African Journal of Medicine and Medical Sciences

Editor: O.A. Ladipo
Assistant Editors:
B.O. Osotimehin and A.O. Uwaifo

Volume 18
1989

BLACKWELL SCIENTIFIC PUBLICATIONS
Oxford London Edinburgh Boston Melbourne

Afr. J. Med. med. Sci. (1989) **18**, 109–116.

Cardiovascular responses to maximal treadmill exercise in healthy adult Nigerians

M. O. BALOGUN* AND G. O. A. LADIPO
Department of Medicine, Faculty of Health Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria

Summary

Maximum treadmill exercise, using the Bruce protocol was performed on 124 healthy Nigerians (80 males and 44 females) aged 20–59 years. The mean duration of exercise (DOE) and estimated maximal oxygen uptake (VO_2 max) decreased linearly with increase in age with a high correlation between age and VO_2 max ($r = -0.82$). Males and active subjects had significantly higher values than females and sedentary subjects respectively.

From this study, average values of VO_2 max in healthy Nigerian men and women can be predicted from the following regression equations for VO_2 max (ml of O_2 per kg of body weight per min):

Sedentary men = 57.2 − 0.528 (years of age) ($r = -0.85$),

Active men = 65.0 − 0.579 (years of age) ($r = -0.82$),

Sedentary women = 34.6 − 0.236 (years of age) ($r = -0.61$).

The regression equation for active women is not predictive as none above the age of 29 years volunteered to participate in this study.

The mean maximal heart rate (MHR) was inversely related to age ($r = -0.51$) and average value of MHR (beats/min) expected in healthy Nigerian men and women can be predicted from the regression equation below:

MHR = 207 − 0.620 (age in years) ($r = -0.51$).

This study presents reference data for the assessment of cardiovascular fitness of Nigerians with or without cardiovascular disease.

Résumé

L'exercice maximal de la marche sur tapis roulant suivant la méthode de Bruce a été appliqué à 124 Nigérians en bonne santé (80 hommes, 44 femmes) âgés de 20 à 59 ans. La durée moyenne de l'exercice (DOE) et l'aspiration maximale d'oxygène (VO_2 max) a diminué linéairement selon l'augmentation de l'âge avec une haute correlation entre l'âge et VO_2 max ($r = -0.82$). Les hommes et les patients actifs ont de plus hautes valeurs significatives que les patientes et les patients sédentaires respectivement. A partir de cette étude, les valeurs moyennes de VO_2 max d'un Nigérian et d'une Nigérianne en bonne santé peuvent être prévues selon la regression suivante des equations pour VO_2 max (ml of O_2/kg body wt/min):

Hommes sédentaires = 57.2 − 0.528 (âge) ($r = -0.85$),

Hommes actifs = 65.0 − 0.579 (âge) ($r = -0.82$),

Femmes sédentaires = 34.6 − 0.236 (âge) ($r = -0.61$),

L'équation de regression pour les femmes actives n'est pas sûre puisque personne au-dessus de l'âge de 29 ans a accepté de participer à cette étude.

On a trouvé que la moyenne maximale du puls (MHR) était liée inversement à l'âge ($r = -0.51$) et la valeur moyenne du MHR (beats/min) chez un Nigérian et une Nigérianne en bonne santé peut être calculée à partir de l'equation de la regression ci-dessous:

MHR = 207 − 0.620 (âge) ($r = -0.51$).

*To whom correspondence should be addressed.

This paper was presented at the 16th Annual Scientific Conference, Nigerian Cardiac Society, Calabar, Cross River State, Nigeria, on the 9th April, 1987.

Cette etude présente les données de reférence pour l'évaluation de santé cardiovasculaire des Nigérians avec ou sans maladie cardiovasculaire.

