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# Abnormal Blood Pressure Response During Exercise in Hypertrophic Cardiomyopathy

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To investigate the incidence of abnormal exercise blood pressure responses in hypertrophic cardiomyopathy (HCM) and the potential role of hemodynamic instability as a mechanism of sudden death, 129 consecutive patients with HCM underwent maximal symptom-limited treadmill exercise testing with blood pressure recording. Four patterns of blood pressure response were observed. Forty-three patients had significant exercise hypotension, with either a continuous fall in systolic blood pressure ( $n=5$ ) from the start of exercise or a sudden fall in systolic blood pressure (20–100 mm Hg; mean, 40 mm Hg) from the peak value ( $n=38$ ), 23 patients had a normal response during exercise but an abnormal blood pressure response in the recovery period, and the remaining 62 patients demonstrated a normal blood pressure response. Patients with exercise hypotension were younger ( $33\pm 14$  versus  $46\pm 14$  years) and more of them had a family history of HCM and sudden death compared with those with a normal blood pressure response (15 of 43 versus 6 of 62 patients). Similarly, the 23 patients with abnormal recovery blood pressure responses were younger ( $43\pm 16$  versus  $46\pm 14$  years) and had a higher incidence of a family history of sudden death (10 of 24 versus 6 of 62 patients). Left ventricular cavity dimensions were smaller in those with exercise hypotension, but 11 other clinical, echocardiographic, and arrhythmic variables were similar. To assess the mechanism of exercise hypotension, 14 patients who demonstrated exercise hypotension and 14 symptomatic patients with a normal exercise blood pressure response underwent invasive hemodynamic exercise testing. In the hypotensive group, cardiac index increased from 2.6 to 9.5 l/min/m<sup>2</sup> at peak exercise similar to the increase found in patients with a normal blood pressure response. Cardiac index at peak exercise was marginally higher in the hypotensive group at peak exercise. Systemic vascular resistance was similar at rest and after 2 minutes of exercise, but resistance was significantly lower in the hypotensive group at peak exercise ( $428\pm 185$  versus  $744\pm 187$  dynes/cm<sup>-5</sup>;  $p=0.0001$ ). Exercise hypotension is common in HCM (33%) and is due to a fall in systemic vascular resistance occurring despite a rising cardiac index. The association of hemodynamic instability, young age, and an adverse family history emphasizes the potential role of hemodynamic collapse as an initiating mechanism of sudden death in HCM. Prospective evaluation, particularly of young patients, is warranted. (*Circulation* 1990;82:1995–2002)

**S**udden death is common in hypertrophic cardiomyopathy (HCM).<sup>1,2</sup> There are numerous potential mechanisms, but rarely is a cause identified.<sup>2</sup> Abnormal blood pressure responses have been reported in HCM and in other cardiac diseases associated with a high incidence of sudden death.<sup>3–7</sup> In HCM hemodynamic collapse has been documented with and without arrhythmia.<sup>8,9</sup> To assess the potential for hemodynamic instability, we have performed maximal treadmill exercise with careful doc-

umentation of blood pressure response during exercise in a consecutive population with HCM.

## Methods

### Patients

**Clinical.** One hundred twenty-nine consecutive patients with HCM who were attending St. George's Hospital, London, were studied. The diagnoses were made from 1 month to 25 years (mean, 6 years) before the study and were based on typical clinical, echocardiographic, and hemodynamic features.<sup>1,10</sup> All patients had left ventricular hypertrophy (1.5 cm or more demonstrated on two-dimensional echocardiography) in the absence of cardiac or systemic disease that could have caused hypertrophy.<sup>11,12</sup> Patients with blood pressure of more than 160/90 were

