Physiological Analysis of Middle-Aged and Old Former Athletes

Comparison with Still Active Athletes of the Same Ages

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SUMMARY

Blood lipids, red cell volume, heart volume, dynamic spirometry, electrocardiograms made at rest and during exercise, and maximal oxygen uptake were determined in 29 former athletes 45 to 70 years old. The subjects had been very successful competitors in endurance events before the age of 30, but for at least 10 years preceding this study had been sedentary.

Maximal oxygen uptake averaged 40 ml/kg/min which is 20% higher than that of sedentary middle-aged men but 25% lower than that of still active athletes of the same ages. Vital capacity, forced expiratory volume, and maximal voluntary ventilation showed normal values. Heart volume was large in relation to maximal oxygen uptake and was of the same magnitude as in still active athletes. Red cell volume was also large in relation to maximal oxygen uptake, but normal in relation to the body weight. Cholesterol in serum averaged 260 mg/100 ml. Values for neutral fat averaged 1.6 mM, which was higher than that for still active athletes.

In the athletes still active, the frequency of S-T changes was as common as in unselected healthy old men but in the former athletes the frequency was reduced. This was also true for the frequency of right bundle-branch block, ST-junction elevation and high T waves.

Additional Indexing Words:

Maximal oxygen uptake   ECG during exercise   Dynamic spirometry

Heart volume   Red cell volume   Blood lipids in former endurance athletes

IN A GROUP of well-trained and still competing middle-aged and old athletes, high aerobic work powers (maximal oxygen uptake) and large heart volumes were found.[1] This was a highly selected group of men who had trained continuously for at least 20 years and still trained and competed in "orienteering" (cross-country track finding) and skiing.

ECG findings which are common in well-trained men (ST-junction elevation, tall R and T waves, and minor intraventricular conduction changes) were recorded, but a relatively high frequency of S-T depressions also were found at maximal exercise. Also, in former athletes a high frequency of ECG changes and large heart volumes have been found[2, 3] although in another group the ECG changes did not deviate significantly from what was found in normal material and the heart volumes corresponded to the observed high maximal oxygen pulse.[4]

The aim of the present study was to analyze, in a manner identical to the previous study,[1] a group of former athletes. The men in the present report had trained in their twenties, as much and as successfully as those who were still active athletes. Thus, we might

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Table 1
Average and Range Values for Age, Height, Weight, and Period of Physical Training

No. of individuals	Age (yr)	Height (cm)	Weight (kg)	Regular physical training, age at Beginning (yr)	Last year (yr)
10	47.4	177.8	74.5	18.6	31.2
	44-49	173-182	64-80	14-22	27-38
14	53.6	177.1	77.3	18.6	36.8
	50-59	169-188	62-96	15-26	28-45
5	63.0	177.1	70.2	19.8	45.2
	60-67	172-183	62-89	16-23	35-54

to some extent be able to elucidate the often-asked questions about the physical work performance and the cardiovascular condition in men who had once been very well trained but now are sedentary.

Material

Group Studied

All athletes who took part in the previous study[1] gave the name of two persons who had been as successful as themselves before the age of 30, but since then had stopped all competition and most training. All of these received a questionnaire regarding their physical activities on and off their jobs. Sixty of 65 persons replied to the questionnaire. The selection was then made on the basis of the physical activity level that the former athletes had maintained since the termination of their active competition. Subjects with activity patterns lower than group 2 (see appendix) were selected. A total of 29 males aged 44 to 67 years fulfilled this criterion and were chosen for this study. One other man fulfilled the criterion and was asked to participate, but time prevented him from joining the group. It should be noted that the names of the former athletes were submitted by athletes who were still active and there is reason to believe that, directly or indirectly, persons with a history of serious illness were excluded. It is not clear to what extent this possibility would influence the results of study in these subjects.

All the studied subjects had trained and competed in "orienteering," cross-country running and skiing intensively for at least 8 years but had been sedentary during at least 10 years preceding this study (table 1). Twelve subjects were studied in Göteborg and the remaining 17 in Stockholm.

Methods and Procedures

Before the physiological studies, a medical history specially concerning cardiopulmonary symptoms was taken using a questionnaire on cardiac pain recommended by the World Health Organization in 1962 and a questionnaire approved by the British Medical Research Council's Committee on the Aetiology of Chronic Bronchitis.[5] A clinical examination including blood pressure measurement and ECG recording at rest was then made.

