Exercise Capacity and Blood Pressure Associations With Left Ventricular Mass in Prehypertensive Individuals

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Abstract—Prehypertensive individuals are at increased risk for developing hypertension and cardiovascular disease compared with those with normal blood pressure. Early compromises in left ventricular structure may explain part of the increased risk. We assessed echocardiographic and exercise parameters in prehypertensive individuals (n=790) to determine associations between exercise blood pressure and left ventricular structure. The exercise systolic blood pressure at 5 metabolic equivalents (METs) and the change in blood pressure from rest to 5 METs were the strongest predictors of left ventricular hypertrophy. We identified the systolic blood pressure of 150 mm Hg at the exercise levels of 5 METs as the threshold for left ventricular hypertrophy. There was a 4-fold increase in the likelihood for left ventricular hypertrophy for every 10-mm Hg increment in systolic blood pressure beyond this threshold (OR: 1.15; 95% CI: 1.12 to 1.18). There was also a 42% reduction in the risk for left ventricular hypertrophy for every 1 MET increase in the workload (OR: 0.58; $P<0.001$). When compared with low-fit, moderate, and high-fit individuals exhibited significantly lower systolic blood pressure at an exercise workload of 5 METs (155±14 versus 146±10 versus 144±10; $P<0.05$), lower left ventricular mass index (48±12 versus 41±10 versus 41±9; $P<0.05$), and prevalence of left ventricular hypertrophy (48.3% versus 18.7% versus 21.6%; $P<0.001$). This suggests that moderate improvements in cardiorespiratory fitness achieved by moderate intensity physical activity can improve hemodynamics and cardiac performance in prehypertensive individuals and reduce the work of the left ventricle, ultimately resulting in lower left ventricular mass. **(*Hypertension*. 2007;49:55-61.)**

Key Words: prehypertension ■ left ventricular hypertrophy ■ exercise capacity ■ exercise blood pressure

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) introduced prehypertension as a new classification of blood pressure (BP) that includes those with resting systolic BP of 120 to 139 mm Hg and/or diastolic BP 80 to 89 mm Hg.[1] Prehypertensive individuals are at increased risk for developing hypertension and cardiovascular disease compared with those with normal BP.[2,3] It is estimated that substantial reductions in hospitalizations, nursing home admissions, and deaths would be realized if prehypertension is eliminated[4] or the progression from prehypertension to hypertension is prevented.

The factors involved in the increased risk are not well defined. Prehypertension may mark the beginning of a progressive remodeling of the left ventricle that may go unnoticed for years. Increased left ventricular mass (LVM) is an independent predictor of cardiovascular disease and mortality.[5–7] Naturally, reversing or retarding the rate of progression from prehypertension to hypertension and preventing target-organ injury is desirable.

Daytime ambulatory systolic BP is directly associated with LVM and is a stronger predictor of it than resting BP.[8,9] This suggests that the impetus for increased LVM is an elevated hemodynamic load during routine daily activities. Because the metabolic demand of most routine daily activities is within 5 metabolic equivalents (METs),[10] the BP taken during an exercise tolerance test (ETT) at the workload of 5 METs is likely to reflect the hemodynamic load during daily activities. Thus, this exercise BP may be used as a practical and relatively inexpensive predictor of increased risk for left ventricular hypertrophy (LVH) in prehypertensive individuals.

Moderate and high-fit prehypertensive individuals exhibit significantly lower ambulatory BP,[11] exercise BP, and heart rate (HR) at submaximal and absolute workloads[12] when compared with unfit. We also reported significantly lower exercise BP at the absolute submaximal workloads of 3 to 6 METs[13] and LVM[14] in hypertensive patients after 16 weeks of low-to-moderate intensity exercise training. Collectively, these findings support that moderate increases in cardiorespiratory fitness may result in lower BP, HR, and hemodynamic

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load during physical exertion, such as routine daily activities. The lower hemodynamic load may lead to lower LVM. Thus, we echocardiographically assessed cardiac parameters and exercise BP in prehypertensive individuals to determine the associations among exercise capacity, BP, and left ventricular structure and function.