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excluded; however, two patients with mild systemic hypertension, marked hypertrophy, resting left ventricular outflow tract gradients, typical clinical features, and a family history of HCM were included. Patients were aged 10–74 years (mean, 41 years); 49 patients were aged less than 35 years, 65 patients were aged 35–60 years, and 15 patients were more than 60 years old. Seventy-seven were male, and 52 were female. One hundred twenty-one were in sinus rhythm, seven were in atrial fibrillation, and one patient had a dual-chamber (DDD mode) pacemaker for symptomatic transient complete heart block. Sixty-seven (52%) patients had a family history of HCM, and of these, 31 also had a family history of premature (<55 years) sudden cardiac death. Twenty-nine (22%) had experienced syncope, 29 (22%) had exertional chest pain, and 61 (47%) had dyspnea NYHA grade II ( $n=46$ ) or III ( $n=15$ ). At the time of study, no patient was receiving cardioactive medication. Symptomatic therapy was discontinued for at least five half-lives. Amiodarone was discontinued at varying intervals before the study, and only patients who had not received amiodarone for at least 3 months and with plasma concentrations of 0.2 mg/l or less were presented in the analysis. On two-dimensional and M-mode echocardiography using previously published methods,<sup>12,13</sup> the 129 patients showed maximal left ventricular wall thickness of  $23\pm 7$  mm, left ventricular end-systolic and end-diastolic cavity dimensions of  $26\pm 6$  and  $43\pm 6$  mm, respectively, and left atrial dimension of  $41\pm 9$  mm (>45 mm in 30 patients [23%]). Complete systolic anterior motion of the mitral valve with septal contact was present in 36 (28%) patients; 34 (26%) patients had a calculated resting Doppler gradient of greater than 30 mm Hg.<sup>14</sup> Ejection fraction was measured by R wave-gated equilibrium blood pool studies after in vivo labeling of red blood cells with technetium 99m. Images were acquired using a large field-view gamma camera and a medium-sensitivity parallel-hole collimator oriented in 45° left anterior oblique projection with caudal tilt. Data were acquired in list mode from 600–900 consecutive cycles, and an RR interval histogram was constructed; cycles more than 20% from the mean cycle length were rejected. A background-corrected left ventricular activity time curve was generated at a frame rate of 10–25 msec. A standard count-based method calculation of left ventricular ejection fraction was  $77\pm 9\%$ .<sup>15,16</sup>

All patients underwent 48-hour electrocardiographic monitoring at the time of diagnosis or within 6 months of the study and were not receiving cardioactive medication.<sup>17</sup> Twenty-eight (22%) had nonsustained ventricular tachycardia, defined as three or more consecutive ventricular extrasystoles with a mean rate of 120 beats/min or more for less than 30 seconds, and 34 (26%) had episodes of paroxysmal atrial fibrillation or supraventricular tachycardia, defined as three or more consecutive narrow complex extrasystoles at a mean rate of 120 beats/min or more.

As part of routine clinical follow-up, 42 patients underwent repeat noninvasive evaluation 3–12 months after the initial exercise test.

#### *Exercise Testing*

Maximal symptom-limited treadmill exercise testing was performed using a Bruce protocol<sup>18</sup> with continuous measurement of oxygen consumption. Respiratory gas analysis was performed using an established technique with a metabolic measurement cart (Horizon Sensor Medics, Anaheim, Calif.). Oxygen and carbon dioxide levels were measured with a temperature-controlled rapid polarographic sensor and a dual-beam infrared optical sensor, respectively, linked to an on-board microprocessor.<sup>19</sup> Printouts of minute ventilation, oxygen consumption, carbon dioxide production, and respiratory quotient were obtained at 15-second intervals during exercise. Before the study, patients were guided in the techniques of exercise and respiratory gas collection and had demonstrated a less than 10% difference in maximal oxygen consumption on at least two consecutive tests. Anaerobic threshold, a measure of the adequacy of exercise, was measured by a conventional algorithm.<sup>20</sup>

#### *Blood Pressure Recording*

Systolic blood pressure was measured using a mercury sphygmomanometer at rest, at 1-minute intervals during exercise, and at 15-second intervals for 5 minutes during the recovery period after exercise. Measurements were made by digital palpation of the brachial artery in all patients. Thirty patients in whom blood pressure recording was problematic underwent repeat exercise blood pressure recordings with direct intra-arterial measurements from the nondominant brachial artery.