The same methods and the same general procedure were used as in the previous investigation of still active athletes.[1] Exercise tests were performed on a bicycle ergometer on two or three submaximal loads and several maximal loads, usually on different days. The procedures for the exercise tests and for the determination of maximal oxygen uptake were reported earlier.[1] The ECG was recorded during exercise by unipolar chest leads (CH leads). After exercise leads I, II, III, aV_R, aV_L, aV_F, and $CR_{1,2,4,5,6}$ were recorded. The findings were classified according to the Minnesota Code[6] as modified by I. Åstrand for these leads.[7]

Heart volume in the prone position, hemoglobin, hematocrit, serum cholesterol and neutral fat were determined as in the previous report.[1] Red cell volume was determined in the 12 subjects from Göteborg with ^{51}Cr,[1] but for the Stockholm subjects was calculated from the total amount of hemoglobin determined by the CO-Hb method.[8] Dynamic spirometry including determination of the timed vital capacity and maximum voluntary ventilation with a free respiratory frequency was performed with a Bernstein spirometer and the subjects in the sitting position.

Results

Clinical Examination and Medical History

The body weight by history had on the average increased 6.6 (range, 1 to 12) kg in the 44 to 49-year-old men and 8.3 (range, 1 to 20) kg in the 50 to 59-year-old group after the subjects stopped regular training. None of the former athletes had signs of cardiorespiratory

Table 2

Results at Rest: Means, Standard Deviations and Ranges

Age group (yr)	Nos.	Heart rate (beats/min)	Heart volume (ml)	Red cell volume (L)	Hemoglobin (g/100ml)	Hematocrit (%)	Cholesterol (mg/100 ml)	Neutral fat (mM/L)	Blood pressure (mm Hg) Systolic	Diastolic
44-49	10	62.3	835	2.24	13.6	42.6	231	1.56	128	82
		10.6	79	0.20	0.8	2.0	45	0.45	8	7
		47-78	740-960	1.91-2.56	12.4-14.6	39-45	156-300	0.80-2.38	115-140	70-90
50-59	14	61.6	916	2.21	14.0	41.8	277	1.44	130	82
		11.6	184	0.30	0.5	2.7	45	0.52	15	6
		37-84	670-1330	1.79-2.72	13.2-14.7	35-45	178-338	0.87-2.82	110-160	75-95
60-67	5	67.6	864	2.17	13.1	42.8	266	1.84	123	86
		10.5	175	0.27	0.3	0.9	59	1.35	17	11
		53-78	700-1150	1.83-2.44	12.7-13.5	42-44	215-355	0.64-4.14	105-150	70-95

disease at the clinical examination. Six men, two being smokers, had frequent symptoms of mild bronchitis. Six subjects (two also belonging to the above-mentioned six) had occasionally experienced pain in the chest, but none of them described a typical effort angina. Two of these subjects had abnormal S-T changes at maximal exercise (see table 4). The father of one of the subjects had died before 50 years of age of myocardial infarction. This person, who now was 47 years old, had occasional ventricular ectopic heart beats before and after exercise. The concentrations of cholesterol and neutral fat were within the normal range, however.

The most common reason given for discontinuing training and competition among this group (three out of five) was that their time was taken up by their employment.

Physiological Data

The results will be compared with those in the previous study of still active athletes in the same age ranges and with different control materials presented in that study.[1] In table 2 are given the results from the determinations at rest. The blood pressures are of the same range as those of the still active athletes, the average systolic pressures being even somewhat, but not significantly, lower. The average blood pressure did not deviate significantly from that of 855 men selected by chance from the population of 50-year-old men in Göteborg.[5] The cholesterol values were for most subjects within the same range as for still active athletes. However, seven men in the present group, had values above 300 mg/100 ml compared with only one among the active athletes. The mean value for neutral fat was significantly increased in all age groups, over that of the active athletes, although there was a large individual variation. Nineteen of 29 men in the present group showed values above the average value from the population study mentioned above[5] compared with four of 33 among the still active athletes.

Table 3 presents the results obtained during submaximal exercise. The mean values

Table 3
Results from Submaximal Work Loads: Means, Standard Deviations, and Ranges

