METABOLIC SYNDROME AND RELATED DISORDERS
Volume 6, Number 1, 2008

Pp. 8–14
DOI: 10.1089/met.2007.0013

Metabolic Syndrome Status Changes with Fitness Level Change: A Retrospective Analysis

MARK S. MAXWELL, M.S.,[1] BRIAN R. GOSLIN, Ph.D.,[1] RONALD L. GELLISH, M.S.,[1]
KENNETH R. HIGHTOWER, Ph.D.,[1] RONALD E. OLSON, Ph.D.,[1]
VIRINDER K. MOUDGIL, Ph.D.,[1] and GARY D. RUSSI, Ph.D.[1]

ABSTRACT

Background: **Cardiorespiratory fitness level is inversely related to the incidence of Metabolic Syndrome (MetS). This study examined the effects of changes in cardiorespiratory fitness level on MetS status.**

Methods: **Male and female participants in a health enhancement program ($n = 212$) were clinically examined for changes in their MetS status and estimated aerobic capacity over a 3-year period. Two physical examinations, each including a maximal treadmill stress test, occurred within this time frame. Participants were divided into three groups: Group 1 ($n = 103$) was composed of individuals who presented with MetS at exam 1 and reversed their MetS disease status by exam 2; Group 2 ($n = 75$) members presented with MetS at both exams; and Group 3 ($n = 34$) individuals were MetS-free at exam 1 but acquired MetS by exam 2. The relationships between MetS clinical characteristics at exam 1 and exam 2 and changes in graded exercise test (GXT) duration were contrasted for the three groups.**

Results: **GXT duration, estimated aerobic capacity (VO_2 max), and MetS characteristics improved significantly in Group 1 ($P < 0.01$). Group 2 individuals also increased GXT duration ($P < 0.05$) but showed only nonsignificant improvements ($P > 0.05$) in clinical characteristics. Group 3 members declined in most MetS characteristics and in estimated VO_2 max ($P < 0.05$).**

Conclusions: **Increases in GXT duration accompanied MetS reversal while declines in GXT duration occurred with MetS acquisition. On an individual basis, these changes in GXT duration may be an indicator of disease status.**

INTRODUCTION

THE IMPORTANCE OF PHYSICAL ACTIVITY and cardiorespiratory fitness has grown both as a modifiable lifestyle factor and treatment intervention for Metabolic Syndrome (MetS) in recent years. Low levels of physical activity and cardiorespiratory fitness are associated with increased metabolic abnormalities and increased incidence of MetS. Lakka et al.[1] found that the least fit men with below average aerobic capacity (VO_2 max) were almost seven times more likely to develop MetS than the most fit. Laaksonen et al.[2] determined that men who are more fit, those in the upper third of VO_2 max for their age, were 75% less likely to develop MetS than men who were unfit. Inverse associations between cardiorespiratory fitness and

[1]School of Health Sciences, Oakland University, Rochester, Michigan

the prevalence of metabolic abnormalities have been established across all fitness levels.[3,4,5]

Exercise training, including aerobic and resistance exercise and combinations thereof, is emerging as an effective treatment for MetS.[4,6] Exercise as a treatment intervention has improved all-cause mortality and has reduced the risk of heart disease and type 2 diabetes mellitus. More and more research-based evidence is showing that exercise-related increases in cardiorespiratory fitness lessen the entire array of MetS risk factors including insulin resistance.[7] Exercise has also been instrumental in reversing MetS. Katzmarzyk et al.[8] reported that 30.5% of a sample of 105 middle-aged persons became MetS-free after a 20-week aerobic training program.