Introduction

Exercise stress testing is designed to evaluate an individual's cardiovascular responses to physical activity in order to determine his capacity to adapt to physical stress [1]. The maximal oxygen uptake is a basic measure of fitness for sustained and strenuous muscular work [2]. This parameter cannot be measured easily in clinical situations, but studies have shown that it can be predicted from the duration of work performed on a standard treadmill protocol [3,4].

In the evaluation of cardiovascular fitness, reference data, obtained from the cardiovascular responses of normal individuals to exercise, are usually provided. Such data, based on adequate samples, are available for Caucasians in the developed countries [2,5,6]. There is a scarcity if not total lack of such data for black Africans. The data available for the developed countries may be of little use to black Africans because absolute values for maximal oxygen uptake (VO_2 max) have been shown to vary for different groups and populations [7]. In view of this variability in different population groups, it is therefore necessary to have normal reference values for black Africans with which values in diseased states can be compared.

These reference values should include the maximal oxygen uptake (VO_2 max) and maximal exercise heart rate (MHR). Only if the range and variability of maximal heart rate are known is it possible to apply the graded exercise test principle appropriately to black Africans.

This study was undertaken in order to provide reference data for the evaluation of cardiovascular responses to exercise of Nigerians with or without cardiovascular disease.

Subjects and methods

This study was conducted at the Electro-Diagnostic Unit of the Obafemi Awolowo University Teaching Hospitals Complex. The participants were consecutive volunteers who responded to a request to participate in a cardiovascular screening survey of residents in Ife and comprised of 124 healthy Nigerians (80 males and 44 females) aged 20–59 years.

The physical activity levels for the population studied were assessed by interview with questioning on recreational, occupational and habitual exercise participation. Habitual participation in running exercise or similar dynamic exercise was used to separate the sedentary from the active groups. The classification used was similar to the one used by McDonough *et al.* [5].

Before the exercise testing was performed, all the subjects had a thorough clinical examination as well as full laboratory investigations. All had chest X-rays and resting 12-lead electrocardiograms. The examination was done in order to exclude individuals with contra-indications to exercise testing [8–10].

Informed consent was obtained in all subjects who had a demonstration of how to mount, walk, run and get off the treadmill; received written instructions concerning eating, appropriate clothing to wear and the time of testing. They were requested to avoid non-essential physical work and strenuous exercise on the day before the test. They were also requested not to smoke, or drink alcohol or coffee on the day of the exercise test which was conducted between 08.00 hours and 12.00 hours. On the day of exercise, each subject had a repeat cardiovascular examination with the blood pressure and heart rate taken in the supine and standing positions after the subject had rested for at least 5 min.

The electrocardiographic procedure conformed to the accepted standards for adult exercise testing recommended by the American Heart Association [1,8].

A standard multi-stage maximal exercise test was conducted on a motorized treadmill (model 3060 Cambridge Medical Instruments Division, New York, U.S.A.) according to the Bruce protocol [3]. The exercise testing began with the subjects walking at 1.7 mph on a 10% gradient with the speed and gradient changing every 3 min (Table 1).

Each subject was instructed to exercise to his maximum possible performance but was made to understand that he could stop voluntarily by indicating if he had any symptoms such as chest pain, muscle cramps, intolerable fatigue, low-back ache or dizziness, etc.

Table 1. The treadmill exercise protocol

Time (min)	Stage no.	Speed Mph	Speed Kph	Gradient (%)
3	1	1.7	2.74	10
3	2	2.5	4.02	12
3	3	3.4	5.47	14
3	4	4.2	6.76	16
3	5	5.0	8.05	18
3	6	5.5	8.86	20
3	7	6.0	9.66	22

The electrocardiogram, heart rate and blood pressure were recorded during the last minute of each stage of exercise. The electrocardiogram was continuously monitored on the CM 3400 non-fade 4-channel electrocardiographic monitor. This was recorded by a CM 3000 automatic 3-channel electrocardiograph. Leads II, avF and V_5 were continuously displayed on the monitor throughout exercise and also the digital heart rate meter continuously displayed the heart rate during each part of the test. The heart rate was also cross-checked by auscultation.