Work load (kpm/min)*	Age group (yr)	Nos.	Oxygen uptake (L/min)	Ventilation volume (L/min)	Heart rate (beats/min)	Blood lactate (mM/L)
600	44-49	10	1.51	35.3	114	2.1
			0.16	3.6	16	0.6
			1.28-1.74	28.3-41.5	93-143	1.3-3.3
	50-59	14	1.53	38.5	110	2.7
			0.09	3.3	11	0.8
			1.33-1.65	31.8-43.7	97-132	1.4-4.1
	60-67	5	1.45	36.3	120	2.8
			0.10	6.4	12	1.1
			1.31-1.55	27.0-42.6	102-134	1.6-4.5
900	44-49	10	2.18	52.5	141	4.8
			0.19	6.7	18	1.2
			1.95-2.54	43.5-63.3	114-175	3.7-6.8
	50-59	14	2.10	54.6	139	5.3
			0.19	9.0	18	2.4
			1.77-2.49	42.8-75.2	118-180	2.4-11.1
	60-67	5	2.22	66.0	151	6.4
			0.14	15.4	18	1.7
			2.03-2.36	51.9-86.8	131-180	4.8-9.2
1200	44-49	10	2.65	76.7	163	7.1
			0.11	14.1	15	1.9
			2.51-2.83	54.5-105.1	130-179	5.1-11.0
	50-59	12	2.73	78.5	158	7.6
			0.19	10.0	11	2.2
			2.43-3.06	67.3-98.3	135-175	4.8-11.4
	60-67	3	2.61	79.8	160	9.5
			—	—	—	—
			2.60-2.63	70.6-94.0	154-163	8.4-10.3

*kpm = kilopound-meter; 1 kp is the force acting on the mass of 1 kg at normal acceleration of gravity (100 kpm/min = 723 ft-lb/min = 16.35 W).

for oxygen uptake at the different work loads were very close to those found in the active athletes, and there was no difference between the different age groups. The heart rates on the submaximal work did not increase with age, but there were slightly higher values of blood lactate with increasing age. With the exception of the 51 to 59-year-old group, the mean values for the heart rate were higher than in the active athletes. The mean values for the blood lactic acid were higher or even considerably higher (cf fig. 6).

None of the subjects complained of chest pain during or after the work test. The ECG changes at rest and during exercise are given in table 4. Of the 29 subjects, three had S-T depressions classified as IV: 1-2 during or after maximal exercise. Two subjects exhibited S-T depressions of IV: 1 classification at about 60% of their maximal oxygen uptake. The S-T depressions increased with increasing work loads and remained 4 minutes after exercise (see example in one subject in figure 1). The third subject got the S-T depression during maximal exercise, and it remained for 4 minutes after exercise. Three out of 29 subjects is a smaller incidence of such purportedly ischemic changes than was found in the still active athletes. Ectopic heart beats were also less common in the present group. High T waves were recorded but, not nearly as often as in the active athletes. A right intraventricular conduction defect was found in only one man. The maximal values for oxygen uptake, heart rate, and lactic acid in blood are given in table 5.

In figure 2 the maximal oxygen uptake is related to age. As in the following figures,

Table 4

Electrocardiographic Findings

Code	ECG changes	Incidence of changes by age groups 44-49 (n = 10)	50-59 (n = 14)	60-68 (n = 5)
	At rest			
IV:5	ST-junction depression, 1 mm or more and ST-segment sloping upward	0	1	0
IV:8	ST-junction elevation, 2 mm or more	1	1	0
V :3	T diphasic in CR_5 (V_5)	0	0	1
VI:3	PR > 0.21 sec	0	1	0
IX:6	Occasional ventricular ectopic beats	1	0	0
IX:7	Occasional supraventricular ectopic beats	0	0	1
X :2	T waves, 12 mm or more	5	4	1
X :3	Notching of QRS in CR and QRS 0.11 sec	1	0	0
	In exercise test			
IV:1	ST-junction depression, 1 mm or more, and ST-segment horizontal or downward sloping	0	2	0
IV:2	ST-junction depression, 0.6-0.9 mm, and ST-segment horizontal	1	0	0
IV:4	No ST-junction depression as much as 0.5 mm but ST-segment horizontal or downward sloping but not reaching 0.5 mm below P-R base line	2	1	0
IV:5	ST-junction depression, 1 mm or more, and ST-segment upward sloping	1	2	1
IV:6	ST-junction depression, 0.6-0.9 mm, and ST-segment upward sloping	0	1	0
V :2	Negative T wave, 1-5 mm	1	0	0
IX:3	Frequent ventricular ectopic beats after exercise ($\geq$ 4/40)	1	1	0
IV:4	Frequent supraventricular ectopic beats after exercise ($\geq$ 4/40)	0	0	1
IX:6	Occasional ventricular ectopic beats during and after exercise	0	1	0
IX:7	Occasional supraventricular ectopic beats after exercise	0	1	0

the subjects with S-T changes classified as IV: 1 and IV: 2 on ECG at exercise tests are marked with filled dots. All but four subjects fell within the mean values for nonathletes,[6, 9] and only two had maximal oxygen uptake higher than the mean value for the still active athletes. The values for those with abnormal S-T changes fell within the range for the other subjects.

As in previous studies the maximal heart rate (fig. 3) at a certain age showed large individual variation. The values fell within the same range recorded from the still active athletes.