#### *Exercise Hemodynamics*

Fourteen patients who demonstrated hypotension during exercise underwent invasive exercise hemodynamic studies; 14 patients with a normal exercise blood pressure response but with severe or refractory symptoms were studied for comparison. On the day of the study, patients arrived after fasting in the morning. A Swan-Ganz catheter was inserted into a central vein under local anesthesia and advanced into the pulmonary artery. A 20-gauge cannula was inserted into the brachial artery of the nondominant arm. Pulmonary artery pressures, pulmonary capillary wedge pressures, systemic blood pressure, and cardiac output were measured at rest and during each minute of exercise. Pressures were measured by Statham transducers (Gould, Cleveland) referenced to atmosphere at midchest level and recorded using a multichannel recorder (Mingograph 7, Siemens-Elma, Hamburg, FRG). Cardiac output was measured by the direct Fick method during treadmill exercise: cardiac output (l/min) = [oxygen consumption (ml/min)  $\times$  10]  $\div$  [hemoglobin (g/dl)  $1.34 \times$  arteriovenous oxygen difference]. Systemic vascular resistance expressed in

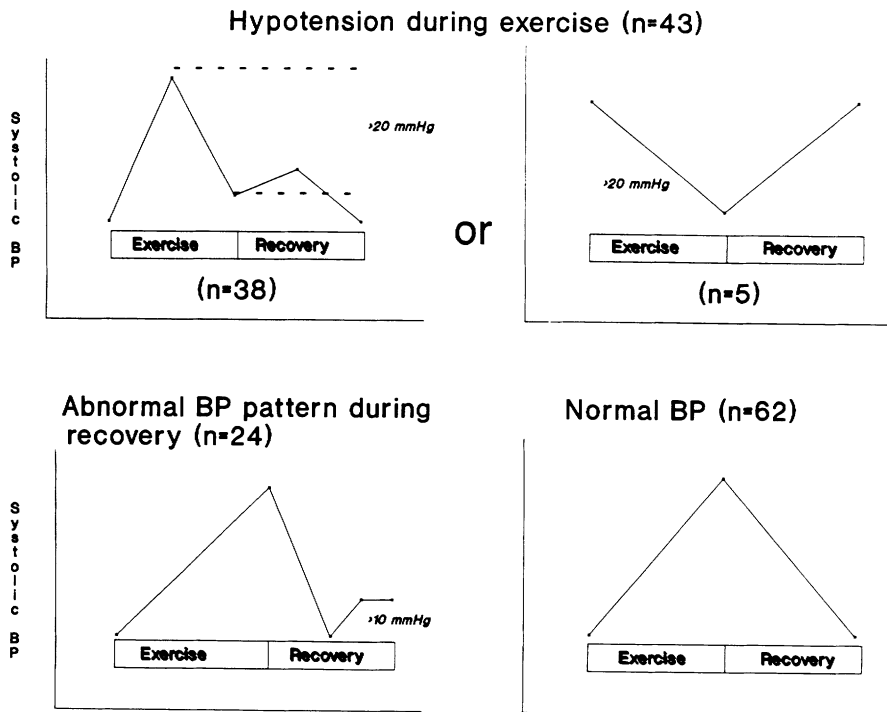


FIGURE 1. Schematic representation of four patterns of exercise blood pressure (BP) response in 129 patients with hypertrophic cardiomyopathy.

absolute units ( $\text{dynes} \cdot \text{sec} \cdot \text{cm}^{-5}$ ) was calculated from the mean arterial pressure and cardiac output.

#### Statistical Analysis

Data are expressed as mean  $\pm$  1 SD. Statistical analysis was performed by paired and unpaired *t* test and  $\chi^2$  test where appropriate. A value of  $p < 0.05$  was considered significant.

