Relation between cardiorespiratory fitness and selected risk factors for coronary heart disease in a population of Canadian men and women

Maurice Jetté,* PhD; Ken Sidney,† PhD; Josée Quenneville,* MSc; Fernand Landry,‡ PhD

Objective: To determine the relation between cardiorespiratory fitness, as determined with the Canadian Aerobic Fitness Test (CAFT), and selected risk factors for coronary heart disease (CHD) in a Canadian population.
Design: Cross-sectional study. On the basis of age-specific and sex-specific national percentile scores, subjects were classified as being in the low-fitness, moderate-fitness or high-fitness category according to maximum oxygen consumption ($\dot{V}O_2$ max) predicted from performance on the CAFT.
Participants: A total of 4082 male and 1205 female Canadian federal public servants aged 30 to 59 years who participated in a voluntary fitness testing program between 1984 and 1991.
Outcome measures: Body composition (body mass index, triceps skinfold thickness, sum of four skinfold measurements, predicted percentage of body fat and waist–hip ratio), blood lipid levels (total cholesterol, triglycerides, high-density lipoprotein cholesterol [HDL-C], low-density lipoprotein cholesterol and ratio of total cholesterol to HDL-C) and hemodynamic measurements (heart rate and blood pressure at rest and during exercise and predicted $\dot{V}O_2$ max).
Main results: For both men and women the mean anthropometric measurements, blood lipid levels and blood pressure measurements at rest and after exercise were significantly associated with fitness category ($p < 0.05$).
Conclusions: In both men and women a higher level of aerobic fitness, as defined by $\dot{V}O_2$ max predicted from performance on the CAFT, is associated with a more favourable CHD risk profile. The results support the use of $\dot{V}O_2$ max predicted from performance on the CAFT as a valid procedure for classifying people according to fitness level.

Objectif : Déterminer la relation entre la condition aérobie, telle que mesurée par le Physitest Aérobie Canadien (PAC), et certains facteurs de risque de coronaropathie dans une population canadienne.
Conception : Enquête transversale. En fonction de scores percentiles à l'échelle nationale spécifiques selon l'âge et le sexe, on a classé des sujets en catégories de faible, modérée et élevée condition physique selon la consommation maximale d'oxygène ($\dot{V}O_2$ max) prédite à partir des résultats au PAC.
Participants : Au total, 4 082 hommes et 1 205 femmes, membres de la Fonction publique fédérale du Canada, âgés de 30 à 59 ans ont participé volontairement à un programme d'évaluation de la condition physique entre 1984 et 1991.
Mesures des résultats : Composition corporelle (indice de la masse corporelle, épaisseur du pli cutané tricipital, somme de quatre mesures des plis cutanés, pourcentage prédit

*From *the School of Human Kinetics, Faculty of Health Sciences, University of Ottawa, Ottawa, Ont., †the School of Human Movement, Laurentian University, Sudbury, Ont., and the ‡Laboratoire des Sciences de l'activité physique, Université Laval, Quebec, Que.*

Reprint requests to: Dr. Maurice Jetté, School of Human Kinetics, Faculty of Health Sciences, University of Ottawa, 125 University Pr., Ottawa, ON K1N 6N5

← For prescribing information see page 1416

du taux d'adiposité corporelle et du rapport abdomen–hanche), taux de lipides sanguins (cholestérol total, triglycérides, cholestérol à lipoprotéines de haute densité [HDL-C], cholestérol à lipoprotéines de basse densité et rapport entre le cholestérol total et le HDL-C) et mesures hémodynamiques (fréquence cardiaque et tension artérielle au repos et à l'effort et la $\dot{V}O_2$ max prédite).

Principaux résultats : Chez les hommes et chez les femmes, les moyennes des mesures anthropométriques, des taux de lipides sanguins et des mesures de la tension artérielle au repos et après l'effort étaient reliées de façon significative à la capacité aérobie ($p <$ 0,05).

Conclusions : Chez les hommes et chez les femmes, une meilleure capacité aérobie, telle que définie par la $\dot{V}O_2$ max prédite selon les résultats au PAC, est reliée à un profil de risques plus favorable de coronaropathie. Les résultats appuient l'utilisation de la $\dot{V}O_2$ max telle que mesurée par le PAC comme une méthode valable pour classer les personnes selon leur condition physique.

Regular physical exercise has a beneficial effect on health and well-being. An ever-growing number of epidemiologic studies confirm the inverse relation between physical activity and the incidence of coronary heart disease (CHD).[1-10] Furthermore, myocardial infarction not only occurs more often among sedentary people than among active people but also is more often fatal and occurs at a much lower age.[11-13] Although the epidemiologic evidence has been labelled as circumstantial,[4] the statistical consistency of these studies is supported by laboratory results[14-26] and provides a strong argument that regular, vigorous physical activity plays a role in the prevention of myocardial infarction.