In figure 4 the heart volume in the supine position is plotted against the maximal oxygen uptake. All subjects except two had higher heart volumes in relation to the maximal oxygen uptake than young healthy men (20 to 29 years of age). Nearly half of our subjects had values above 2 standard deviations away from the regression line. The mean value of the heart volume was significantly lower in our group below 50 years of age than in the still active athletes of the same age. There was no such difference for the two older age groups. Unfortunately, the heart volume could be determined in only two of the three subjects with abnormal S-T changes as the third was severely injured in a car accident. One of those subjects, however, showed marked increase in the heart volume (1,330 ml) in relation to the maximal oxygen uptake. He had been well trained and held the world record in walking. He once had a brief period of chest pain, but no other cardiovascular symptoms and had no pain on the maximal exercise test. The cholesterol value was 272 mg/100 ml and neutral fat, 1.18 mM/L.

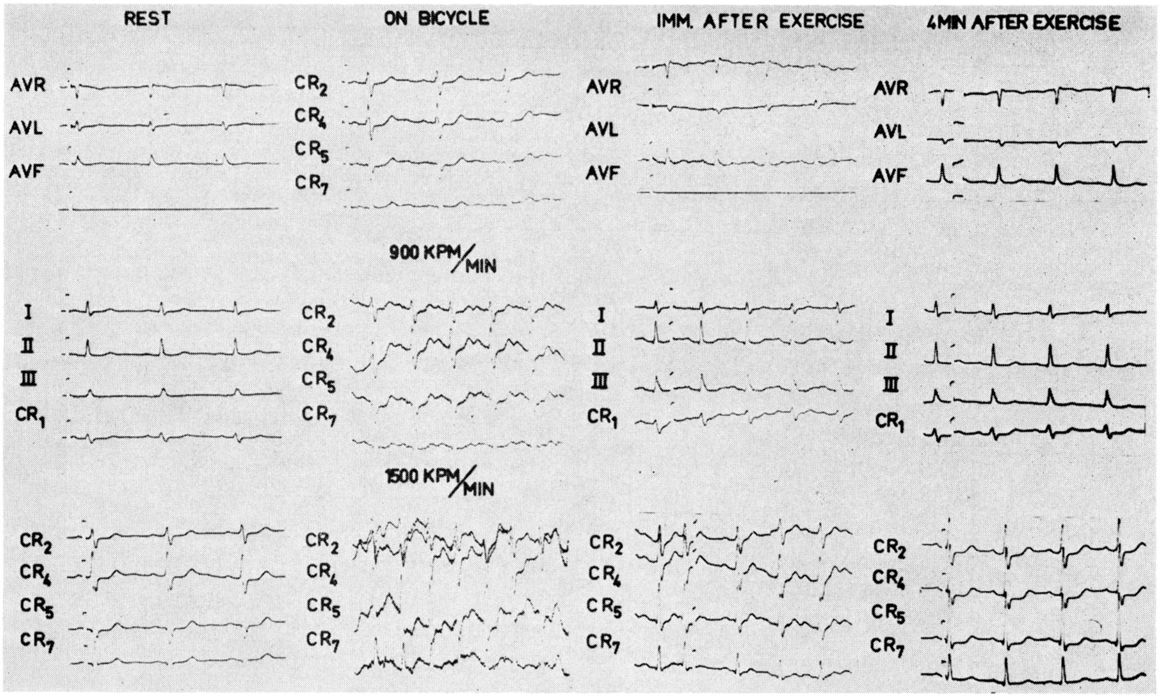

Figure 1

ECG recordings at rest and during and after bicycle exercise in one subject with S-T depression.

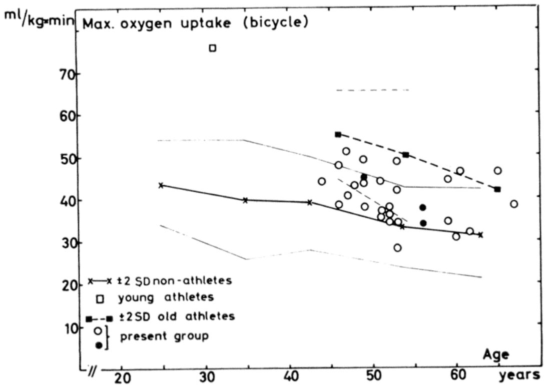

Figure 2

Individual values for maximal oxygen uptake in relation to age of former athletes. Filled circles denote the former athletes with S-T changes classified as IV:1-2 (see table 4). The heavy solid line (with ± 2 SD) denotes material on nonathletes of different ages.[9] The dashed line between the squares (with ± 2 SD) denotes the still active athletes.[1] The unfilled rectangle denotes the mean value for the nine best Swedish "orienteering" runners of today.[10]