#### Results

Patients completed exercise testing without complication, and anaerobic metabolism was demonstrated in all patients. The limiting symptom was fatigue and breathlessness in 92 (71%), chest pain in 28 (22%), and symptomatic hypotension in three (2%); in six patients the exercise was discontinued by the physician because of the development of supraventricular arrhythmia ( $n=1$ ) or hypotension ( $>50\%$  fall from the peak value) ( $n=5$ ). During exercise, one patient developed atrial fibrillation with rapid ventricular response and hypotension. Three patients developed frequent unifocal ventricular extrasystoles in the initial postexercise recovery phase. Four patterns of blood pressure response were observed (Figure 1). In 62 patients, there was a normal blood pressure response with a linear increase in systolic blood pressure to peak exercise and a gradual decline during the recovery period. Forty-three patients experienced hypotension during exercise. Two patterns of hypotension were observed; in five patients, systolic blood pressure fell continuously from the first minute of exercise. The remaining 38 patients had an initial rise in systolic blood pressure to a maximum and a subsequent fall of 20–100 mm Hg (median, 40 mm Hg) from the peak value recorded.

In 12 patients, the fall in blood pressure from the peak value was greater than 40 mm Hg. Symptoms of impaired consciousness during hypotension were more common in patients aged 30 years or more than in younger patients (9 of 25 versus 1 of 18;  $p < 0.001$ ). Twenty-three patients had a normal blood pressure response during exercise but an abnormal response during the recovery period, with an initial rapid fall and subsequent increase of at least 10 mm Hg from the minimum value. The resting blood pressure was lower in the patients with exercise hypotension ( $118 \pm 26$  mm Hg) and abnormal recovery ( $116 \pm 20$  mm Hg) than in those with a normal response ( $131 \pm 24$  mm Hg) ( $p < 0.01$ ). Peak blood pressure during exercise was lower in those with exercise hypotension ( $153 \pm 37$  mm Hg) and those with abnormal recovery pattern ( $157 \pm 36$  mm Hg) than in those with a normal blood pressure response ( $192 \pm 37$  mm Hg) ( $p < 0.001$ ).

Blood pressure at peak exercise was  $190 \pm 38$  mm Hg in those with a normal blood pressure response,  $119 \pm 35$  mm Hg ( $p < 0.001$ ) in the hypotensive group, and  $149 \pm 39$  mm Hg ( $p < 0.001$ ) in the abnormal recovery group. All three groups achieved a similar degree of cardiovascular stress as judged by anaerobic threshold and maximal heart rate achieved (Table 1). Of the 42 patients who underwent repeat evaluation during follow-up, the qualitative blood pressure response was the same as the original study in all 16 with a normal exercise blood pressure response and in 24 of 26 who had previously demonstrated exercise hypotension or an abnormal pattern of recovery blood pressure.

The 43 patients with exercise hypotension were significantly younger than the 62 patients with a

**TABLE 1. Exercise Blood Pressure Response in 129 Patients With Hypertrophic Cardiomyopathy**

	Hypotensive (n=43)	<i>p</i> *	Normal (n=62)	<i>p</i> †	Abnormal recovery (n=24)
<b>Sex</b>					
Male	23 (53%)		41 (66%)		13 (54%)
Female	20 (47%)		21 (24%)		11 (46%)
Age (yr)	33±14	<0.001	46±14	0.02	43±16
<b>FHx</b>					
HCM	12 (28%)		18 (29%)		6 (25%)
HCM/SD	15 (35%)	<0.001	6 (10%)	0.001	10 (42%)
NYHA II	13 (30%)		22 (35%)		11 (46%)
NYHA III	8 (19%)		5 (8%)		2 (8%)
Chest pain	17 (39%)		29 (47%)		12 (50%)
Syncope	11 (25%)		13 (21%)		5 (21%)
Sinus rhythm	40 (93%)		60 (97%)‡		22 (92%)
Established AF	3 (7%)		2 (3%)		2 (8%)
SVT	18 (42%)	0.05	11 (17%)		5 (21%)
VT	10 (23%)		14 (22%)		4 (17%)
PG>30 mm Hg	9 (21%)		17 (28%)		7 (24%)
LVEDD (mm)	41±5	0.01	45±7		43±7
LVESD (mm)	24±5	0.04	27±7		27±7
LA (mm)	40±10		41±8		41±9
Max LVWT	23±8		21±6		23±7
<b>Exercise</b>					
Max heart rate (beats/min)	155±33		151±25		149±28
Anaerobic threshold (ml/kg/min)	23±9	NS	21±6	NS	19±5
Peak $\dot{V}O_2$ (ml/kg/min)	28±11		26±7		25±7
Predicted $\dot{V}O_2$ (%)	74±22		77±17		76±19
Peak BP (mm Hg)	153±37	0.0001	192±37	0.0001	157±36
BP at peak exercise (mm Hg)	119±35	0.001	190±38	0.001	149±39