Methods

Participants

From 1998 to 2005, we collected data on subjects from an outpatient clinic at Tzanio Hospital, Women's Social Welfare Clinic, and a private cardiology clinic (Mediton), located in Athens and Piraeus, Greece. Individuals scheduled for an ETT as a routine evaluation, preemployment requirement, or for participation in a health/fitness club, were considered for the study if they: (1) achieved ≥90% of the age-predicted maximal HR during the ETT with no evidence suggestive of ischemia based on the ACC/AHA guidelines[15]; (2) had resting BP <140/90 mm Hg; (3) did not use tobacco products for ≥1 year; (4) were not alcoholics; (5) had no overt chronic disease; (6) were not taking any cardiac, antihypertensive, or any other medication that would affect BP; (7) did not use digoxin; (8) did not have sleep apnea; and (9) did not have history of an implanted pacemaker, congenital valvular heart disease, pre-excitation syndrome, left bundle branch block, and impaired chronotropic response.[16]

A total of 888 individuals met these criteria. The study was described in detail to all of the individuals. A written consent, as per local guidelines, was obtained to undergo an echocardiographic evaluation. Of those, 790 (408 men; mean age: 50.1±11; range: 20 to 77 years; and 382 women; mean age: 53.7±9.9; range: 20 to 79) had resting systolic BP between 120 and 139 mm Hg and diastolic 80 to 89 mm Hg, classified by JNC 7 as prehypertensive,[1] and were included in this study. The study was approved by the local institutional review committee, and all of the procedures followed were in accordance with institutional guidelines.

To assess the effects of exercise capacity on cardiac and BP parameters, we established 3 fitness categories (low, moderate, and high) according to the peak exercise time achieved during ETT and age, as described in detail previously.[11,17]

Resting BP Assessments

Resting BP and HR were recorded before the ETT. BP measurements began after subjects were seated in a chair for 5 minutes with their backs supported and their arms supported at heart level. Proper cuff size was determined based on arm circumference. Systolic and diastolic BP levels were recorded as the first and fifth Korotkoff phases, respectively, using a mercury sphygmomanometer. Three BP readings were taken separated by 2 minutes between readings. The third reading was recorded as the resting BP, and BP classification for that individual was based on that reading. The HR at this time was recorded as the resting HR.

Exercise Assessments

The standard Bruce protocol[18] was used for all of the individuals. Exercise HR was recorded continuously. Exercise BP was assessed at the end of each stage, at peak exercise, and within 1, 3, and 6 minutes after the cessation of exercise. All of the resting and exercise BP assessments were made by indirect arm-cuff sphygmomanometer in the right arm.

Exercise capacity was recorded as peak exercise time in minutes. Peak exercise workload was estimated on the basis of the speed and grade of the treadmill and recorded as METs (1 MET equals 3.5 mL of oxygen uptake per kilogram of body weight per minute).[18] Subjects were encouraged to exercise until volitional fatigue in the absence of symptoms or other indicators of ischemia. For more accurate estimated workload assessment of fitness, participants were not allowed to lean against handrails of the treadmill.

Additional parameters recorded were: body weight, height, smoking habits as reported by the patient, and history of diabetes and other chronic diseases. Body mass index (BMI) was calculated as weight (kilograms) divided by height squared (meters).

Echocardiographic Evaluations

All of the echocardiographic studies were performed by a cardiologist blinded to the results of the exercise test using the ATL Ultra Mark (Advanced Technology Labs Inc) with a high-definition 3.2-MHz transducer. Left ventricular systolic dimension (LVSD) and left ventricular diastolic dimensions (LVDDs), interventricular septal (IVS) thickness, and posterior wall (PW) thickness were measured following the American Society of Echocardiography guidelines. LVM was calculated using the anatomically validated formula by Devereux[19]:$LVM=0.8\times[1.04\times (IVS+PW+LVDD)^3-(LVDD)^3]+0.6$. LVM was then indexed to body size by dividing raw LVM by height in meters to the allometric power of 2.7 to obtain LVM index. LVH was defined as LVM index >50 g/m$^{2.7}$ for men and >47 g/m$^{2.7}$ women, as suggested by de Simone,[20] shown to predict event-free survival well.