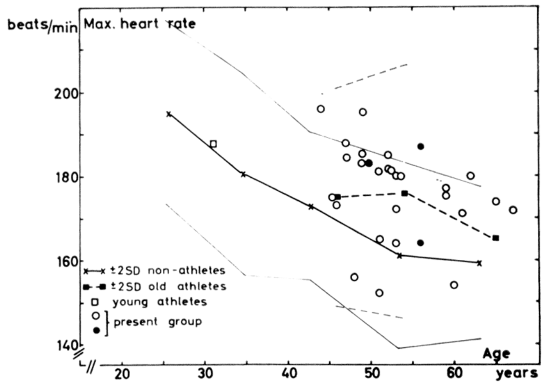

Figure 3

Individual values for maximal heart rates in relation to age. Symbols, same as in figure 2. The heavy solid line (with ± 2 SD) denotes material on nonathletes of different ages.[6, 9]

The relation of red cell volume to maximal oxygen uptake is demonstrated in figure 5.

All subjects except one had values above the regression line for 20 healthy subjects in the age group of 20 to 40 years. This is in contrast to the still active athletes who had values in the same range as young subjects with similar maximal oxygen uptake. The subject with the extremely high heart volume

Table 5
Results from Maximal Exercise Tests: Means, Standard Deviations and Ranges

Age group (yr)	Nos.	Oxygen uptake (L/min)	Ventilation volume (L/min)	Heart rate (beats/min)	Blood lactate (mM/L)
44-49	10	3.28	112.8	182	11.9
		0.32	16.8	12	2.9
		2.92-3.62	85.5-137.4	156-196	5.7-15.7
50-59	14	2.90	95.5	175	10.0
		0.41	8.4	9	2.0
		2.02-3.65	55.4-129.9	152-187	7.5-13.2
60-67	5	2.60	83.2	170	10.7
		0.42	7.3	10	3.0
		2.09-2.98	74.9-94.0	154-180	5.8-13.2

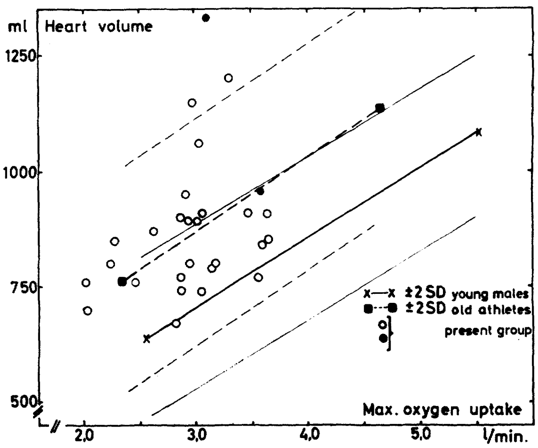

Figure 4

Individual values for heart volume in relation to maximal oxygen uptake. Symbols same as in figure 2. The solid line ($y = 251 + 144.9\ x$; $r = 0.81$) with ± 2 SD denotes material of 32 healthy males aged 20 to 29 years.[1] The dashed line between the squares denotes the still active athletes.[1]

(1,330 ml) did not have higher red cell volume (1.80 L) than expected from his maximal oxygen uptake (3.10 L/min). He had normal hemoglobin concentration (14.7 g/100 ml). The mean values in the present group did not differ significantly from those of the still active athletes (mean, 2.14 L; SD, 0.20), although the maximal oxygen uptake was lower.

Figure 6 relates the lactic acid concentration in relation to the maximal oxygen uptake. There was a large individual variation, but the values fell fairly symmetrically around the average values in the control group of nonathletes (20 to 58 years) presented in the previous article. Most values fell above the mean values for the still active athletes. The maximal lactic acid concentration, however, did not deviate significantly from that of the still active athletes and nonathletes.

The measured volumes from the dynamic spirometry (fig. 7) are expressed as a percentage of the predicted normal value according to Berglund and associates[11] and for maximal voluntary ventilation according to Grimby and Söderholm.[12] Two residual standard deviations for the regression equations