There is little research available, however, that links changes in aerobic capacity or cardiorespiratory fitness to changes in MetS status. Franks et al.[9] found a strong, inverse association between physical energy expenditure and MetS. Ekelund et al.[10] concluded that aerobic capacity was not an independent predictor of MetS after adjusting for physical activity. LaMonte et al.[11] determined that low cardiorespiratory fitness was a strong and independent predictor of the incidence of MetS. The absolute level of cardiorespiratory fitness by itself may or may not predict MetS, but increases or decreases in aerobic exercise capacity over time may be associated with MetS acquisition, retention, or reversal. The present study examined changes in graded exercise test duration, a predictor of aerobic exercise capacity, in individuals who presented with MetS and persons who were MetS-free and then acquired the syndrome.

METHODS

The participants for this study were a subgroup ($n = 212$: male = 182; female = 30) of individuals from a cohort of 4,666 adults who were members of a health assessment/fitness institute located on the campus of Oakland University in Rochester, MI. The members underwent comprehensive health and wellness assessments during their tenure at the institute consisting of a full physical exam that included pulmonary function testing, vision testing, audiometric screening, blood tests, urine specimens, and stool samples. Weight, height, and flexibility were also measured.

Following these assessments and tests, each person performed a symptom-limited maximum treadmill stress test. Data were collected from 1979 until early 2003. All participants gave written informed consent for their information to be included in future research. The present retrospective study of this clinical information was conducted in 2006. The University's Institutional Review Board gave approval for this research. The authors of this study have no conflicts of interest to declare.

The sample members for this study presented with or acquired MetS while being part of the program at the institute. In the current study, National Cholesterol Education Program Treatment Panel III (NCEP ATP III) guidelines[12] for defining MetS were applied, except for the measure of obesity. The World Health Organization (WHO) guideline[13] for using body mass index (BMI) to gauge obesity as a MetS risk factor was applied, instead, primarily because waist circumference and body fat percentage were not consistently obtained from members. The following standard cut-off points were then used to identify persons with MetS: high-density lipoprotein (HDL) <1.04 mmol/L (<40 mg/dL) for men and <1.30 mmol/L (<50 mg/dL) for women; triglycerides ≥1.69 mmol/L (≥150 mg/dL); resting blood pressure (BP) ≥130 mmHg systolic or ≥85 mmHg diastolic; fasting blood glucose ≥5.55mmol/L (≥100 mg/dL); and BMI ≥30 kg/m^2.[14] Individuals with three or more of these risk factors were considered to have MetS.

Exercise capacity was measured by a treadmill graded exercise test (GXT) that used a modification of the Balke-Ware protocol.[15] The test began at a 0% grade and a speed of 88.5 m/min (3.3 mph) for 3 minutes. Every 3 minutes thereafter the grade was increased by 3% until a peak elevation of 24% was achieved while maintaining the speed at 3.3 mph. Beyond that, the treadmill grade remained at 24% while the speed increased by 5.4 m/min (0.2 mph) until the person reached exhaustion.

The GXT procedure was explained to all persons immediately before proceeding with the test. Participants were encouraged to exercise (without rail-holding) beyond 85% of their 220 − age-predicted maximum heart rate threshold and to a rating of perceived exertion of at least 18 units on the 6-20 Borg scale.[16] Time to exhaustion on the treadmill test or GXT duration was the measure of exercise capacity. Aerobic capacity or VO_2 max was estimated by standard metabolic calculations based on the progression of the GXT. The total elapsed time spent on the treadmill, and the highest speed and grade achieved, were the determinants of the estimated VO_2 max.[16]

The participants were divided into three groups: Group 1 ($n = 103$; males = 88; females = 15) included individuals who presented with MetS at the time of their first exam and became MetS-free by their second exam; Group 2 ($n = 75$; males = 69; females = 6) presented with MetS at both exams; and Group 3 ($n = 34$; males = 25; females = 9) was comprised of persons who were MetS-free at their first exam but then developed MetS by their second exam. The health assessment historical data examined for the members in this study were from two consecutive exams separated by 1 to 3 years with a mean span of 1.5 ± 0.7 years. Table 1 displays their mean ages at each health exam by MetS status group. Overall, the ages of the participants investigated in this research ranged from 23 to 79 years old with a mean of 49.0 ± 10.0 years. Participants were strongly encouraged to make positive lifestyle changes based on their initial test results. The main interventions included promoting increased exercise participation (aerobic and resistance training) and recommending dietary modifications to reduce obesity, lessen cardiovascular disease risk, and improve cardiorespiratory fitness.