Pulsed Doppler examination of the transmitral diastolic inflow was also performed. Measurements of the transmitral inflow were performed from the apical 4-chamber view, with the Doppler sample volume placed between the leaflet tips of the mitral valve during diastole. The following variables were obtained: e-wave velocity, a-wave velocity, e-wave to a-wave ratio, and deceleration time of e-wave velocity. To minimize variability, 5 cardiac cycles were read and averaged. All of the echocardiographic data were read at the end of the study by a cardiologist, blinded to the results of all of the other tests related to the study. Only tracings with optimal visualization were used. In our echocardiographic laboratory, the range of intraobserver variability by a single reader is 0 to 1.5 mm for left ventricular cavity dimensions and 0 to 0.5 mm for wall thickness.

Data Analysis

Continuous variables are presented as mean±SD. One-way ANOVA was performed to identify gender differences for age, body weight, BMI, and HR and BP measurements at rest and during exercise. Interactions between BP groups and gender for the exercise BP were tested. One-way ANOVA was also applied to identify differences in age, body weight, BMI, resting HR, and BP among the 3 fitness categories. The Bonferroni rule to correct for inflation in the type I error was applied with multiple comparisons. Normality of the dependent variables was assessed by the Kolmogorov–Smirnov test. Equality of variances was assessed by the Levene test. Fixed-effects general linear models were applied to evaluate differences on echocardiographic and exercise parameters among the fitness categories after controlling for age and BMI as potential confounders.

Simple regression analyses were performed to assess the relationship among resting BP, exercise, and echocardiographic parameters and subject characteristics. Multiple logistic regression analysis was applied to evaluate the association between BP at various exercise intensities on the likelihood of having LVH after controlling for age, BMI, and resting BP. Similarly, deviance residuals were used to evaluate models goodness of fit. Cutoff analysis was used to determine the BP threshold for LVH.

All of the reported *P* values are based on 2-sided *t* tail test. *P* value <0.05 was considered as statistically significant. All of the statistical analyses were performed in SPSS software (SPSS version 11.5, SPSS Inc).

Results

Baseline Characteristics

Men were significantly younger than women (age: 50±11 years versus 53±10 years; $P<0.001$) and had higher body weight in kilograms (81.0±9.1 versus 66.0±10.5; $P<0.001$) and BMI (26.8±2.5 versus 24.9±3.7; $P<0.001$) but similar resting BP (129±10/76±8 mm Hg versus 128±10/

TABLE 1. Resting and Exercise Parameters for Prehypertensive Individuals

Variable	
No. of participants	790
Age, y	52±10
Weight, kg	73.6±12.5
BMI, g/m^2	25.9±3.3
Rest HR, bpm	79±8
Rest systolic BP, mm Hg	131±6
Rest diastolic BP, mm Hg	77±8
Exercise HR at 5 METs, bpm	116±15
Systolic BP at 5 METs, mm Hg	148±12
Diastolic BP at 5 METs, mm Hg	81±7
Exercise HR at 7 METs, bpm	135±17
Systolic BP at 7 METs, mm Hg	165±17
Diastolic BP at 7 METs, mm Hg	84±7
Peak exercise HR, bpm	163±15
Peak exercise SBP, mm Hg	183±18
Peak exercise DBP, mm Hg	87±7
Peak exercise time, min	9.2±2.0
Peak workload, METs	8.5±1.5

Data are number or mean±SD.

75±8 mm Hg). There was no intragender-by-BP group interaction for all of the exercise BP variables considered ($P>0.6$), and, therefore, the data were not stratified by gender.

Clinical Characteristics and Exercise Parameters

Clinical characteristics and exercise parameters for the entire group are presented in Table 1. Comparisons among the fitness groups are presented in Table 2. Age was significantly lower in the moderate-fit group ($P<0.01$), and BMI was significantly lower in the high-fit individuals ($P<0.01$). The resting systolic BP was similar among groups, but resting diastolic BP was significantly higher in the low-fit compared with the high-fit group (78±7 versus 77±8 versus 75±8 mm Hg; $P<0.01$, for low, moderate, and high-fit groups, respectively). Similarly, resting HR was significantly higher in the low-fit group compared with other 2 groups ($P<0.01$). Thus, age, diastolic BP, and BMI were used as covariates when appropriate.