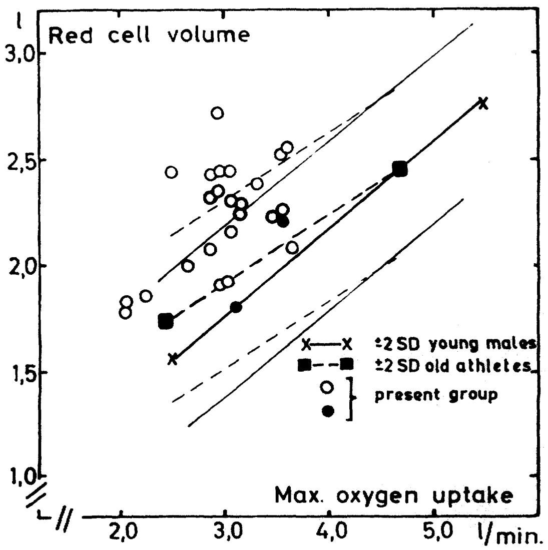

Figure 5

Individual values for red cell volume in relation to maximal oxygen uptake. Symbols same as in figure 2. The solid line denotes the regression line ($y = 0.51 + 0.4\ x$; $r = 0.87$) with ± 2 SD for healthy males, 20 to 40 years old.[1] The dashed line between the squares denotes the still active athletes.[1]

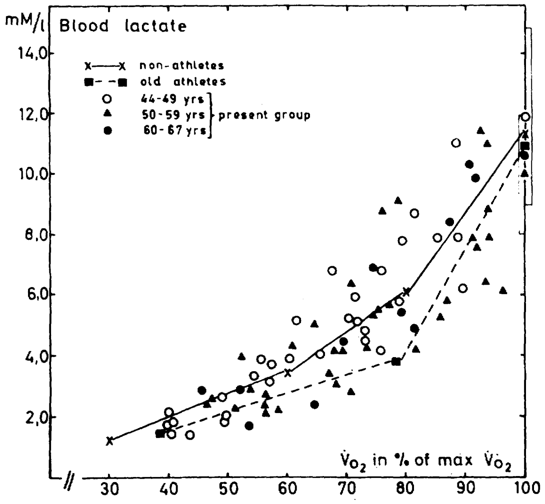

Figure 6

Individual values for blood lactic acid in relation to the oxygen uptake expressed as percentage of the maximal oxygen uptake. The solid line denotes the mean value for a group of nonathletes, 20 to 58 years old.[1] The dashed line between the squares denotes the still active athletes.[1]

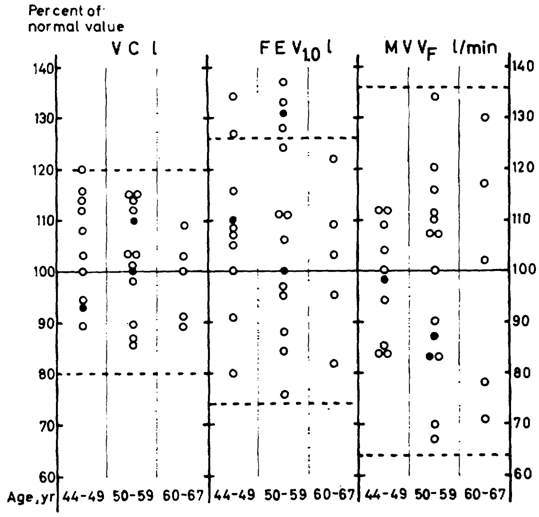

Figure 7

Vital capacity (VC): forced expiratory volume in 1 sec ($FEV_{1.0}$) and maximal voluntary ventilation with a free frequency (MVV_F) as a percentage of predicted normal values.[11,12] The horizontal dashed lines denote the normal values ± 2 SD.

of the normal material are shown as broken lines. The vital capacity (VC) fell in the normal range. The forced expiratory volume in 1 second ($FEV_{1.0}$) was above 2 standard deviations in six of the 29 subjects, which is similar to the findings for still active athletes. However, neither for $FEV_{1.0}$ nor for maximal voluntary ventilation (MVV_F) was there such a marked tendency to higher than predicted values as in the group of still active athletes.

Discussion

The present group was selected to correspond as closely as possible to the still active

Table 6
Mean Values for Active and Former Middle-Aged Athletes

	43-49 yr		50-59 yr		60-67 yr	
	Active (n = 14)	Former (n = 10)	Active (n = 15)	Former (n = 14)	Active (n = 4)	Former (n = 5)
Maximal $\dot{V}_{O_2}$ (L/min)	3.98	3.28	3.39	2.90	2.68	2.60
Maximal $\dot{V}_{O_2}$ (ml/kg/min)	57	44	53	38	43	37
Maximal heart rate	175	182	176	175	165	170
Maximal blood lactate (mM)	11.2	11.9	10.8	10.0	9.5	10.7
Heart volume (ml)	1047	835	937	916	830	864
Red cell volume (L)	2.07	2.24	2.01	2.21	—	2.17
Hemoglobin (g/100 ml)	13.4	13.6	13.7	14.0	13.4	13.1
Blood pressure rest, supine (mm Hg)	135/83	128/82	137/81	130/82	138/80	123/86
Vital capacity (L)	4.9	5.0	4.2	4.6	3.2	4.3
Forced expiratory volume (1.0 sec, L)	4.2	3.9	3.8	3.5	2.1	3.0
Maximal voluntary ventilation (L/min)	170	146	155	139	119	121
Cholesterol (mg/100 ml)	222	231	251	277	286	266
Neutral fat (mM)	0.85	1.56	0.95	1.44	1.10	1.84
Abnormal S-T segment (Minnesota Code IV:1-3)	2	1	4	2	1	0