FHx, family history; HCM, hypertrophic cardiomyopathy; SD, sudden death; NYHA, New York Heart Association classification; AF, atrial fibrillation; SVT, supraventricular tachycardia; VT, nonsustained ventricular tachycardia; PG, pressure gradient; LVEDD, left ventricular end-diastolic dimension, LVESD, left ventricular end-systolic dimension; LA, left atrial; Max, maximum; LVWT, left ventricular wall thickness;  $\dot{V}O_2$ , maximal oxygen consumption; BP, blood pressure.

\*Normal versus hypotensive group.

†Normal versus abnormal recovery.

‡Dual-chamber pacemaker.

normal blood pressure response (33±14 versus 46±14 years;  $p=0.001$ ) and the recovery group (33±14 versus 43±16 years;  $p=0.01$ ). There was no significant difference in the age of patients with an abnormal recovery pattern and those with a normal response (43±16 versus 46±14;  $p=NS$ ). An abnormal blood pressure response during exercise and during recovery was associated with a family history of HCM and sudden death (15 of 43 and 10 of 24 versus 6 of 62;  $p<0.001$ ). Left ventricular end-systolic and end-diastolic dimensions were less in the hypotensive group compared with the other two groups (Table 1). An abnormal blood pressure response during exercise and recovery, however, was independent of gender, symptoms, radionuclide ejection fraction, the maximum left ventricular wall thickness, left atrial dimension, complete systolic anterior motion of the mitral valve, and ventricular arrhythmias during

48-hour electrocardiographic monitoring. Medication during follow-up included  $\beta$ -blockers in 51 patients, verapamil in 17, and amiodarone in 32. Three patients experienced sudden death; two of these were resuscitated from out-of-hospital ventricular fibrillation, and one patient, an asymptomatic, 12-year-old child, collapsed while walking. None of these patients had experienced syncope before sudden death and were not on medication at the time of collapse. These three patients did not have supraventricular or ventricular arrhythmias during 2, 4, and 5 days of electrocardiographic monitoring.

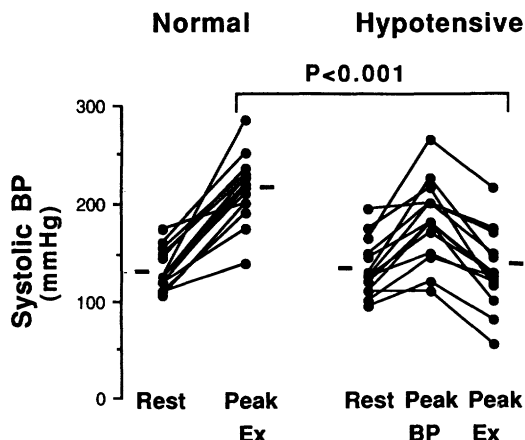
Exercise hemodynamic monitoring was performed in 14 patients with exercise hypotension and in 14 patients with a normal blood pressure response. The hypotensive group were younger, less symptomatic, and had a greater degree of left ventricular hypertrophy than the 14 normotensive patients. In the