The effects of physical training include reduced levels of total cholesterol and low-density lipoprotein cholesterol (LDL-C),[14] increased levels of high-density lipoprotein cholesterol (HDL-C),[15,16] increased insulin receptor density,[17,18] increased glucose clearance,[19] reduced blood pressure[20-22] and increased fibrinolytic activity of plasma.[23-25] Other studies have shown an inverse relation between fitness level and the incidence of CHD as well as the number of risk factors for CHD.[6,10,26] The investigators typically used relatively simple methods to assess fitness, and most employed limited samples or population groups, which restricts the generalizability of their findings.

We have for a number of years been involved in the fitness testing and health profiles of federal public servants from across Canada attending management courses in the Ottawa area.[27] Although involvement in the fitness testing session is voluntary, the participation rate for these on-site sessions is usually greater than 90%. The fitness module includes assessment of health status and physical fitness (including cardiorespiratory fitness, as assessed with the Canadian Aerobic Fitness Test [CAFT][28]). As such, the data accumulated over the years for these public servants constitute a unique source of information to evaluate the relations between certain risk factors for CHD and level of fitness. The purpose of this study was to determine the relation between maximum oxygen consumption ($\dot{V}O_2$ max), as predicted by performance on the CAFT, and selected CHD risk factors in a Canadian population.

Methods

Before undergoing testing the participants completed a consent form and a questionnaire on readiness for physical activity.[27] Those who had a heart problem or hypertension or were taking medication that could influence their response to exercise testing were excluded. A total of 4082 men and 1205 women aged 30 to 59 years underwent testing between 1984 and 1991.

The resting heart rate and blood pressure were measured and a sample of venous blood was withdrawn (after at least 10 hours of fasting) between 7 and 8 am. The triglyceride concentration was analysed by means of an enzymatic assay after saponification with ethanolic potassium hydroxide (Test-Combination Triglycerides, Neutral Fat kit; Boehringer Mannheim [Canada] Ltd., Laval, Que.). The total cholesterol concentration was determined by means of an enzymatic colorimetric method with the Cholesterol C-system, CHOD-PAP kit (Boehringer Mannheim). The HDL-C concentration was analysed with the Precipitant kit (Boehringer Mannheim) after the chylomicrons, very-low-density cholesterol and LDL-C were precipitated.

Anthropometric measurements were taken and the CAFT was administered between 9 am and noon. Anthropometric variables included height, weight, girth of chest, waist, hips and thighs, and skinfold measurements over the triceps, biceps and subscapular muscles and above the ilium.[29] From these measurements we derived the following indices: sum of four skinfold measurements, predicted percentage of body fat,[30] body mass index (BMI)[28] and waist–hip ratio.

The subject then performed the CAFT,[28] which consists of a series of stepping sequences of progressively increasing intensity done on double steps 20.3 cm in height to a six-count recorded musical rhythm. The test begins with a 3-minute warm-up stage (stage A) at an intensity corresponding to 65% to 70% of the average aerobic power expected for a person 10 years older than the subject. If a predetermined postexercise heart rate is not exceeded and no adverse signs or symptoms are noted the subject performs a second 3-minute stage (stage B) at an intensity corresponding to 65% to 70% of the average aerobic power expected for his or her age group. In the absence of adverse signs and symptoms, and provided that the ceiling heart rate is not surpassed, a final 3-minute stage (stage C) is performed at an intensity equivalent to 65% to 70% of the average aerobic power expected for a person 10 years younger than the subject. In this study the CAFT was slightly modified in that we measured the blood pressure immediately after recording the heart rate at 10 seconds after exercise (i.e., between 15 and 45 seconds after exercise).[31]

We predicted the $\dot{V}O_2$ max (in millilitres per kilogram per minute) from the performance on the CAFT using the following formula: $\dot{V}O_2 \text{ max} = 42.5 + 16.6(\dot{V}O_2) - 0.12(W) - 0.12(H) - 0.24(A)$, where $\dot{V}O_2$ is the average oxygen cost of the last exercise stage completed, W is body weight (in kilograms), H is the postexercise heart rate (in beats per minute) and A is the age (in years).[32] On the basis of national norms[28] subjects with a $\dot{V}O_2$ max at or below the 30th percentile for their age group were classified as being in the low-fitness category, from the 31st to the 69th percentile in the moderate-fitness category and at or above the 70th percentile in the high-fitness category.