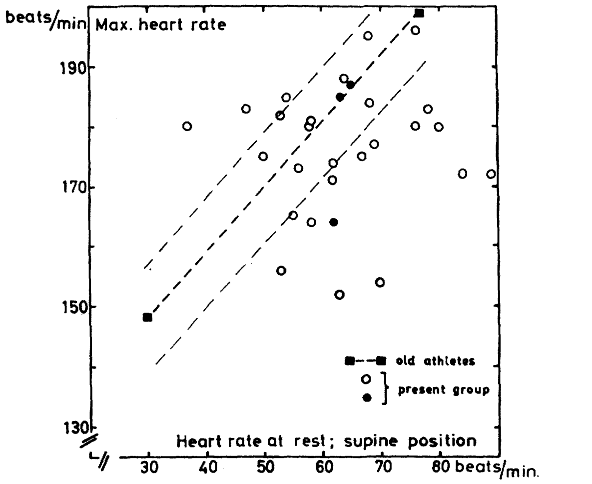

Figure 8

Individual values for maximal heart rate at exercise in relation to the heart rate at rest in supine position. The dashed line ± 1 SD between the squares denotes the still active athletes.[1]

athletes but without regular training for at least 10 years (mean, 16 to 18 years, table 1). Therefore it is reasonable to assume that the main differences (table 6) between the still active and the former athletes are caused, to a large extent, by the difference in physical activity during the last one or two decades. It is important to emphasize that the present group was as successful in competition in their twenties as the previously investigated still active athletes. Furthermore, most of the former athletes stopped their competition and regular intensive training after a successful season. For almost all former athletes, the aerobic power is above the average of a comparable group of nonathletes.[9, 13, 14] The mean values for the former athletes were 44, 38, and 37 ml/kg/min, respectively, for age groups 44 to 49, 50 to 59, and 60 to 67. The corresponding values for the still active athletes[1] were 57, 53, and 43 ml/kg/min (fig. 2). Thus the maximal oxygen uptake of former athletes is 20-25% lower than that of the still active athletes. These data suggest that regular physical training in middle-aged men can substantially prevent the decrease in aerobic power with age. The former athletes average about 20% higher values of maximal oxygen uptake than nonathletes of the same ages, for example, when compared to a group of 53 randomly selected 54-year-old men, who had an average maximal oxygen uptake of 30 ml/kg/min (2.30 L/min) and heart rate of 172 beats/min (Grimby et al., 1968, unpublished data). It is impossible, however, to determine whether the fairly high values of maximal oxygen uptake recorded on the former athletes are due to the earlier periods of training or to constitutional factors.

In the present material there was no correlation between the maximal oxygen uptake and the heart volume. The mean value or heart volume was lower for the 44 to 49-year-old group than for the still active athletes. This is true even if differences in maximal oxygen uptake are taken into consideration (tables 2 and 5; fig. 4). For the two older age groups there was no difference between the former and the still active athletes. This observation may be explained by a longer period of regular training for the former athletes in the oldest age groups (table 1). When the heart volumes of former athletes in relation to body weight were compared with those of a group of healthy middle-aged and old men,[15] all except three of the latter were within ±2 standard deviations of the regression line, but 23 of 28 of the former athletes were above the regression line. Also, comparison of the heart volumes of the former athletes and of another group of healthy middle-aged and old men[16] showed that the former athletes averaged slightly higher values.

Our results are in agreement with the finding of a longitudinal study of girl swimmers, who 5 years after finishing competition had only slight reduction in heart volume but larger reduction in the maximal oxygen uptake (Åstrand, Billing, Engström, Eriksson, Karlberg, Saltin, and Thoren, unpublished data). Holmgren and Strandell[2] also found larger heart volumes in relation to physical working capacity in former racing cyclists. There are, however, several differences between their group and ours. Some of the cyclists had raced less than 10 years before the investigation, and about one third had continued moderate physical training, whereas all our subjects had had only light physical work and no regular training for at least 10 years. The physical performance might still have been somewhat higher in our group than in the cyclists, as judged by submaximal exercise tests. The mean heart rate at 1,200 kpm/min was about 160/min, in our group, but in the former racing cyclists about 170/min. Roskamm and associates,[4] however, found that the larger heart volumes in their former athletes correlated fairly well with their increased physical performance capacity.