All statistical analyses were performed using SPSS version 14.0 (SPSS, Chicago, IL). Paired and independent t-tests along with repeated measures analysis of variance (ANOVA) were used to evaluate the significance of changes in GXT duration or MetS clinical characteristics in these three groups of participants over time. The 0.05 level of probability (two tailed) was used to test the significance of any changes.

RESULTS

As shown in Table 1, Group 1 members had a highly significant improvement ($P < 0.01$) in all MetS risk factors, GXT duration, and estimated VO_2 max as they became MetS-free. The Group 2 MetS retention participants showed an improvement in all MetS risk factors except glucose level but the improvements were not statistically significant ($P > 0.05$). Group 2 did have a statistically significant increase in GXT duration ($P < 0.05$) but their initial GXT duration on exam 1 was lower than persons who became MetS-free (Group 1; $P < 0.05$). Group 3, those who acquired MetS between exams 1 and 2, declined in GXT duration and declined in all MetS clinical characteristics. Most pertinent to this study was the finding that treadmill GXT duration increased by 1.4 minutes for Group 1, and increased by 1.0 minute for Group 2, but declined by 1.0 minute for Group 3.

Because both Groups 1 and 2 demonstrated improvement in their GXT duration from exam 1 to exam 2, they were combined and contrasted against Group 3 in subsequent statistical analyses. Repeated measures ANOVA for GXT duration using appropriate sum-of-squares calculations for unequal group sizes found evidence of a highly significant interaction between Exam and MetS Status [F (1,210) = 8.64, $P < 0.01$] (data not shown). The nature of this interaction is detailed in Table 2, which presents t-test results for the difference between groups in their change in GXT duration across exams. The mean difference of 2.2 ± 10.7 minutes was highly significant ($P < 0.01$). Chi-square analysis (not shown) revealed a significant ($P < 0.05$) difference in the proportion of sexes within the combined Groups 1 and 2 versus Group 3: 157 males (88%) and 21 females (12%) in the former, whereas the latter contained 25 men (74%) and 9 women (26%). Although the males' GXT duration was significantly greater than the females' within the same group and exam, there was no significant difference between the sexes in how their GXT duration changed between exams (data not shown). That is, the Exam × Sex and Exam × Sex × MetS Status interactions were nonsignificant ($P = 0.22$ and $P = 0.64$, respectively). These results indicate that changes in GXT du-

TABLE 1. CLINICAL CHARACTERISTICS (MEAN ± STANDARD DEVIATION) FOR PARTICIPANTS IN THE CURRENT STUDY AT THEIR INITIAL AND FOLLOW-UP PHYSICAL EXAMS, BY METS STATUS GROUP

