Effect of Exercise on Systolic Left Ventricular Outflow Velocity in Healthy Adults

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The occurrence of exercise-induced dynamic obstruction of the left ventricular outflow tract in patients without cardiomyopathy has recently been reported. However, it is not known if this phenomenon is a normal response to exercise in healthy adults. We studied 23 healthy adults using exercise Doppler echocardiography. We measured the left ventricular outflow velocity at rest and after maximum tolerated exercise. After a mean exercise duration of 12 min 45 s (2 min 32 s), the heart rate was 97.61 (6.71)% of the theoretical maximum. Left ventricular outflow velocity increased from 1.07 (0.18) m/s (range: 0.77-1.44 m/s) to 1.58 (0.35) m/s (range: 1.09-2.4 m/s). In healthy adults, exercise increased the left ventricular outflow velocity by 50%, though in no subject was it greater than 2.5 m/s. This observation appears to rule out the possibility that a high intraventricular pressure gradient is a normal response to exercise in healthy adults.

Key words: *Exercise echocardiography. Left intraventricular pressure gradient. Left ventricle.*

Efecto del ejercicio sobre las velocidades de flujo sistólico ventricular izquierdo en adultos sanos

Recientemente se ha descrito la aparición de obstrucción dinámica intraventricular izquierda inducida por esfuerzo y caracterizada por aparición de gradientes intraventriculares en pacientes sin miocardiopatía hipertrófica. Se desconoce si este hallazgo podría aparecer en sujetos sanos como respuesta normal al ejercicio.

Se estudió a 23 sujetos sanos mediante ecocardiografía-Doppler de esfuerzo. Basalmente y tras el esfuerzo máximo tolerado, medimos las velocidades del flujo de salida ventricular izquierdo. Tras un ejercicio de 12 min 45 s ± 2 min 32 s alcanzaron frecuencias cardíacas del 97,61 ± 6,71% respecto a la máxima teórica. Las velocidades del flujo aumentaron de 1,07 ± 0,18 m/s (rango, 0,77-1,44 m/s) hasta 1,58 ± 0,35 m/s (rango, 1,09-2,4 m/s). Concluimos que el ejercicio máximo tolerado por sujetos sanos aumentó hasta un 50% las velocidades de flujo de salida ventricular y en ningún caso se alcanzaron los 2,5 m/s. Esto parece descartar que los gradientes intraventriculares elevados sean una respuesta normal al ejercicio en sujetos sanos.

Palabras clave: *Ecocardiografía esfuerzo. Gradiente intraventricular izquierdo. Ventrículo izquierdo.*

INTRODUCTION

Cases of exercise-induced left intraventricular pressure gradient detected thru exercise Doppler echocardiography have been reported recently.[1-3] The clinical significance of this condition has not been definitively established although it may be related to symptoms of dyspnea or effort angina of no apparent cause.[2,3]

The presence of small pressure gradients in healthy ventricles, detected with high fidelity 6-10 mm Hg magnitude micromanometers was described some years ago.[4,5] More recently, Yotti et al[6] confirmed their existence and the possibility of recording them with Doppler echocardiography. However, the information available about flow velocity behavior and intraventricular gradients during exercise in healthy adults[7] is limited. Consequently, values that might be considered "normal" during exercise are poorly-defined.

The objective of this study is to analyze the behavior of systolic left ventricular outflow velocity (SLVO) during exercise in healthy adults.

PATIENTS AND METHOD

We studied 23 healthy, male volunteers, without pathologic antecedents whose physical examination, electrocardiogram and Doppler echocardiogram gave normal results.

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Received January 31, 2005.
Accepted for publication May 13, 2006.

Baseline and post-exercise echocardiography was performed by an experienced cardiologist with a VingMed echocardiograph equipped with Super-VHS recording system and Pinnacle DV500 Plus video-digitalizer, using a 2.5-3.25 MHz probe

We performed a complete standard baseline Doppler echocardiogram. Measurements were taken according to American Society of Echocardiography recommendations.[8]

Immediately after exercise (30-60 s), with the volunteer in lateral decubitus, we again analyzed SLVO, transmitral flow and systolic function.

Exercise was taken on a Marquette Case 8000 treadmill ergometer (Marquette Medical Systems Inc., Milwaukee, US) following the Bruce protocol after 4 hours fasting, and continued until subjects presented symptoms of exhaustion or achieved maximum theoretical heart rate.

RESULTS

The 23 subjects were men of age 32.5±5.9 years (range, 25-45), weight 78.7±7.1 kg, height 176.6±4.9 cm, mean body mass index 25.7±2.4, and body surface area 1.94±0.09 (range, 1.74±2.13). Baseline echocardiogram data appears in Table 1. Maximum SLVO velocity at rest was 0.77-1.44 m/s, mean 1.07±0.18 m/s.

Mean exercise time was 12 min 45 s±2 min 32 s after which subjects achieved a mean heart rate of 97.6±6.7% of the estimated theoretical maximum for their age. Data relative to performance is in Table 2.

Following exercise (Table 3), maximum SLVO velocity was 1.09-2.45 m/s (mean, 1.58±0.35 m/s). None of the subjects presented morphology indicating dynamic gradient or anterior movement of the mitral valve.