The subjects' electrocardiogram, blood pressure and heart rate were monitored and recorded during the postexercise period with electrocardiographic (ECG) recording every 2 min for an average of 10 min.

The exercise ECG was considered abnormal if a horizontal or downsloping ST-segment depression of 1 mm or more occurred for 0.08 sec after the J-point of the QRS complex [8,11, 12]. The J-junctional changes alone with upward sloping ST segments were considered as normal responses [10,11].

The laboratory and equipment conformed to the specifications for exercise testing equipment [13]. The exercise laboratory was provided with an air-conditioner and the room temperature was kept between 20°C and 25°C.

A defibrillator, Cardio/PAK 936/S (Mennen Medical Inc., New York, U.S.A.) equipped with a portable ECG monitor, and emergency care drugs were provided.

The following parameters were measured:

(a) duration of exercise (DOE) in sec; from this, maximal oxygen uptake was estimated.

(b) Maximal (exercise) heart rate (MHR) in beats per min.

Previous studies have shown a high correlation between maximal oxygen uptake (VO_2 max) and DOE ($r = +0.90$) [3,5,6]. Bruce *et al.* [3], therefore, derived regression equations for estimated VO_2 max in ml/kg/min for healthy persons from the DOE on the treadmill using the Bruce protocol and these are shown below:

Estimated VO_2 max (ml/kg/min) = 6.70 − 2.82 (weighting factor for sex) + 0.056 (duration in seconds) ($r = +0.920$)

The weighting factor for sex is 1 for men and 2 for women such that:

Estimated VO_2 max (men) = 3.88 + 0.056 (duration in seconds)

Estimated VO_2 max (women) = 1.06 + 0.056 (duration in seconds) [3].

For our subjects, the VO_2 max was estimated from their DOE values using the regression equations derived by Bruce *et al.* [3]. To facilitate evaluation of exercise parameters in relation to appropriate peer groups, we determined regression equations to predict MHR and VO_2 max values. This would facilitate comparison with other subjects that would be exercised in our laboratory.

Multiple regressions were computed with the IBM system 370 model 135 of the computer department of Obafemi Awolowo University, Nigeria. The variables (estimated (est.) VO_2 max, MHR, age, sex and activity status) were coded on printed program and data coding forms and transmitted to the computer department for analysis and interpretation.

Differences between subject groups compared were considered statistically significant at $P < 0.05$ using Student's t-test.

Since all the subjects included in this study were volunteers, the data obtained will not necessarily be identical to data obtained in a probability sample from the population at large.

Results

Table 2 shows the age–sex distribution and the pattern of habitual physical activity of these subjects. There was a decline in participation with increase in age and greater response by

Table 2. Age and sex distribution with respect to level of habitual physical activity

Age group (years)	Male subjects (n = 80)		Female subjects (n = 44)		Total (n = 124)
	Sed.	Act.	Sed.	Act.	
20–29	27(21.8)	12(9.7)	20(16.1)	7(5.7)	66(53.2)
30–39	16(12.9)	6(4.8)	9(7.3)	—	31(25.0)
40–49	9(7.3)	4(3.2)	4(3.2)	—	17(13.7)
50–59	6(4.8)	—	4(3.2)	—	10(8.1)
Total	58(46.8)	22(17.7)	37(29.8)	7(5.7)	124(100.0)

Percentage given in parentheses; Sed. = sedentary; Act. = active.

males than females to participate. Seventy-six point six per cent of subjects were sedentary while 23.4% were active. No active females above the age of 29 years volunteered to participate in this study.

Duration of exercise (DOE)

The mean DOE was significantly higher in males than females in all age groups and decreased linearly with increase in age in both males and females (Table 3). This parameter was also significantly higher in active than sedentary subjects (Table 4). There were no active females above the age of 29 years and no active subjects in the 50–59 age group.