MetS Status Group	*Group 1 (n = 103)*		*Group 2 (n = 75)*		*Group 3 (n = 34)*	
Measure	*Exam 1*	*Exam 2*	*Exam 1*	*Exam 2*	*Exam 1*	*Exam 2*
Age (years)	48.3 ±10.0	49.6 ±10.0	48.5 ±9.2	49.9 ±9.2	47.8 ±11.8	49.3 ±11.6
BMI (kg · m^{-2})	29.4 ±5.5	28.3** ±4.8	31.1 ±4.1	30.9 ±4.2	28.0 4.1	28.9* ±4.6
Glucose (mmol · L^{-1})	5.50 ±1.07	5.16** ±0.79	6.24 ±2.05	6.50 ±2.39	5.11 ±0.71	5.16 ±0.75
HDL (mmol · L^{-1})	1.01 ±0.22	1.11** ±0.21	0.99 ±0.24	1.01 ±0.23	1.17 ±0.24	1.05** ±0.25
Triglycerides (mmol · L^{-1})	2.28 ±1.00	1.66** ±0.72	2.69 ±1.67	2.36 ±1.27	1.74 ±0.72	2.27* ±1.27
SBP (mm Hg)	132.7 ±14.9	128.2** ±16.1	136.2 ±13.3	133.5 ±13.2	130.2 ±16.8	133.5 ±10.5
DBP (mm Hg)	88.8 ±8.7	85.1** ±10.0	90.0 ±8.7	88.5 ±8.4	85.8 ±10.5	88.7 ±8.1
GXT Duration (min.)	17.1 ±4.9	18.5** ±5.2	15.3 ±5.7	16.3* ±5.2	17.9 ±5.1	16.9 ±4.5
VO_{2max} (mL · kg^{-1} · min^{-1})	36.2 ±8.4	38.2** ±8.5	33.1 ±9.1	34.5 ±8.4	37.3 ±8.4	35.4* ±7.2

Note. MetS = metabolic syndrome; Group 1 = MetS/MetS-free; Group 2 = MetS/MetS; Group 3 = MetS-free/MetS; BMI = body mass index; HDL = high-density lipoproteins; SBP = systolic blood pressure; DBP = diastolic blood pressure; GXT = graded exercise (treadmill) test; VO_{2max} = estimated aerobic capacity.

*$P < 0.05$, **$P < 0.01$ (two-tailed p-value statistical significance for the Exam 1 vs. Exam 2 paired t-test contrast; the difference in "Age" across time within each group was also significant, but considered irrelevant).

ration across exams were linked to changes in MetS status: as fitness level improved (GXT duration increased) MetS status improved; and as fitness level declined (GXT duration decreased) MetS status worsened.

DISCUSSION

The purpose of the present study was to simultaneously examine changes in GXT duration and changes in MetS status. GXT duration was the main determinant of estimated VO_2 max or aerobic capacity. Group 1 ($n = 103$) participants who presented with MetS at exam 1 became MetS-free at exam 2 while simultaneously demonstrating a significant ($P < 0.01$) increase in GXT duration. Group 1 participants also had the greatest positive change in clinical characteristics. Group 2 individuals, who retained MetS, had a similar increase in GXT duration ($P < 0.05$) and also had positive changes in almost all MetS characteristics. However, their clinical changes were not as great as for Group 1 and, because they started further from the criteria values for MetS at their initial exam, their disease status did not change over the course of this study. Group 3 members, who acquired MetS by exam 2, went in the opposite direction. Group 3 participants experienced a decline in all clinical characteristics and a simultaneous decline in GXT duration.

There were clinical differences between Group 1 members who reversed MetS and Group 2 participants who retained MetS. MetS reversal individuals had higher initial GXT duration and estimated VO_2 max values. As participants became MetS-free, they demonstrated statistically significant ($P < 0.01$) improvement between exams in BMI, glucose levels, HDL levels, triglycerides levels, and blood pressure. Group 1 individuals were most likely healthier and more fit at exam 1 than persons in Group 2 who retained MetS.

There were also significant clinical differences between MetS reversal participants (Group 1) and those individuals who acquired MetS (Group 3). Persons who acquired MetS became significantly ($P < 0.05$) worse in BMI, HDL levels and triglycerides levels in direct

Table 2. Independent Samples *t*-test for Equality of the Mean Difference in the Change in Treadmill Graded Exercise Test Duration (Minutes; Mean ± Standard Deviation), Across Exams, for the Metabolic Syndrome Disease Status Groups Examined in this Study