Exercise Parameters and Fitness Categories

Moderate- and high-fit individuals had significantly lower HR and BP at 5 METs and 7 METs compared with low-fit individuals ($P<0.01$). The rate-pressure product at 5 METs and 7 METs was significantly different among all of the fitness groups along with peak exercise time and METs ($P<0.01$). Peak exercise systolic BP was lower only in the high-fit individuals compared the other 2 groups ($P<0.01$). Peak HR and rate-pressure product were similar among the fitness groups (Table 2).

Echocardiographic Parameters and Fitness Categories

LVM index was related to age ($r=0.43$; $P<0.001$), BMI ($r=0.17$; $P<0.001$), exercise BP at 5 METs ($r=0.67$;

TABLE 2. Resting and Exercise Parameters for Prehypertensive Individuals According to Fitness Levels

Variable	Low Fit (n=176)	Moderate Fit (n=401)	High Fit (n=213)
Age, y	53±11	51±10*	54±10
Weight, kg	74±13	76±12	69±12*
BMI, g/m^2	26.8±3.7†	26.1±209	24.7±3.4
Rest HR, bpm	83±9*	79±8	77±6
Rest systolic BP, mm Hg	131±7	132±6	130±6
Rest diastolic BP, mm Hg	78±7	77±7	75±8*
Systolic BP at 5 METs, mm Hg	155±14*	146±10	144±10
Diastolic BP at 5 METs, mm Hg	83±7*	80±7	79±7
HR at 5 METs, bpm	127±16†	115±13	110±14
Rate-pressure product at 5 METs	19 292±3193†	16 641±2256	15 511±2212
Systolic BP at 7 METs, mm Hg	177±17*	164±16	160±15
Diastolic BP at 7 METs, mm Hg	87±8*	84±7	82±7
HR at 7 METs, bpm	145±18†	134±16	126±14
Rate-pressure product at 7 METs	25 853±3949†	21 772±3407	19 984±2748
Systolic BP at peak exercise, mm Hg	183±18	179±19	176±18*
Diastolic BP at peak exercise, mm Hg	88±8	87±7	86±7
Peak HR, bpm	158±19	166±14	163±15
Rate-pressure product at peak exercise	29 257±4156	29 982±3838	28 997±3425
Peak exercise time, min	6.6±1.6†	9.7±1.2	10.3±1.6
METs	6.4±1.2†	8.8±0.8	9.5±1.1

*Different from other fitness groups ($P<0.01$).
†Differences among all fitness groups ($P<0.01$).

TABLE 3. Echocardiographic Parameters for Prehypertensive Individuals According to Fitness Levels

Variable	Low Fit (n=176)	Moderate Fit (n=401)	High Fit (n=213)
PW, mm	9.9±1.2*	9.6±0.9	9.4±0.9
IVS, mm	10.4±1.1*	10.0±0.9	9.8±0.9
LVDD, mm	49.0±3.2*	48.2±2.9	47.5±2.8
LVSD, mm	27.1±3.2	26.7±3.4	26.0±3.0*
LVM, g	184±43*	170±35	162±34
LVM index, g/m$^{2.7}$	48±12*	41±10	41±9.3
Individuals with LVH, %	48.3*	18.7	21.6
e-wave, m/s	0.61±0.13*	0.69±0.12	0.70±0.13
a-wave, m/s	0.62±0.11	0.60±0.12	0.59±0.10
e/a wave	1.0±0.3*	1.2±0.3	1.2±0.3
Deceleration time, s	232±22*	221±20	219±20

*Different from other fitness groups ($P<0.05$).

$P<0.001$) and 7 METs ($r=0.74$; $P<0.001$), maximal exercise BP ($r=0.63$; $P<0.001$), and resting BP (0.40; $P<0.001$). LVM index and peak METs were inversely related ($r=-0.44$; $P<0.001$).