We computed descriptive analyses, analyses of variance, correlations and factor analyses using SAS statistical software.[33] When a significant F was attained ($p < 0.05$) Scheffé's post-hoc analysis was performed.

Results

Of the 4082 men tested 1595 (39.1%) were found to be in the low-fitness category, 1950 (47.8%) in the moderate-fitness category and 537 (13.2%) in the high-fitness category (Table 1). The corresponding figures for the 1205 women were 199 (16.5%), 774 (64.2%) and 232 (19.2%).

For both men and women the mean body weight, BMI, triceps skinfold thickness, sum of four skinfold measurements, predicted percentage of body fat and waist–hip ratio were significantly lower with increasing fitness (Table 1).

For both men and women the mean levels of total cholesterol, triglycerides, HDL-C and LDL-C and the mean ratio of total cholesterol to HDL-C differed significantly between the fitness groups

Table 1: Mean age and anthropometric measurements of a population of Canadian federal public servants who participated in a voluntary fitness testing program, by sex and fitness category

	Mean (and standard deviation [SD]);* fitness category					
	Men			Women		
Variable	Low	Moderate	High	Low	Moderate	High
		NS	NS	NS	NS	
Age, yr	44.1 (6.8) (n = 1595)	42.7 (6.3) (n = 1950)	43.3 (6.1) (n = 537)	40.4 (6.9) (n = 199)	40.3 (5.6) (n = 774)	38.9 (6.0) (n = 232)
				NS	NS	NS
Height, cm	178.1 (6.9) (n = 1595)	176.7 (6.6) (n = 1950)	175.5 (6.5) (n = 537)	164.5 (6.0) (n = 199)	163.8 (6.2) (n = 774)	163.3 (6.0) (n = 232)
Weight, kg	86.0 (11.8) (n = 1595)	78.3 (9.4) (n = 1950)	73.5 (8.3) (n = 537)	73.0 (13.7) (n = 199)	62.3 (8.3) (n = 774)	57.4 (6.0) (n = 232)
Body mass index (BMI), kg/m²	27.1 (3.3) (n = 1595)	25.1 (2.7) (n = 1950)	23.8 (2.2) (n = 537)	27.0 (5.1) (n = 199)	23.2 (3.0) (n = 774)	21.5 (2.0) (n = 232)
Triceps skinfold thickness, mm	15.8 (5.9) (n = 1589)	13.0 (4.4) (n = 1949)	10.8 (3.5) (n = 536)	27.4 (8.2) (n = 197)	21.7 (6.3) (n = 773)	17.2 (5.4) (n = 232)
Sum of four skinfold measurements,† mm	66.0 (21.0) (n = 1585)	53.4 (16.7) (n = 1944)	44.2 (13.1) (n = 534)	83.6 (30.5) (n = 197)	60.5 (20.8) (n = 770)	45.9 (14.8) (n = 232)
Predicted % body fat	27.2 (4.9) (n = 1585)	24.1 (4.6) (n = 1944)	22.1 (4.4) (n = 534)	35.3 (5.7) (n = 197)	31.5 (4.8) (n = 770)	28.0 (4.6) (n = 232)
Waist–hip ratio	0.96 (0.05) (n = 1587)	0.93 (0.05) (n = 1945)	0.91 (0.04) (n = 537)	0.78 (0.08) (n = 196)	0.75 (0.07) (n = 771)	0.73 (0.04) (n = 231)

*All between-group differences are significant ($p < 0.05$) except as indicated. NS = not significant.
†The four areas are the skinfolds over the triceps, biceps and subscapular muscles and above the ilium.

except for the mean HDL-C level for women, which differed significantly only between the low-fitness and high-fitness groups (Table 2). For each variable the best profile was observed in the high-fitness group and the worst profile in the low-fitness group.

The mean resting heart rate, resting systolic blood pressure (SBP) and resting diastolic blood