DISCUSSION

The appearance of left intraventricular gradients in patients without hypertrophic cardiomyopathy is well documented in relation to hypercontractile states,[9] following valvular surgery,[10-13] acute coronary syndromes,[14,15] or dobutamine stress echocardiography.[16,17] Recently, it has also been reported in relation with exercise.[1-3,18] Elsewhere, we reported on a series[3] that constitued a population with high incidence of hypertension and of women in which the only predictor factor of this phenomenon was left ventricular outflow tract diameter.

However, the presence of small intraventricular gradients in healthy ventricles is known. In 1980, Falsetti et al[4] found 2.10±0.47 mm Hg gradients between the left ventricular apex and base using high precision micromanometers in dogs. Later, Pasipoularides et al[5] also used catheters in 6 patients without valvular or ventricular abnormalities and found gradients at rest of 6.7±1.9 mm Hg, which increased to 13±2.3 mm Hg following bicycle exercise. More recently, Yotti et al[6] have confirmed the existence of this phenomenon and the possibility of recording it using a new echocardiographic method, detecting values of 3.3±1.6 mm Hg in 20 healthy volunteers at rest.

However, little data is available on the behavior of these small "physiologic" gradients during physical exercise.[7] In the series of 6 cases, Pasipoularides et al[5] specifically studied this aspect and found that gradients

TABLE 1. **Baseline Echocardiographic Data***

	Baseline, mean±SD	Range
EDD, mm/m²	25.4±1.9	21.4-28.5
ESD, mm/m²	15.9±1.8	11.1-19.5
Septum, mm/m²	4.42±0.46	3.48-5.33
Posterior wall, mm/m²	4.56±0.50	3.38-5.49
LVOT, mm/m²	10.9±0.7	9.75-12.11
Septum/posterior wall	0.97±0.07	0.84-1.18
LVMI, g/m²	78.7±11.9	47.3-95.8
RPT	0.35±0.03	0.28-0.42
E, m/s	0.85±0.14	0.63-1.16
A, m/s	0.61±0.11	0.42-0.80
E/A	1.40±0.26	0.84-2.00
IVT E/A	2.63±1.16	1.31-4.97

*A indicates A wave velocity; EDD, end-diastolic diameter; ESD, end-systolic diameter; E, E wave velocity; RPT, relative parietal thickness; LVMI, left ventricular mass index; IVT, integral velocity-time; LVOT, left ventricle outflow tract.

TABLE 2. **Exercise Performance Data***

	Baseline	Post-Exercise
	Mean±SD	Mean±SD
AP systolic, mm Hg	120.4±10.9	151.5±16.8
AP diastolic, mm Hg	75.0±7.5	74.5±6.8
HR, beats/min	73.3±15.4	183.8±12.24
% maximum theoretical HR, beats/min		97.61±6.71
MET		14.96±2.38
Double product		25 552±3748

*SD indicates standard deviation; HR, heart rate; AP, arterial pressure.

TABLE 3. **Hemodynamic Parameters Before and After Exercise***

	Baseline	Post-Exercise
	Mean±SD	Mean±SD
Ejection fraction, %	74.7±3.8	84.9±4.8
Shortening fraction, %	36.77±3.23	47.03±6.04
V_{max} LVOT, m/s	1.07±0.18	1.58±0.35
IVT LVOT, cm	19.6±3.2	22.6±5.0
Cardiac output, L/m	4.6±1.1	10.5±2.5
Cardiac index, L/m	2.4±0.5	5.4±1.3

*SD indicates standard deviation; IVT, integral velocity-time; LVOT, left ventricle outflow tract; V_{max}, maximum velocity.

doubled with submaximal physical exercise of decubitus pedaling.

Various studies[19,20] related with the effects of exercise show an increase in SLVO velocities during exercise and, although they studied different populations, none of them found a two-fold increase in flow velocity at rest.

In our series of 23 healthy volunteers, SLVO flow velocity exceeded 1.07±0.18 m/s (range, 0.77-1.44) at rest, reaching 1.58±0.35 m/s (range, 1.09-2.45) after exercise, which represents a 50% increase.

These data suggest that, in the post-exercise treadmill echocardiogram, SLVO velocities of 1.58±0.35 m/s, with a range of 1 up to 2.4 m/s can be considered normal.

We conclude that maximum exercise tolerated by healthy adults increases left ventricular outflow velocity by up to 50% but that in no case does it reach 2.5 m/s. Although this does not entirely exclude the possibility that elevated intraventricular gradients may be a habitual response to exercise in healthy adults, it does make this highly unlikely.

Limitations of the Study

In addition to the sample size, this study is limited by the fact that the SLVO velocities were recorded immediately after exercise and not during maximum exercise. This is inevitable with treadmill exercise but could lead to an underestimate, given the tendency to diminish in the minutes after ceasing exercise, despite the fact we recorded high levels of exercise (97.61±6.71%).

This series only included young men. Although this implies a bias in terms of gender and age, we considered on this study design to facilitate optimization of echocardiographic images (as pectoral anatomy is easier in men) and to attain high levels of exercise. Moreover, the appearance of dynamic obstruction during exercise has not been linked with gender.[3]

Use of the simplified Bernouilli equation to calculate intraventricular gradients in these cases is inexact due to the absence of anatomic obstruction and the relatively low velocities; consequently, it may be more adequate to express results in terms of velocity without transforming this into gradient, or rather, to apply the recently described method of measurement with color M-mode Doppler[6].

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