Echocardiographic comparisons among the fitness groups are presented in Table 3. After controlling for age, BMI, and resting diastolic BP, the low-fit individuals had significantly higher IVS and PW thickness, LVM, LVM index, and LVDD than the moderate- and high-fit individuals ($P<0.01$). In addition, the e-wave, e/a wave ratio, and deceleration time were also significantly different ($P<0.01$). LVH was more prevalent in the low-fit individuals (48.3% versus 18.7% versus 21.6%, $P<0.001$, for low-, moderate-, and high-fit groups, respectively).

LVH Predictors

To determine associations between LVM and exercise parameters and the strongest predictors of LVH, we applied simple and multiple logistic regression analyses. We observed strong associations between LVM index and BP at all levels of exercise ($r=0.67$, $r=0.74$, and $r=0.63$ for BP at 5 METs, 7 METs, and peak exercise, respectively; all P values <0.001) and weaker associations between resting BP and LVM index ($r=0.40$; $P<0.001$). LVM index was inversely associated with the MET level with ($r=-0.44$; $P<0.00$).

We then applied multiple logistic regression analysis to determine predictors of LVH. To avoid colinearity between the BP variables at different exercise levels (5 METs, 7 METs, and peak exercise) and the change in BP from rest to a specific exercise level, we created several models, each to include the BP of only 1 exercise level.

After adjusting for resting systolic BP, BMI, and age, the strongest predictors of LVH were exercise systolic BP at 5 METs (OR: 1.15; 95% CI: 1.12 to 1.18), followed by the change in systolic BP from rest to 5 METs (OR: 1.14; 95% CI: 1.11 to 1.17) and systolic BP from rest to 7 METs BP (OR: 1.13; 95% CI: 1.11 to 1.16). Resting and peak exercise systolic BP were substantially weaker predictors. There was also a 42% reduction in the risk for LVH for every 1 MET increase in the workload (OR: 0.58; $P<0.001$).

TABLE 4. Echocardiographic and Exercise Parameters for Prehypertensive Individuals According to Blood Pressure at 5 METs

Variables	Systolic BP <150 mm Hg (n=430)	Systolic BP ≥150 mm Hg (n=360)
PW, mm	9.1±0.6*	10.3±1.0
IVS, mm	9.60.4±0.7*	10.6±1.0
LVDD, mm	47.0±2.6*	50.0±2.6
LVSD, mm	25.6±3.0	28.0±3.2*
LVM, g	152±24*	195±38
LVM index, g/m$^{2.7}$	36.6±6.3*	49.8±10.2
e-wave, m/s	0.74±0.10*	0.60±0.13
a-wave, m/s	0.55±0.08	0.66±0.12
e/a wave	1.3±0.2*	0.9±0.3
Deceleration time, s	214±16*	235±21
Exercise time, min	9.9±1.6*	8.2±2.1
METs	9±1.1*	7.7±1.6

*Difference between the groups ($P<0.001$).

Cutoff analysis revealed that the threshold for LVH was ≥150 mm Hg for systolic BP at 5 METs and ≥20 mm Hg change from rest to exercise at 5 METs. For the prehypertensive individuals, there was a 4-fold increase in the likelihood for LVH for every 10-mm Hg increments above this threshold. For exercise systolic BP at 5 METs, the sensitivity and specificity of the test were 86.3% and 71.4%, respectively. The positive and negative predictive values were 52.2% and 93.5%, respectively.

We also stratified the data based on the exercise systolic BP and compared those who achieved and exceeded systolic BP of 150 mm Hg at 5 METs and those whose systolic BP was <150 mm Hg. After adjusting for age, BMI, and resting BP, we noted that all of the echocardiographic parameters assessed were significant differences and more favorable in those with systolic BP <150 mm Hg (Table 4). In addition, there were significantly more individuals who achieved a systolic BP of ≥150 mm Hg in the low-fit versus moderate- and high-fit groups (67.6% versus 39.7% versus 31.5%, respectively; $P<0.001$).