**TABLE 2. Clinical Characteristics in 28 Patients Who Underwent Exercise Hemodynamic Studies**

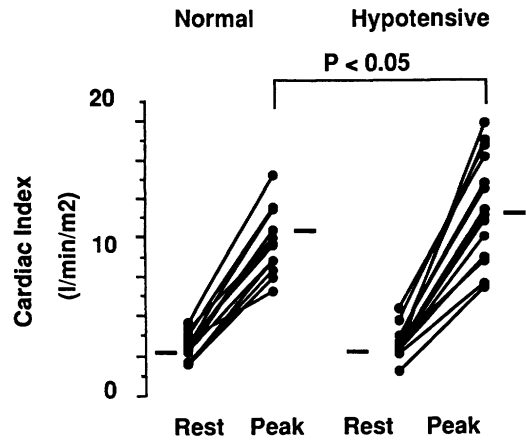
	Normotensive (n=14)	Hypotensive (n=14)
Age	42±11	32±14
Sex		
Male	9	8
Female	5	6
Family history		
HCM	3 (21%)	5 (36%)
HCM/SD	2 (14%)	5 (36%)
Chest pain	10 (71%)	6 (43%)
NYHA II/III	6 (43%)	4 (29%)
Syncope	7 (50%)	3 (21%)
Maximum LV wall thickness (mm)	21±4	23±9
LA size (mm)	45±10	40±8
Gradient (>30 mm Hg)	6 (43%)	3 (21%)
SVT/VT	6 (43%)	7 (50%)

HCM, hypertrophic cardiomyopathy; SD, sudden death; NYHA, New York Heart Association classification; LV, left ventricular; LA, left atrial; SVT, supraventricular tachycardia; VT, nonsustained ventricular tachycardia.

normotensive group, seven had experienced syncope; five of these seven patients experienced syncope in association with paroxysmal atrial fibrillation (Table 2). In the hypotensive group, two had a continuous fall in blood pressure, while 12 demonstrated an initial rise and subsequent fall in blood pressure during exercise of 25–100 mm Hg (median, 50 mm Hg) from the peak value (Figure 2). Cardiac index increased in both groups and was higher in the hypotensive group at peak exercise (9.5±2.8 versus 7.8±1.6 l/min/m<sup>2</sup>; p=0.05), reflecting the higher peak V<sub>O</sub><sub>2</sub> and younger age of this group (Figure 3). The systemic vascular resistance at rest was similar in the normotensive and in the hypotensive patients. During the first 2 minutes of exercise, the fall in systemic



**FIGURE 2. Plot of exercise systolic blood pressure (BP) response in 14 patients with normal response and 14 with hypotensive response. Peak Ex, peak exercise.**

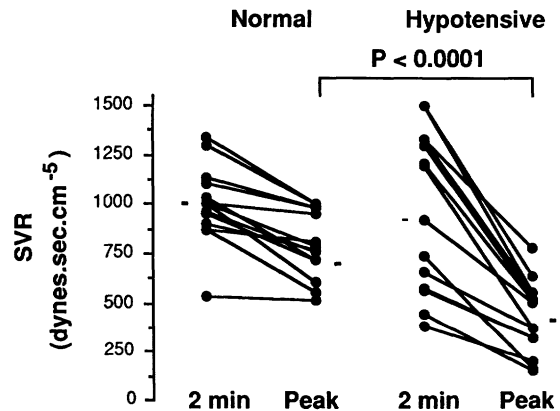


**FIGURE 3. Plot of Fick-derived cardiac index during exercise in 14 patients with normal blood pressure response and 14 with abnormal blood pressure response. Cardiac index increased fivefold in both groups though magnitude of increase was greater in hypotensive patients.**

vascular resistance was similar in both groups; however, at peak exercise, the systemic vascular resistance was significantly lower in the hypotensive group than in controls (Figure 4). The fall in systemic vascular resistance expressed as the percentage decrease from baseline to peak exercise was also significantly greater in patients with a hypotensive response than in those with a normotensive response.