Table 2: Mean blood lipid values, by sex and fitness category

	Mean (and SD);* fitness category					
	Men			Women		
Variable	Low	Moderate	High	Low	Moderate	High
Total cholesterol level, mmol/L	5.70 (1.06) (n = 1493)	5.54 (1.04) (n = 1846)	5.36 (1.01) (n = 507)	5.34 (1.04) (n = 183)	5.08 (0.93) (n = 729)	4.87 (0.88) (n = 217)
Triglyceride level, mmol/L	1.79 (0.88) (n = 1482)	1.50 (0.76) (n = 1835)	1.30 (0.72) (n = 507)	1.30 (0.58) (n = 183)	1.08 (0.48) (n = 729)	0.99 (0.36) (n = 217)
				NS	NS	
High-density lipoprotein cholesterol (HDL-C) level, mmol/L	1.19 (0.28) (n = 1490)	1.27 (0.31) (n = 1841)	1.37 (0.31) (n = 506)	1.53 (0.41) (n = 183)	1.58 (0.34) (n = 727)	1.63 (0.34) (n = 217)
Low-density lipoprotein cholesterol (LDL-C) level, mmol/L	3.68 (0.98) (n = 1491)	3.57 (0.96) (n = 1843)	3.42 (0.91) (n = 507)	3.21 (0.91) (n = 183)	3.00 (0.88) (n = 728)	2.80 (0.83) (n = 217)
Ratio of total cholesterol to HDL-C	5.0 (1.6) (n = 1490)	4.6 (1.4) (n = 1841)	4.1 (1.3) (n = 506)	3.7 (1.3) (n = 183)	3.4 (1.0) (n = 727)	3.1 (0.8) (n = 217)

*All between-group differences are significant ($p < 0.05$) except as indicated. NS = not significant.

Table 3: Mean hemodynamic measurements, by sex and fitness category

	Mean (and SD);* fitness category					
	Men			Women		
Variable	Low	Moderate	High	Low	Moderate	High
Resting heart rate, beats/min	71 (11) (n = 1523)	65 (9) (n = 1873)	59 (9) (n = 511)	77 (10) (n = 188)	72 (10) (n = 731)	65 (9) (n = 217)
		NS				
Resting systolic blood pressure (SBP), mm Hg	130 (16) (n = 1520)	124 (14) (n = 1868)	124 (14) (n = 512)	120 (16) (n = 188)	114 (14) (n = 733)	111 (12) (n = 216)
Resting diastolic blood pressure (DBP), mm Hg	86 (10) (n = 1521)	82 (9) (n = 1867)	80 (9) (n = 512)	79 (10) (n = 188)	76 (9) (n = 733)	73 (9) (n = 217)
Heart rate at stage A,† beats/min	137 (16) (n = 1593)	119 (14) (n = 1947)	103 (15) (n = 537)	152 (19) (n = 199)	131 (17) (n = 774)	110 (15) (n = 232)
SBP at stage A, mm Hg	159 (24) (n = 1276)	149 (19) (n = 1608)	144 (17) (n = 452)	146 (25) (n = 179)	133 (17) (n = 705)	127 (16) (n = 218)
DBP at stage A, mm Hg	85 (11) (n = 1179)	83 (10) (n = 1487)	81 (10) (n = 419)	81 (12) (n = 153)	78 (10) (n = 624)	75 (10) (n = 187)
					NS	
Increase in SBP from rest to exercise at stage A, mm Hg	29 (18) (n = 1276)	24 (15) (n = 1608)	21 (13) (n = 452)	27 (19) (n = 179)	20 (14) (n = 705)	17 (12) (n = 218)
Predicted maximum oxygen consumption ($\dot{V}O_2$ max), mL/kg per min	32.9 (3.6) (n = 1595)	38.6 (3.5) (n = 1950)	42.6 (4.1) (n = 537)	25.7 (3.8) (n = 199)	30.5 (2.7) (n = 774)	35.3 (2.5) (n = 232)

*All between-group differences are significant ($p < 0.05$) except as indicated. NS = not significant.
†Stage A is a relatively mild exercise stress. See the Methods section.

pressure (DBP) differed significantly between the fitness groups for both men and women, with the exception that there was no significant difference in the mean resting SBP between men in the moderate-fitness group and those in the high-fitness group (Table 3). For both men and women the mean heart rate, SBP and DBP at stage A of the CAFT were significantly lower with increasing fitness. The mean increase in SBP from rest to exercise at stage A was lower with increasing fitness for both men and women; the difference between all groups was significant except for women in the moderate-fitness group as compared with those in the high-fitness group.

The mean predicted $\dot{V}O_2$ max values for men in the low-fitness, moderate-fitness and high-fitness groups were 32.9, 38.6 and 42.6 mL/kg per minute respectively (Table 3). The corresponding values for women were 25.7, 30.5 and 35.3 mL/kg per minute. All differences were significant.

The correlation between predicted $\dot{V}O_2$ max and indices of body composition, blood lipid levels and cardiorespiratory fitness is shown in Table 4. For lipid variables the coefficients ranged from 0.15 to −0.23 for men and from 0.10 to −0.30 for women. For hemodynamic measurements all the correlations were statistically significant, the highest being with heart rate at stage A (−0.35 for men and −0.36 for women).