Discussion

Prehypertensive individuals are at an increased risk for developing hypertension and cardiovascular disease.[2,3] Because LVH is a powerful and independent predictor of cardiovascular morbidity and mortality,[5–7] early compromises in LV structure may explain part of the increased risk. The findings of this retrospective study support that LVH is prevalent in prehypertensive individuals ,especially in those with low exercise capacity. Furthermore, the presence of LVH can be predicted by the systolic BP at exercise level of 5 METs or the change in systolic BP from rest to the exercise levels of 5 METs. In this group, the likelihood of having LVH increased by 4-fold for every 10-mm Hg increment above the exercise systolic BP threshold of 150 mm Hg (Table 5). More than 86% (176 of 204) of the individuals with LVH who achieved or exceeded the systolic BP threshold of 150 mm Hg were correctly identified as having LVH (sensitivity of test).

TABLE 5. Multiple Logistic Regression Analysis for Predictors of LVH in Prehypertensive Individuals

Variables	Coefficient (β)	SE	Walt χ^2	OR	95% CI	*P*
SBP at 5 METs	0.141	0.021	107.6	1.15	1.12–1.18	<0.001
5-MET ΔSBP	0.138	0.013	107.9	1.14	1.11–1.17	<0.001
7-MET ΔSBP	0.131	0.011	147.1	1.14	1.11–1.16	<0.001
SBP at 7 METs	0.126	0.011	140.1	1.13	1.11–1.15	<0.001
Peak exercise SBP	0.079	0.008	107.2	1.08	1.01–1.15	0.016
Resting SBP	0.102	0.017	35.9	1.10	1.10–1.15	<0.001

SBP indicates systolic BP.

Approximately 94% of those who achieved systolic BP levels below this threshold were identified as not having LVH (negative predictive value). The sensitivity of 86% is substantially higher than the 6% to 53% range offered by standard ECG criteria.[21,22]

The clinical implications of these finding are significant. First, the exercise level of 5 METs can be achieved easily by most and especially older individuals. Second, the relatively lower treadmill speed at an exercise intensity of 5 METs reduces patient arm movement and interference with the auscultation of BP and, therefore, allows for a more accurate assessment; thus, observer error is substantially reduced. Third, the high sensitivity and negative predictive value of the exercise BP at 5 METs allows a great degree of confidence that the presence of LVH is unlikely. Because of the wide use of exercise stress testing, exercise systolic BP at 5 METs along with the change in systolic BP from rest to exercise can be easily applied in a clinical setting to assess the likelihood of LVH in prehypertensive individuals.

An exaggerated systolic BP at peak exercise, usually defined as systolic BP >210 mm Hg, has been reported by some as the predictor of LVH.[23,24] Others, however, questioned such relationship.[25] Our data support that the systolic BP at 5 METs is a substantially stronger predictor of LVH than that observed for the peak systolic BP (OR: 1.154; 95% CI: 1.12 to 1.18 versus OR: 1.09: 95% CI: 1.07 to 1.11, for systolic BP at 5 METs and peak exercise, respectively). In fact, peak systolic BP exhibited similar predictive value with resting BP (Table 5). Unfortunately, early studies only considered peak exercise BP, and, therefore, direct comparisons with our findings are limited. In a recent study, the investigators reported that prehypertensive, sedentary individuals exhibited significantly higher BP at low exercise levels (≈3 METs) and greater left ventricular wall thickness compared with sedentary and normotensive subjects.[26] In another study, significant associations were noted only among the exercise BP at 5 METs, wall thickness, and LVM.[27]

The findings of our study also support that improved physical fitness may prevent or at least attenuate the development of LVH. Moderate- and high-fit prehypertensive individuals had significantly lower left ventricular wall thickness and LVM and more favorable indexes of cardiac function than low-fit individuals. The prevalence of LVH was significantly higher in the low-fit individuals (48.3% versus 18.7% versus 21.6%; Table 3), and the likelihood of LVH was reduced by 42% for every 1-MET increase in exercise capacity.