Estimated maximal oxygen uptake (est. VO_2 max)

The est. VO_2 max was significantly higher in males than females ($P < 0.05$) and decreased linearly with increase in age (Table 3). Active subjects had significantly higher values than sedentary subjects (Table 4).

Regression equations to estimate maximal oxygen uptake from age

Analysis was done using est. VO_2 max as the dependent variable and age as the independent variable. Regression equations were provided separately with respect to sex and habitual physical activity status, as these two variables, apart from age, have major influences on VO_2 max [3].

Bivariate regression equations to estimate VO_2 max in ml/kg/min from age for each type of healthy person is given below:

Active men: est. VO_2 max = 65.0 − 0.579 (years of age) ($r = -0.82$; adj $r^2 = 0.66$; s.e. = 0.09)

Table 3. DOE and estimated VO_2 max of subjects in relation to age group and sex

Age group (years)	DOE (sec)		Est. VO_2 max (ml/kg/min)	
	Male	Female	Male	Female
20–29	753.3 ± 74.7*	534.1 ± 68.5	46.1 ± 4.2*	31.0 ± 3.8
30–39	700.8 ± 86.4*	466.0 ± 84.2	43.1 ± 4.9*	27.2 ± 4.7
40–49	557.6 ± 67.5**	418.7 ± 4.2	35.1 ± 3.8*	24.5 ± 0.3
50–59	454.0 ± 54.5***	290.8 ± 101.3	29.3 ± 3.1**	17.3 ± 5.7

DOE (sec) = duration of exercise in sec; Est. VO_2 max = estimated maximal oxygen uptake.

*$P < 0.001$; **$P < 0.005$; ***$P < 0.02$.

Table 4. Exercise performance of active subjects compared with sedentary subjects between age 20 and 49 years

Age group (years)	Sex	DOE (sec)		Est. VO_2 max (ml/kg/min)	
		Act.	Sed.	Act.	Sed.
20–29	Male	826.3 ± 46.6	718.3 ± 58.6*	50.2 ± 2.6	44.1 ± 3.3*
	Female	622.9 ± 21.8	503.0 ± 48.5*	35.9 ± 1.2	29.2 ± 2.7*
30–39	Male	797.7 ± 40.3	652.3 ± 56.0*	48.6 ± 2.2	40.4 ± 3.1*
	Female	—	466.0 ± 84.2	—	27.2 ± 4.7
40–49	Male	610.5 ± 32.0	527.4 ± 64.5**	38.1 ± 1.8	33.4 ± 3.6**
	Female	—	418.7 ± 4.2	—	24.5 ± 0.3

DOE (sec) = duration of exercise in sec; Est. VO_2 max = estimated maximal oxygen uptake; Act. = active; Sed. = sedentary.
*$P < 0.001$; **$P < 0.02$.

Sedentary men: est. VO_2 max = 57.2 − 0.528 (years of age) ($r = -0.85$; adj $r^2 = 0.72$; s.e. = 0.05)

Sedentary women: est. VO_2 max = 34.6 − 0.236 (years of age) ($r = -0.61$; adj $r^2 = 0.36$; s.e. = 0.06)

Analysis was not done for active women as none above the age of 29 years volunteered to participate in this study.

Maximal heart rate (MHR)

Table 5 shows the range of MHR values and the mean MHR values in the various age groups. Male subjects had higher mean MHR values than female subjects. This difference was statistically significant only in the 20–29 age group. The mean MHR values decreased with advancing age in both male and female subjects. There was no statistically significant difference in the mean MHR values between active and sedentary subjects ($P > 0.05$).

Table 6 compares the averages of MHR by decades of age in the present study with other published figures.