Discussion

Directly measured $\dot{V}O_2$ max is considered to be the best indicator of cardiorespiratory fitness.[34] In our study we derived the $\dot{V}O_2$ max from the performance on the CAFT. Each subject was then classified into one of three fitness categories on the basis of age-specific and sex-specific national percentile scores. The equation used to predict $\dot{V}O_2$ max takes into consideration the subject's age, weight, heart rate response and energy cost of the last stage completed. Although some investigators have expressed reservations about the use of the CAFT, particularly in extremely fit people,[35,36] it is judged a satisfactory, practical and useful measurement of cardiorespiratory fitness for adults.[32,37–40] The CAFT can also provide a valid measure of a group's average cardiorespiratory fitness level.[41] In a clinical setting without access to expensive laboratory equipment or personnel, and particularly when dealing with a sedentary or moderately active population, the CAFT can be a very useful diagnostic and intervention procedure.[27]

As a group our subjects were not particularly fit. Only 13% of the men and 19% of the women were found to be in the high-fitness group; on the basis of the normative data[28] 30% could have been expected to be classified in this category. Their low fitness level may be due to the sedentary nature of their occupation or recreation habits. In fact, a recent analysis of the pattern of physical activity of the subjects in our databank indicated that 50% do not participate in any form of regular exercise. Our results support the use of $\dot{V}O_2$ max predicted from performance on the CAFT as a valid procedure for classifying people according to fitness level.[41]

The $\dot{V}O_2$ max can be improved by 15% to 20% in previously sedentary people through participation in physical activity of the appropriate type.[32,42–45] The American College of Sports Medicine recommends that for apparently healthy people an appropriate exercise program would consist of 15 to 60 minutes of aerobic muscular activity performed at an intensity of 50% to 85% of the $\dot{V}O_2$ max three to five times per week.[46] For the average Canadian, exercising daily at a moderate to vigorous (but not exhausting) intensity, such as walking to and from work (at 120 to 130 steps per minute) for up to 1 hour, could provide a sufficient stimulus to improve cardiorespiratory fitness.[47,48]

In our study the difference in mean predicted $\dot{V}O_2$ max between the low-fitness and high-fitness groups was 10 mL/kg per minute for both men and

Table 4: Correlation between predicted $\dot{V}O_2$ max and indices of body composition, blood lipids and cardiorespiratory fitness*

Variable	Men	Women
Age	−0.62	−0.57
Body composition		
Height	−0.12	
Weight	−0.41	−0.55
BMI	−0.40	−0.54
Triceps skinfold thickness	−0.33	−0.51
Sum of four skinfold measurements	−0.40	−0.56
Predicted % body fat	−0.59	−0.66
Waist–hip ratio	−0.41	−0.25
Blood lipid levels		
Total cholesterol	−0.18	−0.29
Triglycerides	−0.22	−0.28
HDL-C	0.15	0.10
LDL-C	−0.15	−0.28
Ratio of total cholesterol to HDL-C	−0.23	−0.30
Cardiorespiratory fitness		
Resting heart rate	−0.33	−0.28
Resting SBP	−0.19	−0.32
Resting DBP	−0.22	−0.31
Heart rate at stage A	−0.35	−0.36
SBP at stage A	−0.21	−0.32
DBP at stage A	−0.16	−0.22
Increase in SBP from rest to exercise at stage A	−0.08	−0.13
No. of stages completed	0.56	0.55

*All correlations are significant at $p < 0.0001$ except for HDL-C in women only ($p < 0.001$).

women; thus, particularly for people who are not already physically active, it should be possible for those in the low-fitness and moderate-fitness groups to achieve a level of aerobic power equivalent to that of people in the high-fitness category with appropriate physical training. Such an improvement in cardiorespiratory fitness is likely to be associated with concomitant reductions in CHD risk factors. Indeed, numerous studies have shown that an improvement in aerobic fitness favourably influences body composition, lipid levels, insulin receptor density, glucose clearance, blood pressure and fibrinolytic activity of plasma.[14-25]

We calculated the proportions of subjects with abnormal resting heart rate, blood pressure at rest and during exercise, and lipid levels (Table 5). In general, the lowest proportions of subjects at risk for CHD were in the high-fitness group, and the highest proportions of subjects at risk were in the low-fitness group. For instance, 48% of the men in the low-fitness group, 44% of those in the moderate-fitness group and 22% of those in the high-fitness group had an elevated ratio of total cholesterol to HDL-C; the corresponding values for women were 20%, 11% and 5%.