The red cell volume was large in the present group when related to the maximal oxygen uptake (fig. 5) compared to that of young men, and was of the same magnitude as that of the still active athletes. The former athletes' total amount of hemoglobin in relation to body weight was scattered in all cases, except one, around the regression line for healthy old men.[17]

In the still active athletes, the incidence of S-T changes was as common (six of 33) as in unselected healthy old men,[6, 16, 18–20] but in former athletes there were three of 29. The frequency of right bundle-branch blocks, ST-junction elevation, and high T waves was also lower in the former athletes. Such ECG changes are often found in groups of well-trained persons, but they are definitely not as common in the present group of former athletes. This is consistent with the observation of Roskamm and associates[4] that incomplete right bundle-branch block can be reversible in well-trained athletes. Two of the still active athletes had Wenckebach heart block during the first minutes after maximal exercise. No such abnormalities were found in the present group of former athletes. Holmgren and Strandell[2] reported a relatively high frequency of abnormal ECG changes in their group of former athletes. However, we cannot confirm that observation, and our results agree more with the results of Roskamm[4] and Pyörälä[3] and their co-workers.

The neutral fat tended to be higher in the formerly active than in the still active athletes. The average cholesterol values did not show such a tendency although a number of the former athletes had high values. Former athletes showed higher values for the neutral fat, body weight, and skin-fold thickness than the active athletes. The skinfold thickness in the subscapular region averaged 12.7 mm (range, 7.5 to 19.0) compared to 9.8 mm (range, 6.6 to 15.0) in the still active athletes. (The former athlete with 7.5 mm was a vegetarian.) The values do not deviate markedly from those in the population study by Tibblin and associates.[5]

In the still active athletes there was fairly good correlation between resting heart rate (supine position) and the maximal heart rate during bicycling.[1] The same was not true for the former athletes (fig. 8) even though the variations in maximal heart rate were the same in the two groups.

In nine of the still active athletes, cardiac output was determined by the dye-dilution technique during submaximal and maximal exercise.[21] The maximal stroke volumes were very high and compared well with those of young athletes, who had the same heart volumes. Due to the high maximal cardiac output observed, we assumed that peripheral factors limited the maximal oxygen uptake in the still active athletes. The same conclusion is made by Strandell regarding old healthy men.[22] In the former athletes, we have no circulatory data, but it is likely that the central circulation is not the main limiting factor in this group either.

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Appendix*

The following two sections have been designed to allow an estimate of your lifetime physical activity, both occupational and recreational. The first section deals with physical activity within your occupation. We have classified all occupations in four groups, from sedentary to hard manual work. Please study the following table and then match your own occupation during various periods of your life with the table by checking appropriate boxes below:

*The complete questionnaire included four pages. The two pages dealing with the physical activity pattern are presented here. These two pages were prepared by Lindholm, Lundgren, and Saltin in collaboration with the National Institute of Public Health, Stockholm, Sweden.

Occupational Activity

Group I	Group II	Group III	Group IV
Predominantly sedentary, sitting: desk worker, watch maker, sitting assembly-line worker (light goods)	*Sitting or standing, some walking:* cashier, general office worker, light tool and machinery worker, foreman	*Walking, some handling of material:* mailman, waiter, construction worker, heavy tool and machinery worker	*Heavy manual work:* lumberjack, dock worker, stone mason, farm worker, ditch digger

	Occupation corresponded most closely to group:				Worked mostly:		
Age	I	II	III	IV	Outdoors	Indoors	Both
20-30							
30-40							
40-50							
50-60							
Over 60							

The following section deals with your spare-time physical activity. The table outlines four different levels. Please read the table carefully and then check appropriate boxes below:

Spare-Time Physical Activity

Group I	Group II	Group III	Group IV
Almost completely inactive: reading, TV watching, movies, etc.	*Some physical activity during at least 4 hours per week:* riding a bicycle or walking to work, walking or skiing with the family, gardening.	*Regular activity:* such as heavy gardening, running, calisthenics, tennis, etc.	*Regular hard physical training for competition* in running events, soccer, racing, European handball, etc. Several times per week.

	Activity during at least 7 months per year corresponding to group:				Activity during 2 to 6 months corresponding to group:			
Age	I	II	III	IV	I	II	III	IV
20-30								
30-40								
40-50								
50-60								
Over 60								

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