MetS status group	*Exam*	*GXT duration (minutes)*	*Exam mean diff.*	*Group mean diff.*	*df*	*t*	*Sig.*	*95% CI of the difference*
Groups 1 & 2	1	16.4 (±5.3)	1.2					
Combined	2	17.6 (±5.3)	(±4.1)					
(n = 178)				2.2				
Group 3	1	17.9 (±5.1)	−1.0	(±10.7)	210	2.94	0.004	0.7 − 3.6
(n = 34	2	16.9 (±4.5)	(±3.1)					

Note. MetS = metabolic syndrome; GXT = graded exercise test; Diff. = difference between treadmill durations across exams and/or groups; df = degrees of freedom; t = Student's *t* coefficient; Sig. = statistical significance (two-tailed *P*-value); CI = confidence interval.

contrast to individuals who became MetS-free while improving significantly ($P < 0.01$) in every MetS characteristic. Participants who acquired MetS also had worsened glucose and blood pressure levels, but these changes were not statistically significant ($P > 0.05$). In addition, MetS acquisition individuals had a decline in estimated VO_2 max that was statistically significant ($P < 0.05$).

GXT duration was the key component in determining an individual's cardiorespiratory fitness level. The treadmill stress test used in this study relied primarily on walking, the most common form of physiologic stress, and a stepped protocol that had consistent and regular work rate increases.[16] Maximal exercise time on similar protocols is highly correlated ($r = 0.92$) with maximal oxygen uptake.[5] Accordingly, GXT duration was used in this study as a surrogate for aerobic capacity.

Cardiorespiratory fitness levels are influenced by the mode of activity, individual genetic factors, and the individual's state of training.[16] There is also significant variability between individuals as to the physiologic adaptations that occur because of exercise.[17] All participants at the institute were strongly encouraged to increase their aerobic and resistance exercise activity and there were facilities, equipment, and trained personnel available to promote this increase. It was not known what level of activity was attained that precisely contributed to increases or decreases in cardiorespiratory fitness levels. However, changes in cardiorespiratory fitness levels occurred along with corresponding changes in metabolic variables, making it likely that those individuals who increased their activity levels improved their cardiorespiratory fitness and those who did not declined.[18]

Studies that examine the relationship between cardiovascular fitness, physical activity, and the clustering of metabolic variables are a fairly recent phenomenon. Few studies have looked previously at the effectiveness of exercise training alone for ameliorating multiple metabolic risk factors. Over the past decade, a number of cross-sectional and prospective studies have consistently linked regular activity and exercise with increases in HDL and decreases in triglycerides levels, glucose levels, blood pressure, and BMI. The improvements in MetS risk factors in this study were consistent with several other studies that examined the effects of exercise on those risk factors.[3,7,8]

Strong inverse associations between cardiorespiratory fitness levels and the clustering of metabolic abnormalities have been established in several studies. The link between low fitness levels, generally less than the 20^{th} percentile for age and gender, is especially strong and predictive of MetS[2,5,11]; however, this relationship in persons at higher fitness levels is less clear. Franks et al.[9] reported that the association between the level of physical activity energy expenditure and MetS was modified by estimated VO_2 max. Their research showed that for unfit people physical activity energy expenditure was inversely related to MetS, but in fit people there was no such relationship.

The participants in the current study generally represent persons within the average range of cardiorespiratory fitness based on norms established for age and sex.[16] The GXT duration times in this study, which ranged between 15.3 minutes (Group 2, Exam 1) to 18.5 minutes (Group 1, Exam 2) would place them well within the moderate fitness range reported by Whaley et al.,[5] who also used GXT duration as the main measure of cardiorespiratory fitness. Since our study sample consisted of people within the same basic range of fitness, and included those who presented with MetS and those who did not, it was essential to examine the changes in cardiovascular fitness level rather than the absolute level alone. Positive changes in cardiorespiratory fitness level in this study were linked to improved MetS status while declines in fitness levels were indicative of deterioration in MetS status.