People who are normotensive or borderline hypertensive at rest but who show an exaggerated blood pressure response to exercise are at higher risk for sustained hypertension.[51-54] Such a response may be an early and sufficiently sensitive indicator of the gradual anatomic restructuring occurring in the heart and resistance vessels and of the dynamics characteristic of sustained hypertension.[55-57] Normative data for blood pressure response to the CAFT immediately after exercise were recently developed for men and women aged 20 to 69 years, and threshold values were established.[31] Frequency analysis indicated that 17% of the men and 32% of the women in the low-fitness group in our study demonstrated an exaggerated SBP response to exercise (mean increase in SBP from rest to exercise of 45 mm Hg or more for men and 35 mm Hg or more for women), compared with 5% of the men and 8% of the women in the high-fitness group. Furthermore, 5% of the men and 10% of the women in the low-fitness group showed a grossly exaggerated SBP response (mean increase in SBP of 60 mm Hg or more for men and 50 mm Hg or more for women), compared with only

Table 5: Proportion of subjects with abnormal values for selected risk factors,[31,49,50] by fitness category

	% of subjects; fitness category					
	Men (n = 4082)*			Women (n = 1205)*		
Variable	Low	Moderate	High	Low	Moderate	High
Resting heart rate ≥ 100 beats/min	1	0	0	2	2	0
Resting SBP, mm Hg						
≥ 140	24	14	13	10	4	2
≥ 160	5	2	2	3	1	0
Resting DBP, mm Hg						
≥ 90	26	21	15	17	6	2
≥ 95	17	9	7	6	3	1
≥ 100	6	4	4	2	1	0
Increase in SBP from rest to exercise at stage A, mm Hg						
≥ 45 (men) or ≥ 35 (women)	17	9	5	32	15	8
≥ 60 (men) or ≥ 50 (women)	5	2	1	10	3	2
Total cholesterol level ≥ 6.20 mmol/L	29	24	18	19	12	8
Triglyceride level ≥ 2.30 mmol/L	23	13	8	8	3	1
HDL-C level ≤ 0.90 mmol/L	13	9	5	4	2	0
LDL-C level ≥ 3.40 mmol/L	61	57	47	40	30	20
Ratio of total cholesterol to HDL-C ≥ 5.0 (men) or ≥ 4.5 (women)	48	44	22	20	11	5

*The number of subjects varies slightly for each variable.

1% of the men and 2% of the women in the high-fitness group.

We recognize that cross-sectional data cannot demonstrate that regular physical activity leading to enhanced aerobic fitness by itself accounts for the differences in CHD risk factors observed in our study. Some of these differences may be related to lower body mass and body fat. However, it is well accepted that regular exercise favourably influences body composition. Heredity undoubtedly exerts a strong influence on body composition, aerobic power and indices of physiologic fitness as well as on the magnitude of any improvements that may be achieved through physical training.[58] Nevertheless, our results reinforce the notion that a higher level of aerobic fitness is associated with a more favourable CHD risk profile.

In our study for both men and women there were significant differences between the fitness groups in measures of total body fat, distribution of body fat, blood lipid concentrations and hemodynamic variables. Mean values were consistently most favourable in the high-fitness group and least favourable in the low-fitness group. The gradation in mean scores for each of the variables shown in Tables 1, 2 and 3 suggests that there tends to be progressively greater benefit to health with increasing level of cardiorespiratory fitness, at least over the $\dot{V}O_2$ max range of 19 to 55 mL/kg per minute for men and 15 to 41 mL/kg per minute for women. There is no apparent threshold or minimum value for $\dot{V}O_2$ max; thus, it may be concluded that the greater one's level of cardiorespiratory fitness, as defined by predicted $\dot{V}O_2$ max, the more favourable one's CHD risk profile. This is an important consideration, since it has been suggested that moderate fitness levels or modest levels of participation in physical activity appear sufficient to reduce the risk of CHD.[10]

This study was supported in part by a grant from the Development Fund of the Faculty of Health Sciences, University of Ottawa.

