Fifty years of training and competition in the marathon: Wally Hayward, age 70 — a physiological profile


Summary

A 70-year-old South African long-distance runner, holder of his age group's marathon record and former Olympic marathon runner, was studied to determine the effects of 52 years of regular training on functional capacity and health. Maximal treadmill exercise testing revealed no ischaemic ECG abnormalities and an excellent functional capacity (58,6 ml/kg/min). Submaximal testing showed that the subject ran at approximately 86% of maximum aerobic capacity when completing the marathon in his record time. The subject was very lean (13.6% fat) for his age. Muscles contained 82% slow-twitch fibres. Pulmonary function and blood chemical values were within normal limits. Although total cholesterol was somewhat high (247 mg/dl), high-density lipoprotein cholesterol was elevated (53 mg/dl). Twenty-four-hour Holter monitoring revealed no significant ventricular ectopic activity although frequent premature atrial contractions were noted. M-mode echocardiography revealed a normal heart with moderately hypertrophied left ventricular wall thickness. Radionuclide cineangiography showed a normal ejection fraction at rest (69%), followed by a slight drop at maximal exercise (52%). Left ventricular regional wall motion was considered normal at both rest and exercise. He had no significant orthopaedic abnormalities but showed normal flexibility and well-balanced muscular strength. Thickened heel pads were also noted. These results appear to indicate a beneficial effect of habitual physical activity upon the retention of functional capacity with ageing.


Recently there has been considerable interest in the effects of extended years of training on the active athlete and the ageing process. Other studies have described physiological and anatomical characteristics of older athletes, but only a few were conducted on athletes in their eighth decade of life. These studies have not included a comprehensive profile of cardiovascular function and other physiological and anatomical characteristics, nor is such information available on a marathon (42 km) to ultra-marathon (up to 160 km) runner who has been in training and competition for over 50 years. During this time span, the subject has been considered world class for his age group.

The purpose of this investigation was to document the physiological and anatomical variables that describe this unique champion athlete, who is now in his 8th decade of life.

The subject

The subject, Wally Hayward of Johannesburg, was 70 years of age at the time these tests were conducted, and was visiting the USA in order to compete in Chicago, Illinois, at the Mayor Daley Marathon (42 km). He was tested during 18-20 October 1978, 1 week before this event. A few months earlier, he had established a world marathon record (3:06:24) for his age group. Since his record run was performed on a hilly course in Johannesburg at an altitude of 1 750 m, it was thought that he was capable of breaking 3:00:00 in the marathon.

The subject has an impressive list of athletic achievements (Table I). He took 10th position in the marathon at the Helsinki Olympic Games (1952), and is a five-time winner of the South African Comrades Marathon (86,4 km; 54 miles). His philosophy regarding training is interesting: once a week he performs a training run in excess of the distance he will race in order to develop confidence. His training for the Comrades race consisted of 5 days of 16-24 km (10-15 miles), 1 day of a gruelling 112 km (70 miles), and 1 day of rest. When training for a marathon, he still follows a similar routine and runs 48 km (30 miles) 1 day per week.

The subject has been an active competitor since 1926 and has trained regularly since that time. During a span of 12 years (1954-1966) competition was eliminated and his training reduced to one or two sessions per week because he had been declared a professional. In 1966 he

<table>
<thead>
<tr>
<th>TABLE I. DISTANCE RUNNING ACHIEVEMENTS FOR WALLY HAYWARD, 1931 - 1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current world marathon age group record — time: 3:06:24, 1979, Johannesburg, South Africa</td>
</tr>
<tr>
<td>Olympic Games Marathon (10th place finish) — time: 2:31:50, 1952, Helsinki, Finland</td>
</tr>
<tr>
<td>Comrades Marathon (86.4 km, 54 miles), South Africa, Winner 1931, 1950, 1951, 1953, and 1954 — best time: 5:53</td>
</tr>
<tr>
<td>160 km (100 miles), Brighton-to-London run, world record, 1953 — Time: 12:17</td>
</tr>
<tr>
<td>24-h run, London, England — distance covered 255.3 km (159 miles, 562 yds); World record, 1953</td>
</tr>
</tbody>
</table>

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was reinstated as an amateur and resumed his heavy training and competition.