Regression equations to predict MHR from age

Analysis was done using MHR as the dependent variable and age as the independent variable. As sex and habitual physical activity status do not have major influences on MHR, a single linear regression equation to predict MHR in healthy persons from age was determined and is given below:

MHR = 207 − 0.62 (years of age)
($r = -0.51$; s.e. = 0.98)

Table 5. Maximal exercise heart rate values (MHR) in beats per min

Age group (years)	Range of MHR		Mean MHR ($\bar{x}$ ± s.d.)		
	Male	Female	Male	Female	Male & female
20–29	180–220	180–210	195.0 ± 9.7*	189.7 ± 9.6	192.8 ± 9.9
30–39	180–204	174–198	188.1 ± 7.8	183.4 ± 7.8	186.8 ± 7.9
40–49	162–192	168–180	181.0 ± 11.7	176.0 ± 6.9	180.0 ± 10.9
50–59	156–186	156–180	173.0 ± 11.6	169.5 ± 10.2	171.6 ± 10.7

*$P < 0.05$.

Table 6. Average of maximal heart rates by decades of age

	Ages by decades					
MHR (men and women)	20–29	30–39	40–49	50–59	60–69	70–79
10 studies*	190	182	179	171	164	—
Present study	193	187	180	172	—	—
Studies on women						
Benestad *et al.* [2] (n = 10)	—	—	—	—	—	153
Profant *et al.* [6] (n = 144)	—	184	180	177	160	—
Cumming *et al.* [14] (n = 357)	197	192	179	167	158	145
Sheffield *et al.* [15] (n = 95)	194	186	178	166	165	—
Astrand [18] (n = 44)	187	185	178	170	—	—
Present study (n = 44)	190	183	176	170	—	—

*Adapted from Exercise testing and training of apparently healthy individuals, Committee on Exercise [11]

Indications for terminating exercise

Exercise was terminated due to exhaustion in 121 subjects (97.6%) and anxiety, dizziness, and increasing frequency of ventricular premature beat for one subject in each case. One female subject in the 20–29 age group had ataxia at exhaustion. None experienced anginal pain. There was no abnormal ST-segment depression during exercise or in the recovery period.

Discussion

The participants in this study were consecutively selected volunteers. Most studies of a similar nature have relied on volunteers [2, 5,15]. The age–sex distribution may reflect Nigerian population and socio-cultural characteristics. There was a decline in physical activity with increasing age in the subjects who participated in this study. The VO_2 max is a basic measure of cardiovascular fitness [2]. Its importance is based on the fact that it defines in otherwise healthy and motivated subjects the functional limits of the cardiovascular system [16]. While it is ideal to measure the VO_2 max directly, during exercise testing direct measurements are difficult and equipment may not be readily available [17]. It has been shown that the VO_2 max can be predicted from the duration of work performed on a standard treadmill protocol [3,5]. With the Bruce protocol, there is a high correlation between the duration of exercise and oxygen uptake [3].

Both the DOE and est. VO_2 max values decreased linearly with increase in age. The 50–59-year-old subjects were performing at between 60% and 70% of subjects in the 20–29 age group. This age-related decline in VO_2 max in Nigerians has confirmed similar observations in other populations [5,6,18,19]. As a result of this similar observation in respect of age and VO_2 max, it has been suggested that the intrinsic biological mechanisms that govern the rate of ageing in adult life are similar in populations with different genetic constitutions [7]. It has also been suggested that the gradual decline in VO_2 max with increasing age is at least partly due to a decrease in MHR and level of habitual physical activity. Inactivity is thought to decrease the stroke volume and the functional range of the oxygen transporting system [20].

It is to be noted that in this study the female subjects were performing at between 63.1% and 74.4% of male subjects. The mean est. VO_2 max of 50–59-year-old males was higher than the value obtained in 30–39-year-old females (Table 3). Higher VO_2 max in men than women has been reported by others and this difference has been attributed to differences in body dimensions, composition and metabolism and also to a higher habitual physical activity in men than women [7,17,21,22]. Despite marked differences in absolute values of VO_2 max between men and women, the decline in VO_2 max with age is comparable. Active subjects had significantly higher values of DOE and est. VO_2 max irrespective of age than sedentary subjects who attained on the average 73–83.5% of the est. VO_2 max of active subjects. Higher habitual physical activity is associated with higher VO_2 max [5,6,23,24]. Regression equations had been derived to predict VO_2 max in Caucasian men and women [3,25]. It is not enough to determine the VO_2 max of an individual. It is also important to evaluate its relationship to expected values of appropriate peers.