References

1. Morris JN, Everitt MG, Pollard R et al: Vigorous exercise in leisure-time: protection against coronary heart disease. *Lancet* 1980; 2: 1207–1210
2. Siscovick DS, LaPorte RE, Newman JM: The disease-specific benefits and risks of physical activity and exercise. *Public Health Rep* 1985; 100: 180–188
3. Paffenbarger RS Jr, Hyde RT, Wing AL et al: Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med* 1986; 314: 605–613
4. Paffenbarger RS Jr, Hyde RT, Wing AL: Physical activity and physical fitness as determinants of health and longevity. In Bouchard C, Shephard RJ, Stephens T et al (eds): *Exercise, Fitness, and Health: a Consensus of Current Knowledge*, Human Kinetics, Champaign, Ill, 1990: 33–48
5. Leon AS, Connett J, Jacobs DR et al: Leisure-time physical activity levels and risk of coronary heart disease and death. The Multiple Risk Factor Intervention Trial. *JAMA* 1987; 258: 2388–2395
6. Sobolski J, Kornitzer M, De Backer G et al: Protection against ischemic heart disease in the Belgian physical fitness study: Physical fitness rather than physical activity? *Am J Epidemiol* 1987; 125: 601–610
7. Slattery ML, Jacobs DR: Physical fitness and cardiovascular disease mortality. The US railroad study. *Am J Epidemiol* 1988; 127: 571–580
8. Ekelund L, Haskell WL, Johnson JL et al: Physical fitness as a predictor of cardiovascular mortality in asymptomatic North American men. *N Engl J Med* 1988; 319: 1379–1384
9. Powell KE, Thompson PD, Caspersen CJ et al: Physical activity and the incidence of coronary heart disease. *Annu Rev Public Health* 1987; 8: 253–287
10. Blair SN, Kohl HR, Paffenbarger RS et al: Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989; 262: 2395–2401
11. *Sport for All — Physical Activity and the Prevention of Disease*, Council of Europe, Strasbourg, France, 1970: 17
12. Siscovick DS, Weiss NS, Hallstrom AP et al: Physical activity and primary cardiac arrest. *JAMA* 1982; 248: 3113–3117
13. Siscovick DS: Risks of exercising: sudden cardiac death and injuries. In Bouchard C, Shephard RJ, Stephens T et al (eds): *Exercise, Fitness, and Health: a Consensus of Current Knowledge*, Human Kinetics, Champaign, Ill, 1990: 707–713
14. Wood PD, Haskell WL: The effect of exercise on plasma high density lipoproteins. *Lipids* 1979; 14: 417–427
15. Wood PD, Haskell W, Blair SN et al: Increased exercise level and plasma lipoprotein concentration. *Metabolism* 1983; 32: 31–39
16. Stein R, Michielli D, Glatz M et al: Effects of different exercise training intensities on lipoprotein cholesterol fractions in healthy middle-aged men. *Am Heart J* 1990; 119: 277–283
17. LeBlanc J, Nadeau A, Boulay M et al: Effects of physical training and adiposity on glucose metabolism and ^{125}I-insulin binding. *J Appl Physiol* 1979; 46: 235–239
18. Pedersen O, Beck-Nielsen H, Heding L: Increased insulin receptors after exercise in patients with insulin-dependent diabetes mellitus. *N Engl J Med* 1980; 302: 886–892
19. Rosenthal M, Haskell WL, Solomon R et al: Demonstration of a relationship between level of physical training and insulin-stimulated glucose utilization in normal humans. *Diabetes* 1983; 32: 408–411
20. Hickey N, Mulcahy R, Bourke GJ et al: Study of coronary risk factors related to physical activity in 15,171 men. *BMJ* 1975; 3: 507–509
21. Gibbons LW, Blair SN, Cooper KH et al: Association between coronary heart disease risk factors and physical fitness in healthy adult women. *Circulation* 1983; 67: 977–983
22. Cooper KH, Pollock ML, Martin RP et al: Physical fitness levels vs selected coronary risk factors — a cross-sectional study. *JAMA* 1976; 236: 166–169
23. Wheeler ME, Davis GL, Gillespie WJ et al: Physiological changes in hemostasis associated with acute exercise. *J Appl Physiol* 1986; 60: 986–990
24. Ferguson EW, Bernier LL, Banta GR et al: Effects of exercise and conditioning on clotting and fibrinolytic activity in men. *J Appl Physiol* 1987; 62: 1416–1421
25. Stratton JR, Chandler WL, Cerqueira MD et al: Exercise training increases tissue plasminogen activator activity [abstr]. *Circulation* 1989; 80 (suppl 2): II-610
26. Peters RK, Cady LD Jr, Bischoff DP et al: Physical fitness and subsequent myocardial infarction in healthy workers. *JAMA* 1983; 249: 3052–3056