Methods
The testing was completed over a 2-day period. The subject reported to the laboratory on the first morning after a 12-hour fast. After 15 minutes of quiet sitting, resting heart rate and blood pressure were determined. Blood was then drawn from a medial antecubital vein and standard blood chemical values, a cell count, and a lipid profile were analysed.

Anthropometric variables included standing height, body weight, skinfold fat and circumference measures. Skinfold fat was determined on the right side with a Lange caliper in accordance with the procedures of Behnke and Wilmore. Body density (BD) was determined in a hydrostatic weighing tank in which a chair seat was attached to a 15-kg Chatillion scale. The technique for determining BD followed the method outlined by Goldman and Buskirk, and the calculation of BD from the formula of Brozek et al. The percentage of fat was calculated according to the formula of Siri. Spriometric values were determined with a rolling seal spirometer (Ohio Medical, Model 2300) according to the procedures outlined by Kory et al. Residual volume was determined with a nitrogen analyser by the nitrogen washout technique described by Wilmore.

Blood pressure and a standard 12-lead ECG were taken in the supine, sitting, and standing positions. Then aerobic capacity (maximum oxygen uptake) was determined using a standard Bruce protocol. The test was terminated when the subject indicated he was fatigued. ECG and heart rate were monitored continuously during all tests on a Hewlett-Packard 3-channel ECG recording system (Model 1517A) and cardiodynamometer (Quinton Instruments, Model 611). Leads II, aVF, and V5 were monitored during exercise and recovery, and the standard 12 leads recorded every minute during exercise, during the last 30 seconds of the test, immediately after test termination, and at 1, 3, and 5 minutes of the recovery period. The immediate post-exercise data were completed in the standing position and the remainder of the recovery period was completed in the sitting position. Blood pressure was determined by auscultation with the pressure cuff attached to the left arm, at rest, every 3 minutes during exercise, immediately after the test, and at 1 and 5 minutes of recovery.

Expired air samples were collected continuously into an automated gas analysis system; actual readouts of expired O2 and CO2 and inspired pulmonary ventilation (VE) were recorded every 30 seconds. The test O2 and CO2 content were analysed by Beckman OM-II polarographic O2 and LB-2 infra-red CO2 gas analysers. Calibaration gases and analysers were checked by a modified Lloyd Haldane gas analyser. VE was determined by means of a Parkinson-Cowan gas meter (Model CD-4) and calibarated by a Collins 120 L tissot gasometer. The smallest inside diameter of the system was 3.18 cm. The metabolic technique and procedures outlined by Consolazio et al. were followed.

For determination of blood lactic acid, approximately 3 ml of blood was drawn from a medial antecubital vein at 3-4 minutes of the recovery phase. The enzymatic method described by Henry et al. was used in the analysis of lactic acid. After a short rest period, the subject was connected to an ECG Holter monitor (Avionics, Model 445) for 20 hours, and the data were analysed on an Avionics Dynamic Electrocardioscanner (Model 660A).

The second day of testing included further non-invasive assessment of cardiac function. Data from M-mode echocardiography (Irex, Model 101) were determined at rest while the subject was in the supine position. Measurements were obtained in accordance with the recommendations of Sahn et al. Next, left ventricular ejection fraction and regional wall motion were assessed at rest and during upright bicycle ergometry by first-pass nuclear angiography. Studies were performed using a computerized multiple-crystal gamma-scintillation camera (Cor-dis-Baird System 77).

The subject was studied in the 30° right anterior oblique view while sitting on a magnetically braked bicycle ergometer (W. E. Collins). The bicycle protocol used was a continuous multistage test to volitional fatigue. The test started at 25 watts and increased at 25-watt increments every 2 minutes. A constant pedal rate of 60 rpm was used. Studies were performed at rest, 75 watt, and maximum. After potassium perchlorate was given by mouth to block radioactive uptake by the thyroid, 15 mCi technetium pertechnetate (99mTc) was given as a bolus by a medial antecubital vein. Counts were collected at a 30-millisecond framing rate for 25 seconds. After flagging the chambers of the heart, a specific region of interest (i.e. the left ventricle) was flagged and analysed. A histogram was then developed of the left ventricular activity (counts plotted against time). There were 25 000 total counts per second over the left ventricle. Background was then subtracted temporally and spatially to give a corrected left ventricular time-activity curve. By summing the peaks (end-diastole) and valleys (end-systole) of the curve, a representative cycle was developed and the ejection fraction (EF) calculated in the standard manner.