The regression equations we had derived for predicting VO_2 max from age where sex and activity status are known, had facilitated the application of the concept of functional aerobic impairment (FAI) in the evaluation of subjects tested in our exercise laboratory. FAI represents the percentage difference of observed or estimated VO_2 max and that predicted in health for a person of the same sex, age and habitual activity status [26]:

$$\text{FAI (\%)} = \frac{\text{age-predicted } VO_2 \text{ max} - \text{estimated } VO_2 \text{ max}}{\text{age-predicted } VO_2 \text{ max}} \times 100.$$

The age related decline in MHR is an expected finding in both men and women [5,6,15,18]. Usually there are no sex differences in MHR [7] although Sheffield *et al.* [15] have published heart rate tables for women differing from those published for men especially in the older age groups. In this study amongst 20–29-year-old subjects, males had significantly higher MHR than females ($P < 0.05$). The reason for this difference is not obvious. It is unlikely to be due to motivation as these subjects exercised maximally [27]. There were no significant differences between the MHR of active and sedentary subjects. Profant *et al.* [6] reported identical MHR values for active and sedentary women, while Benestad [28] did not find any significant difference in active compared with sedentary men. McDonough *et al.* [5] found the MHR to be significantly lower in active than in sedentary 40–49-year-old men.

A comparison of the MHR by decades obtained in the present study with figures published by 10 American and European investigators are in good agreement (Table 6). Similarly there is good correlation between the mean MHR for females in this study and those of other authors (Table 6). The MHR found in the studies of Sheffield *et al.* [15] and Astrand [18] are very similar to those we found. The activity pattern of our female subjects while similar to that reported by Sheffield *et al.* [15] was dissimilar to that in Astrand's subjects.

The regression equation derived for predicting MHR in Nigerians is comparable with that derived by Bruce *et al.* [26] for Caucasians:

$$\text{MHR} = 207 - 0.620\,(\text{age in years})\ (r = -0.51)\ \text{(Nigerians)}$$

$$\text{MHR} = 210 - 0.662\,(\text{age in years})\ (r = -0.44)\ \text{(Caucasians).}$$

There were no untoward events with exercise testing in this study and no significant ST-segment depression was observed.

Data on maximal exercise performance of adult Nigerians free of cardiovascular disease are presented. Duration of exercise, estimated maximal oxygen uptake and maximal heart rate values decrease with increasing age. While the number of subjects tested is small, these data should prove useful as normal standards for assessment of cardiovascular functional capacity of Nigerians with or without cardiovascular disease until such time as larger numbers of data on maximal exercise testing become available.

References

1. Committee on Exercise, American Heart Association. Exercise Testing and Training of Individuals with Heart Disease or at High Risk for its Development, A Handbook for Physicians. New York: American Heart Association, 1975: 11–62.
2. Benestad AM, Halvorsrud J, Andersen KL. The physical fitness of old Norwegian men and women. Acta Med Scand 1968;183:73–8.
3. Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and normographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J 1973;85:546–62.
4. Pollock ML, Bohannon RL, Cooper KH, Ayres JJ, Ward A, White SR, Linnerud AC. A comparative analysis of four protocols for

