at rest and at peak exercises utilizing Vingmed 725 Sonotron and Sony recorder equipped with 2 and 3 MHz transducers. The diameters of the aorta were determined by two-dimensionally directed M-mode. Left ventricular diameters, intra-ventricular septum and posterior wall thicknesses were measured from the parasternal short-axis views, just below the mitral valve level, according to the American Society of Echocardiography [5]. Left ventricular volumes were determined according to Simpson's rule.

All echocardiographic studies were performed with the subjects in the Sitting position at rest, at peak anaerobic effort. The probe was held by hand and directed to a marked point from which the resting data were obtained. The beam was directed to the aortic valve outflow tract in the 5-chamber view, or from the supersternal approach in those subjects in whom an adequate imaging of 5-chamber or parasternal long axis views were not obtained. To assess the objectivity of the echocardiographic readings, all recordings were evaluated by two independent experts. High correlation (r = 0.93) was found for inter-observer reliability.

Calculations

- Stroke volume was the product of left ventricular end diastolic volume- end systolic volume.
- Cardiac output was the product of heart rate and stroke volume.
- Total peripheral resistance was calculated as: (mean arterial blood pressure x 80)/cardiac output.
- Ejection fraction = [(end diastolic volume - end systolic volume)/ end diastolic volume] x 100%.
- End-systolic pressure volume ratio = Cuff-determined systolic blood pressure/left ventricular end-systolic volume.
- Mean arterial blood pressure = [(systolic pressure - diastolic pressure)/3 + diastolic pressure].

Statistical methods

One-way ANOVA with repeated measures was employed for each of the variables measured in order to detect variations in the experimental parameters. In addition, the Students Newman-Keuls procedure was used for specific Post-Hoc comparisons.

Results

All subjects completed the exercise challenges without difficulties or ECG abnormality. Mean descriptive data are presented in table 1.

Variable	**Elder**
N of subjects	15
Age (years)	60 ± 1
Weight (kg)	71.1 ± 3
Height (cm)	173.0 ± 2
Aortic valve diameter (cm)	2.4 ± .2
VO_2 max. (ml ▪ kg^{-1} ▪ min^{-1})	3.2 ± .2

Table 1: *Subjects' physical characteristics, echocardiographic and hemodynamic measurement at rest (mean ± S.D).*

Hemodynamic and echocardiographic responses at rest and at peak exercises are presented in table 2. Anaerobic bout compared to aerobic exercise showed significant ($p < 0.05$) lower values for cardiac output, end diastolic volume, heart rate (156 ± 7 vs 182 ± 9), ejection fraction (60 ± 6 vs 78 ± 8%) left ventricular end diastolic volume and stroke volume. While, significant ($p < 0.05$) higher values were seen for total peripheral resistance, end systolic volume and load applied.

Variables	Rest	Ana	Aer
Q (L ▪ min^{-1})	5.1 ± .4	10 ± 1	18 ± 2
EDV (mL)	111 ± 7	105 ± 7	136 ± 8
ESV (mL)	43 ± 5	42 ± 5	30 ± 4
HR (beats ▪ min^{-1})	81 ± 8	156 ± 7	182 ± 9
SV (mL)	67 ± 7	63 ± 6	106 ± 8
EF (%)	60 ± 4	60 ± 6	78 ± 8
P ▪ V^{-1} (ratio)	3 ± .6	4 ± .4	6 ± .9
SBP (mmHg)	119 ± 7	184 ± 13	18810 ±
DBP (mmHg)	84 ± 7	88 ± 6	84 ± 7
MABP (mmHg)	96 ± 7	120 ± 7	119 ± 8
VO_2 (mLO_2 ▪ kg^{-1} ▪ min^{-1})	3.2 ± .2	------	42 ± .3
TPR (dynes ▪ s^{-1} ▪ cm^{-5})/10	150 ± 9	97 ± 8	52 ± 8
LA (mmol ▪ L^{-1})	1.4 ± .3	9 ± 1	9 ± 1
LOAD (watts)	------	284 ± 7	174 ± 6

Table 2: *Hemodynamic responses and echocardiographic measurements at peak anaerobic and aerobic tests (mean + SD).*

**: Significant differences between groups at rest (P< 0.05).*

†: Significant differences between groups at peak anaerobic exercise (P < 0.05).

Ana: Anaerobic; Aer: Aerobic; Q: Cardiac output; EDV: End Diastolic Volume; ESV: End Systolic Volume; HR: Heart Rate; SV: Stroke Volume; EF: Ejection Fraction; P▪V^{-1}: SBP/ESV; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MABP: Mean Arterial Blood Pressure; VO_2: Oxygen uptake; TPR: Total Peripheral Resistance; LA: Lactic Acid.

Discussion

Although reliable measurements have been performed in multiple studies using conventional techniques, this study, is unique because of the manner on which echocardiography measurements were taken with the subjects seated and strapped to a wall. This helped to minimize movement of the upper body thus, enabling clear and reliable imaging and blood pressure measurement even at peak effort [7].

This study indicates that in older men at peak anaerobic bout compared to the aerobic bout, left ventricular function was decreased significantly related to the aging process [3]. The mechanics of ventricular contraction include the concept of the inter-relationship between force, length, velocity and time [8]. Based on that, several researches have proposed the end-systolic pressure/volume relationship as a measure of left ventricular contractility, which is independent of preload [8,9].

Although older subjects were challenged with a higher absolute resistance during the anaerobic bout, contractility and left ventricular function were decreased most likely due to the relatively higher after-load opposing the ejection of the left ventricle [10]. Such after-load does not allow cardiac output to increase as a result of decrease in stroke volume and mimics the increase in inotropism [11]. The decrease in stroke volume during anaerobic exercise in the older subjects results from reduced end-diastolic volume and lower reduced total peripheral resistance as see during aerobic exercise.

It seems that in the older men, the observed lower left ventricular function at peak Wingate Anaerobic challenge is due, at least partially, to the greater elevation in systolic, diastolic, and mean blood pressures, and to the demeaning reduction in total peripheral resistance, due to greater concentrations of vasoactive substances owing to tissue hypoxia and acidosis. This may force the ventricle to eject blood against a relatively higher pressure. This, coupled with low, peak heart rate could result in a low overall cardiac output.

Following warm-up, normal ECG were observed in all older subjects. However, several previous studies on the effect of sudden strenuous exercise have shown to produce ischemia-like ECG abnormalities in young healthy subjects during sudden strenuous exercise without warm-up [12,13]. In the present study it seems that the early warm up and the short bout time in our older subjects evaded ECG abnormalities.

Conclusion

Data suggest that left ventricular function at peak all out anaerobic bout varied markedly from those at peak aerobic exercise. Although during anaerobic exercise load applied was lower than that given in other studies, forces opposing ejection were not reduced enough to allow left ventricular function to be increased compared to resting values. This is attributed to aging of the heart and blood arteries. Therefore, it is suggested that anaerobic-type effort should be performed with great caution in well trained older healthy subjects with reduced load.

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