**Discussion**

Exercise hypotension has been documented in HCM.<sup>21</sup> The potential for hemodynamic collapse was recognized early,<sup>1</sup> and its importance was underscored by the fact that the majority of sudden deaths occurred during or in the recovery period after exercise.<sup>22,23</sup> In this consecutive group of 129 patients with HCM, exercise hypotension was seen in 33%, with falls in blood pressure of more than 40 mm Hg



**FIGURE 4. Plot of systemic vascular resistance (SVR) in 14 patients with normal blood pressure response and 14 with abnormal blood pressure response measured after 2 minutes of exercise and at peak exercise. The decrease in systemic vascular resistance from 2 minutes to peak was significantly greater in hypotensive patients.**

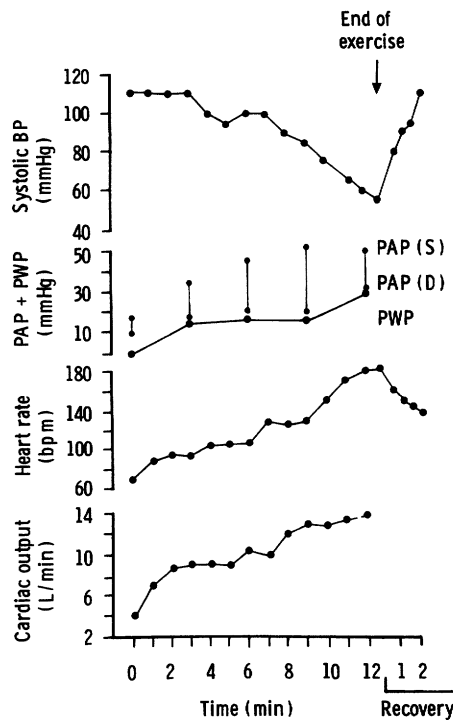


FIGURE 5. Hemodynamic recordings from asymptomatic 25-year-old patient with 1.6 cm asymmetrical septal hypertrophy and no left ventricular outflow tract gradient. Diagnosis was made during family screening after the sudden death of his 22-year-old sister. Systolic blood pressure (BP) fell continuously during exercise despite an appropriate increase in heart rate and cardiac output and maintenance of filling pressure. The patient remained asymptomatic. PAP, pulmonary artery pressure; PWP, pulmonary capillary wedge pressure; S, systolic BP; D, diastolic BP.

documented in 12 patients. A greater percentage of young patients had exercise hypotension. This does not reflect increased exercise duration in the young, as both groups attained similar levels of anaerobic metabolism. Of interest was the absence of symptoms of impaired consciousness in the younger patients despite marked falls in blood pressure (40–100 mm Hg) with systolic pressures as low as 60 mm Hg (Figure 5). In contrast, the adults with marked exercise hypotension complained of fatigue or symptoms of impaired consciousness shortly after blood pressure began to fall. This suggests that patients, especially children and young adults, may be unaware of serious circulatory changes during high levels of exercise resulting in hemodynamic collapse. This may result in regional myocardial ischemia progressing to electrical instability particularly in areas of myocyte disarray, providing a substrate for fatal arrhythmia. The presence of a “distant early warning system” for exercise hypotension, which was only seen in the adults, may be an important protective mechanism.

Arrhythmias were rare during or after exercise, and in only one patient was a hemodynamically significant arrhythmia provoked by exercise. Invasive hemodynamic studies in patients with exercise hypo-

TABLE 3. Exercise Hemodynamics in 14 Patients With Exercise Hypotension and 14 With Normal Blood Pressure Response

	Normotensive (n=14)	Hypotensive (n=14)	p
Systolic BP (mm Hg)			
Rest	132±14	133±29	NS
Peak exercise	214±34	135±80	0.0001
Cardiac index (l/min/m <sup>2</sup> )			
Rest	2.5±0.6	2.6±0.7	NS
Peak exercise	7.8±1.6	9.5±2.8	0.05
SVR (dynes · sec · cm <sup>-5</sup> )			
Rest	1,757±437	1,778±585	NS
After 2 minutes of exercise	999±195	973±404	NS
Peak exercise	744±187	428±185	0.0001
$\dot{V}O_2$ max			
Peak exercise (ml/min/kg)	26.3±7.3	33.2±8.5	NS
Predicted $\dot{V}O_2$ (%)	86±16	74±19	NS