maximal treadmill stress testing. Am Heart J 1976;92:39–46.
5. McDonough JR, Kusumi F, Bruce RA. Variations in maximal oxygen intake with physical activity in middle-aged men. Circulation 1970; 41:743–51.
6. Profant GR, Early RG, Nilson KL, Kusumi F, Hofer V, Bruce RA. Responses to maximal exercise in healthy middle-aged women. J Appl Physiol 1972;33:595–9.
7. Andersen KL, Masironi R, Rutenfranz J, Seliger V, Degre S, Trygg K, Orgim M. Habitual physical activity and health. WHO Regional Publication, European Series 1978;6:18–138.
8. Ellestad MH, Blomqvist CG, Naughton JP. Standards for adult exercise testing laboratories. American heart association committee report. Circulation 1979;59:421A–30A.
9. Ellestad MH. Stress Testing: Principles and Practice, 2nd Edn. Philadelphia: F.A. Davis Company, 1980:105–10.
10. Fortuin NJ, Weiss JL. Exercise stress testing. In: Weissler AM, ed. Reviews of Contemporary Laboratory Methods. American Heart Association Monograph No. 66, 1980:157–87.
11. Committee on Exercise, American Heart Association. Exercise Testing and Training of Apparently Healthy Individuals, A Handbook for Physicians. New York: American Heart Association, 1972:1–40.
12. Abenavoli T, Rubler S, Fisher VJ, Axelrod HI, Zuckerman KP. Exercise testing with myocardial scintigraphy in asymptomatic diabetic males. Circulation 1981;63:54–63.
13. Hellerstein HK. Specifications for Exercise Testing Equipment. American Heart Association committee report. Circulation 1979; 59:849A–54A.
14. Cumming GR, Dufresne C, Kich L, Samm J. Exercise electrocardiogram patterns in normal women. Br Heart J 1973;35:1055–61.
15. Sheffield LT, Maloof JA, Sawyer JA, Roitman D. Maximal heart rate and treadmill performance of healthy women in relation to age. Circulation 1978;27:79–84.
16. Bruce RA. Exercise tests. In: Cohen LS, Mock MB, Ringvist I, eds. Physical conditioning and cardiovascular rehabilitation. New York: Wiley Medical Publication, 1981:3–21.
17. Naughton J, Haider R. Methods of exercise testing. In: Naughton JP, Hellerstein HK, Mohler IC, eds. Exercise Testing and Exercise Training in Coronary Heart Disease. New York: Academic Press, 1973:79–91.
18. Astrand I. Aerobic work capacity in men and women with special reference to age. Acta Physiol Scand 1960;49(Suppl 169):1–92.
19. Astrand PO. Physical performance as a function of age. J Am Med Assoc 1968;205:729–33.
20. Astrand PO, Rodahl K. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1970:115–631.
21. Cotes JE, Davies CM, Edhold OG, Healy MJR, Tanner JM. Factors relating to the aerobic capacity of 46 healthy British males and females, ages 18 to 28 years. Proc R Soc London, B. 1969;174:91–114.
22. MacNab RB, Conger RP, Taylor PS. Differences in maximal and submaximal work capacity in men and women. J Appl Physiol 1969;47:644–8.
23. Pyorala K, Karvonen MJ, Taskinen P, Takkunen J, Kyronseppa H, Peltokallio P. Cardiovascular studies on former athletes. Am J Cardiol 1967;20:191–205.
24. Saltin B, Astrand PO. Maximal oxygen uptake in athletes. J Appl Physiol 1967;23:353–8.
25. Bruce RA. Principles of exercise testing In: Naughton JP, Hellerstein HK, Mohler IC, eds. Exercise Testing and Exercise Training in Coronary Heart Disease. New York: Academic Press, 1973;45–60.
26. Bruce RA, Fisher LD, Cooper MN, Gey GO. Separation effects of cardiovascular disease and age on ventricular function with maximal exercise. Am J Cardiol 1974;34:757–63.
27. Wilmore JH. Influence of motivation on physical work capacity and performance. J Appl Physiol 1968;24:459–63.
28. Benestad AM. Trainability of old men. Acta Med Scand 1965;178:321–7.

(*Accepted* 21 *December* 1987)