The mechanisms by which improved fitness moderates LVM are not within the scope of this study. However, the findings generate some speculation. High-intensity aerobic exercise training has been shown to improve cardiac performance and reduce the work of the heart during submaximal workloads in young individuals.[28–30] The improvement is attributed to hemodynamic changes that include a lower HR at a given cardiac output,[28] the result of increased end-diastolic volume, and the consequent enhanced left ventricular performance,[29] as well as a reduced afterload attributed to lower peripheral resistance.[28] The reduction in cardiac work is also accompanied by a lower myocardial oxygen demand and consumption.[30]

The current findings fit this profile. Note that the systolic BP, HR, and rate-pressure product at the absolute submaximal workload of 5 METs are significantly lower in the moderate- and high-fit individuals when compared with low-fit individuals (Table 3). Subsequently, the workload of the left ventricle will also be lower. Because the metabolic demand of most routine daily activities is ≈5 METs, it is reasonable to assume that the hemodynamic load during routine daily activities for the moderate- and high-fit individuals will also be substantially lower when compared with the low-fit individuals. Consequently, the impetus for an increase in LVM is attenuated.

This view is supported by our previous findings. We reported that moderate- and high-fit prehypertensive individuals exhibit significantly lower ambulatory BP,[11] exercise BP, and HR at submaximal and absolute workloads[12] when compared with unfit. We also reported significantly lower exercise BP at the absolute submaximal workloads of 3 to 6 METs[13] and LVM[14] in hypertensive patients after 16 weeks of low-to-moderate–intensity exercise training.

Our findings regarding the association between fitness levels and LV structure and function have significant public health implications. Recent reports estimate that ≈45 million American adults are prehypertensive.[31] The development and or progression of LVH in this population may be attenuated by moderate increases in cardiorespiratory fitness. We also like to emphasize that the degree of fitness necessary for the health benefits seems to require relatively low physical effort. Note that LVM was significantly lower in our moderate-fit group compared with low-fit, with no additional reduction observed for the high-fit group. The average MET level

achieved by the moderate-fit group was 8.8±0.8. This fitness level is easily achieved by most middle-aged and older individuals by a brisk walk of 30 to 40 minutes most days of the week.[32] This is in accordance with the JNC 7 strong recommendations that lifestyle modifications be used as the primary preventive strategy for all prehypertensive individuals.[1] Based on our findings, the subgroup of prehypertensive individuals at highest risk is the low-fit group. These individuals can be easily identified by the systolic BP response at the workload of 5 METs and targeted for a more aggressive lifestyle modification. However, our findings are based on a retrospective design and future prospective studies are necessary to confirm our findings.

Limitations

The present study is cross-sectional and, therefore, has several limitations. Because of the design, we cannot provide causal relationships but only state hypotheses that could be evaluated in randomized clinical trials. BP classifications were based on 3 reading taken during 1 visit. It is likely that the resting BP would be slightly elevated as an anticipatory response to the exercise test. Thus, it is conceivable that for some truly normotensive individuals with BP in the upper range of normal BP (<120/80 mm Hg), the BP readings before the ETT were elevated enough to artificially place them in the prehypertension category. Our study population consists of white Greeks, leaner than Americans of similar age, and may not represent other populations or ethnic groups.

Conclusions

Our findings provide evidence that the systolic BP at the workload of 5 METs is a strong and practical predictor of LVH in prehypertensive individuals. A 4-fold increase in the risk of LVH was noted for every 10-mm Hg rise in systolic BP beyond the threshold of 150 mm Hg at this exercise level of 5 METs.

Our findings also support an inverse association between LVM and exercise capacity. For every 1-MET increase in the workload we noted a 42% reduction in the risk for LVH. However, we must emphasize that our statements are based on a retrospective design and that future prospective studies are necessary to confirm our findings.

Perspectives

Our findings suggest that low exercise capacity fosters the development of LVH independent of resting BP levels. Moreover, prehypertensive individuals with low exercise capacity are identified as a high-risk subgroup for developing LVH. Prospective studies should assess whether increased fitness can lead to regression of LVM and a more favorable LV function in this subgroup.

Disclosures

None.

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