BP, blood pressure; SVR, systemic vascular resistance;  $\dot{V}O_2$  max, maximum oxygen consumption.

tension and in those with a normal blood pressure response demonstrated that hypotension was related to a fall in systemic vascular resistance and occurred despite an appropriate rise in cardiac index. Exercise hypotension that develops in association with ischemic or valvular heart disease has been presumed to relate to impaired cardiac output response.<sup>4,24,25</sup> In HCM, it has been assumed that exercise hypotension is related to the inability to maintain stroke volume during tachycardia because of inadequate time for filling. In this study, the cardiac index rose similarly in both groups, being marginally higher in the hypotensive patients because they were younger and exercised to a greater workload as judged by peak oxygen consumption at anaerobic threshold. The magnitude of the increase in cardiac index seen in both groups was similar to that of untrained normal subjects of similar age and gender.<sup>26</sup> The peak heart rate and cardiac index during exercise were similar in patients with and without a resting left ventricular gradient, suggesting that in these patients such gradients did not significantly limit the stroke volume response during exercise and that obstruction was not a determinant of exercise hypotension.

At the commencement of exercise, the systemic vascular resistance normally falls to approximately half the resting value as the vasculature of the exercising muscle dilates.<sup>7</sup> In both the normal blood pressure group and the hypotensive group, systemic vascular resistance was similar at rest and at 2 minutes, confirming an initially normal vasodilator response. At peak exercise in the hypotensive group, however, the systemic vascular resistance fell to approximately 25% of the resting value, whereas in the normal group it remained at approximately 45% of the resting value. The mechanism of this exaggerated fall in peripheral vascular resistance is unknown

but may relate to activation of the ventricular baroreceptor reflex resulting in withdrawal of sympathetic tone to the resistance vessels.<sup>25,27-29</sup> This reflex has been implicated in syncope associated with aortic stenosis and, more recently, in the blunted blood pressure response to exercise in some patients with ischemic heart disease.<sup>24,25,28</sup> Support for activation of this reflex as a mechanism in the present study comes from the reduced left ventricular systolic and diastolic dimensions found in the patients with exercise hypotension. Exercise hypotension was more common in the younger patients and was associated with reduced left ventricular cavity dimensions. Increased wall stress is known to activate the ventricular mechanoreceptors; reduced ventricular volume, increased wall thickness, and heightened sympathetic drive might result in increased wall stress.<sup>30-32</sup> Activation of the ventricular mechanoreceptor reflex resulting in decreased sympathetic tone might be expected to affect heart rate. We did not observe any slowing of the peak heart rate coincident with hypotension, but this component of the reflex may be masked by high levels of circulating catecholamines during high levels of exercise.<sup>33</sup>

The relation of exercise hypotension and abnormal recovery blood pressure response to a family history of sudden death suggests that hemodynamic instability is an important potential mechanism for sudden death in HCM.<sup>5,6</sup> Three asymptomatic patients not receiving medication and all under the age of 25 years experienced sudden death; two were successfully resuscitated. All three patients had exercise hypotension. The finding of hemodynamic instability and its association with youth and a family history of sudden death suggests an important initiating mechanism of sudden death. The demonstration of exercise hypotension may provide a useful marker for the high-risk young patient. Identification of patients at high risk is problematic. Syncope in children and ventricular tachycardia in adults are sensitive and specific markers of increased risk but have a low predictive accuracy. The finding of equal proportions of syncope and ventricular tachycardia in the three blood pressure response groups suggests that exercise hypotension is a useful adjunct in risk stratification. This warrants prospective evaluation, particularly in view of the absence of a sensitive marker of sudden death in young patients with HCM.<sup>34</sup>

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