There is great difficulty in comparing studies involving cardiorespiratory fitness and MetS. Besides varying fitness-testing protocols, some testing employed a cycle ergometer, which typically produces lower VO_2 max values than treadmill testing.[16] The clinical criterion for elevated glucose abnormality was changed in 2005, possibly altering the MetS status of participants involved in studies related to cardiorespiratory fitness and MetS. Few studies have examined changes in cardiorespiratory fitness in conjunction with changes in MetS status. Katzmarzyk et al.[8] used cycle ergometry testing following an aerobic training program for persons presenting with MetS. In that study, almost one-third of the participants became MetS-free while improving their cardiorespiratory fitness level, but the change in VO_2 max was not significant ($P > 0.05$). Clearly, additional research is needed to examine the relationship between the clustering of metabolic risk factors and changes in levels of cardiorespiratory fitness for persons at all fitness levels.

Participants in this study who experienced MetS reversal demonstrated significant improvement ($P < 0.01$) in all MetS clinical characteristics. These results suggest that the mechanism for the reversal of MetS centered on the lifestyle interventions of increased physical activity, dietary modifications, and improved cardiorespiratory fitness. Regular aerobic training leads to increases in HDL cholesterol, decreases in triglycerides and blood pressure, improved blood glucose control and insulin sensitivity, and decreased obesity.[16] Resistance training also improves MetS clinical characteristics by enhancing metabolic rate and positively influencing body composition.[4] Although the exact changes in diet and exercise activity were not known, GXT duration increased significantly ($P < 0.01$) between exams for the reversal group. The increases in GXT duration were most likely due to increased cardiorespiratory fitness subsequent to increased levels of physical activity.

The results of this study may not be generalizable to other populations since 86% (182 of 212) of the individuals in the sample were men, and over 90% of the participants were non-Hispanic white adult members of a single health assessment/fitness center. Nevertheless, including both male and female participants with a wide breadth of ages and physical characteristics strengthened the external validity of this research. The absence of a control group was a limitation of the current study along with the retrospective research design. Regardless, the findings of this study were consistent with other studies that examined cardiorespiratory fitness and metabolic risk factors.[3,5,7,8]

Treadmill stress testing has become commonplace in screening for cardiovascular disease, especially for middle-aged and older persons. Decreases in activity and/or exercise along with a decline in the duration of the standard stress test should lead clinicians to also examine changes in a person's MetS status. Measuring (or estimating via a GXT) maximal oxygen consumption provides an effective MetS screening mechanism for everyone including those with borderline metabolic risk factors who may benefit from a preventive intervention.[18] Blood chemistry examinations of HDL cholesterol and glucose, as well as strategies for maintaining a healthy blood pressure level would be recommended for persons demonstrating declining levels of cardiorespiratory fitness. Implementing behavior change to increase activity and exercise participation along with adjusting eating habits would also be appropriate. To provide an early intervention for MetS, medical practitioners should make recommendations to improve cardiorespiratory fitness, especially for persons who have metabolic abnormalities or who have shown evidence of clustering metabolic abnormalities.[11]

ACKNOWLEDGEMENTS

We thank Fred Stransky, Ph.D., Director of the health enhancement institute referenced in this study, for devising the data collection instruments and supervising data collection.