27. Jetté M, Quenneville J, Sidney K: Fitness testing and counselling in health promotion. *Can J Sport Sci* (in press)
28. *Canadian Standardized Test of Fitness. Operations Manual* (cat FAS 7378), 3rd ed, Fitness and Amateur Sport, Dept of National Health and Welfare, Ottawa, 1986
29. Jetté M: *Guide for Anthropometric Measurements of Canadian Adults*, C.T. Management & Consultant Inc, Montreal, 1983
30. Durnin JVGA, Womersley J: Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Br J Nutr* 1974; 32: 77-97
31. Jetté M, Landry F, Sidney K: Blood pressure response to the Canadian Aerobic Fitness Test. *Can J Public Health* 1991; 82: 267-276
32. Jetté M, Campbell J, Mongeon J et al: The Canadian Home Fitness Test as a predictor of aerobic capacity. *Can Med Assoc J* 1976; 114: 680-682
33. *SAS User's Guide: Statistics*, version 5, SAS Institute Inc, Cary, NC, 1985
34. Cooper KH: A means of assessing maximal oxygen intake. *JAMA* 1968; 203: 135-138
35. Bonen A, Gardner J, Primrose J et al: An evaluation of the Canadian Home Fitness Test. *Can J Appl Sport Sci* 1977; 2: 133-136
36. Léger L: The Canadian Home Fitness Test revisited. *Can Assoc Health Physical Educ Recreation J* 1984; July: 6-8
37. Bailey D, Shephard R, Mirwald R: Validation of a self-administered home test of cardiorespiratory fitness. *Can J Appl Sport Sci* 1976; 1: 67-78
38. Jetté M: A comparison between predicted $\dot{V}O_2$ max from the Astrand procedure and the Canadian Home Fitness Test. *Can J Appl Sport Sci* 1979; 4: 214-218
39. Shephard R: The current status of the Canadian Home Fitness Test. *Br J Sports Med* 1980; 14: 114-125
40. Shephard R, Cox M, Corey P et al: Some factors affecting accuracy of Canadian Home Fitness Test scores. *Can J Appl Sport Sci* 1979; 4: 205-209
41. Shephard RJ: *Fitness of a Nation. Lessons from the Canada Fitness Survey*, Karger, New York, 1986: 23-44
42. Jetté M, Sidney K, Campbell J: Effects of a twelve-week walking programme on maximal and submaximal work output indices in sedentary middle-aged men and women. *J Sports Med* 1988; 28: 59-66
43. Pollock M, Wilmore J, Fox S III: *Health and Fitness Through Physical Activity*, Wiley, Toronto, 1978: 117-178
44. American College of Sports Medicine: *Resource Manual for Guidelines for Exercise Testing and Prescription*, Lea & Febiger, Philadelphia, 1988: 62-65
45. Bouchard C, Carrier R, Boulay M et al: *Le développement du système de transport de l'oxygène chez les jeunes adultes*, Éditions du Pélican, Quebec, 1975: 60-63
46. American College of Sports Medicine: *Guidelines for Exercise Testing and Prescription*, Lea & Febiger, Philadelphia, 1986: 31-32
47. Jetté M, Thoden J, Gauthier R: Aerobic exercise prescription intensity in terms of maximal working capacity. *Can J Public Health* 1975; 66: 465-467
48. Jetté M: An exercise prescription program for use in conjunction with the Canadian Home Fitness Test. Ibid: 461-464
49. Canadian Consensus Conference on Cholesterol: Final Report. Canadian Consensus Conference on the Prevention of Heart and Vascular Disease by Altering Serum Cholesterol and Lipoprotein Risk Factors. *Can Med Assoc J* 1988; 139 (11, suppl): 1-8
50. *Arterial Hypertension: Report of a WHO Expert Committee* (WHO Technical Rep ser 628), World Health Organization, Geneva, 1978
51. Jetté M, Landry F, Blümchen G: Exercise hypertension in healthy normotensive subjects. *Herz* 1987; 12: 110-118
52. Jetté M, Landry F, Sidney K et al: Exaggerated blood pressure response to exercise in the detection of hypertension. *J Cardiopulm Rehabil* 1988; 8: 171-177
53. Landry F, Jetté M, Blümchen G: Exercise hypertension in the perspective of systemic arterial hypertension. An overview. *Herz* 1987; 12: 75-82
54. Anlauf M: Der Belastungsblutdruck als diagnostischer Test-Sensitivität, Spezifität (Literaturubersicht). In Anlauf M, Bock K (eds): *Blutdruck unter korperlicher Belastung*, Steinkopff, Darmstadt, Germany, 1984: 115-123
55. Nathwani D, Reeves R, Marquez-Julio A et al: Left ventricular hypertrophy in mild hypertension: correlation with exercise blood pressure. *Am Heart J* 1985; 109: 386-387
56. Naimark B, Axelsson J, Sigurdsson S et al: Echocardiographic indices and their relationship to the blood pressure response to ergometric exercise in apparently healthy men. *Can J Cardiol* 1991; 7: 131-137
57. Lund-Johanssen P: Hemodynamics in hypertension at rest and during exercise. *Cardiovasc Pharmacol* 1987; 10: 51-55
58. Bouchard C: Discussion: heredity, fitness, and health. In Bouchard C, Shephard RJ, Stephens T et al (eds): *Exercise, Fitness, and Health: a Consensus of Current Knowledge*, Human Kinetics, Champaign, Ill, 1990: 147-154

For prescribing information see page 1491