REFERENCES

1. Lakka T, Laaksonen D, Lakka H, Mannikko N, Niskanen L, Rauramaa R, and Salonen J. Sedentary lifestyle, poor cardiorespiratory fitness and the metabolic syndrome. *Med Sci Sports Exerc* 2003;35:1279–1286.
2. Laaksonen DE, Lakka H, Salonen JT, Niskanen L, Rauramaa R, and Lakka T. Low levels of leisure time physical activity and cardiorespiratory fitness predict development of metabolic syndrome. *Diabetes Care* 2002;25:1612–1618.
3. Carroll S, Cooke C, and Butterly R. Metabolic clustering, physical activity and fitness in non-smoking, middle-aged men. *Med Sci Sports Exerc* 2000;32:2079–2086.
4. Jurca R, LaMonte M, Church T, Earnest C, Fitzgerald S, Barlow C, Jordan A, Kampert J, and Blair S. Associations of muscle strength and aerobic fitness with metabolic syndrome in men. *Med Sci Sports Exerc* 2004;36:1301–1307.
5. Whaley M, Kampert J, Kohl III H, and Blair S. Physical fitness and clustering of risk factors associated with the metabolic syndrome. *Med Sci Sports Exerc* 1999;31:287–293.
6. Buemann B, and Tremblay A. Effects of exercise training on abdominal obesity and related metabolic complications. *Sports Med* 1996;21:191–212.
7. Carroll S and Dudfield M. What is the relationship between exercise and metabolic abnormalities? A review of the metabolic syndrome. *Sports Med* 2004;34: 371–418.
8. Katzmarzyk P, Leon A, Wilmore J, Skinner J, Rao DC, Rankinen T, and Bouchard C. Targeting the metabolic syndrome with exercise: evidence from the Heritage family study. *Med Sci Sports Exerc* 2003;35:1703–1709.
9. Franks P, Ekelund U, Brage S, Wong M, and Wareham N. Does the association of habitual physical activity with the metabolic syndrome differ by level of cardiorespiratory fitness? *Diabetes Care* 2004;27:1187–1193.
10. Ekelund U, Brage S, Franks PW, Hennings S, Emms S, and Wareham NJ. Physical activity energy expenditure predicts progression toward the metabolic syndrome independently of aerobic fitness in middle-aged healthy Caucasians: the medical research Ely study. *Diabetes Care* 2005;28:1195–1200.
11. LaMonte MJ, Barlow CE, Jurca R, Kampert JB, Church TS, and Blair SN. Cardiorespiratory fitness is inversely associated with the incidence of metabolic syndrome: a prospective study of men and women. *Circulation* 2005;112:505–512.
12. Raikkonen K, Matthews KA, and Kuller LH. Depressive symptoms and stressful life events predict metabolic syndrome among middle-aged women: a comparison of World Health Organization, Adult Treatment Panel III, and International Diabetes Foundation definitions. *Diabetes Care* 2007;30:872–877.
13. Grundy S, Brewer H, Cleeman J, Smith S, and Lenfant C. Definition of metabolic syndrome. Report of the National Heart, Lung, and Blood Institute / American Heart Association conference on scientific issues related to definition. *Circulation* 2004;109:433–438.
14. Assmann G, Guerra R, Fox G, Cullen P, Schulte H, Willett D, and Grundy SM. Harmonizing the definition of the metabolic syndrome: comparison of the criteria of the Adult Treatment Panel III and the International Diabetes Federation in United States American and European populations. *Am J Cardiol* 2007;99: 541–548.
15. Balke B and Ware R. An experimental study of physical fitness of Air Force personnel. *U.S. Armed Forces Med J* 1959;10:679.
16. American College of Sports Medicine, *ACSM's Guidelines for Exercise Testing and Prescription*, Seventh edition, Baltimore: Lippincott, Williams & Wilkins; 2006:7–10,77,289.
17. Bouchard C, An P, Rice T, Skinner JS, Wilmore JH, Gagnon J, Perusse L, Leon AS, and Rao DC. Familial aggregation of VO2 max response to exercise training: results from the HERITAGE Family Study. *J Appl Physiol* 1999;87:1003–1008.
18. Lakka TA and Laaksonen DE. Physical activity in prevention and treatment of the metabolic syndrome. *Appl Physiol Nutr Metab* 2007;32:76–88.

Address reprint requests to:
Mark S. Maxwell
School of Health Sciences
363 Hannah Hall
Oakland University
2200 N. Squirrel Road
Rochester, Michigan 48309-4482

E-mail: maxwellms@aol.com