Using this representative cycle, end-diastolic and end-systolic images were generated. The distance between the end-diastolic perimeter and the border of end-systolic image in the right anterior oblique projection determined the estimate of the wall motion.

A muscle sample (25–30 mg) was obtained from the lateral head of the gastrocnemius using the percutaneous needle biopsy procedure of Bergstrom. The muscle sample was mounted in OCT (Ames Co.) and frozen in isopentane cooled to the temperature of liquid nitrogen. This specimen was then stored at ~80°C for subsequent histochemical analysis. When analysed, the sample was sectioned in a cryostat (10 µm thick) at ~20°C and incubated for myosin ATPase. Fibre classification was determined according to Dubowitz and Brooke.

Orthopaedic status was assessed by physical examination of the lower extremities, with particular attention to flexibility, joint stability, and relative strength. A series of anteroposterior and lateral radiographs of the feet, legs and hips was also obtained.

After adequate rest (approximately 7 hours), the subject was brought back to the laboratory for a series of submaximal steady-state runs on the treadmill. This test evaluated the approximate metabolic level at which he ran his 3:06:24 marathon, 13.6 km/h (8.5 mph). The submaximal test consisted of a series of 10-minute runs at 11.2 km/h (7.0 mph), 12.8 km/h (8.0 mph), 13.6 km/h (8.5 mph), 14.4 km/h (9.0 mph), and 14.8 km/h (9.25 mph).

Results and discussion
The results from this investigation are presented in Table II. A comparison of selected variables with other athletes and sedentary normals of similar age is presented in Table III. Table III also includes comparable data obtained from young elite distance runners. The subject was shorter than average but not out of the range of normal or the range of heights found for some elite distance runners. His body fat percentage of
The determination, noted.. Vo,max was 74,1 kg% 87 not.

These findings are in and the sedentary population in their eighth kg.

This estimate is almost certainly conservative weight* Elite young runners *a/. 10 for both sedentary and active populations when change significant at 75 watts of exercise weight* Vo,mox. Ill,"

... Hydrostatic weighing. the sum of chest, abdominal and thigh

with age when surveying Vo,max with age, because no earlier laboratory tests are available. If we can assume that Hayward had a VOmax of 74,1 ml/kg/min, as was found for the 27,4-year-old elite marathon runners (not shown in Table III), then that would represent a 0,41 ml/kg/min per year decrease in VOmax from age 27 to age 70. This is a lower decrement than that found by Hodgson and Buskirk, who showed a decrement of 0,45 in VOmax with age when surveying the literature of cross-sectional studies of men aged 20 - 60 years. This same survey showed a similar rate of decline in VOmax for both sedentary and active populations when compared cross-sectionally, but also showed that the slope may be steeper for sedentary groups when studied longitudinally. Thus, although it appears that the years of training and competition may have decreased the subject's rate of decline in VOmax, until more longitudinal data become available, the answer to this question is speculative.

Of interest was the subject's VO of 48,9 ml/kg/min at his 3:06:24 record marathon pace (13,6 km/h). This showed that Hayward ran his record marathon at approximately 86% of VOmax. These findings are in agreement with the results found on other elite marathon runners. This estimate is almost certainly conservative since allowance was not made for either the reduction in VOmax attributable to the moderate altitude of Johannesburg or to the treadmill underestimation of the aerobic demands of running against wind resistance.

Hayward's resting ECG was found to be normal except for occasional atrial premature contractions. With maximal exercise, the atrial premature contractions continued, but no other irritability was noted. ST-segment evaluation during exercise was difficult due to movement artefact, but during the later part of exercise and the immediate post-exercise tracings (good tracing), some J-point depression was found. No other changes were noted. These findings have been reported elsewhere with young as well as older endurance runners and are not considered significant in relation to cardiovascular disease.

Twenty-hour Holter monitor results indicated a normal sinus rhythm with a PR interval of 0,16 second and QRS duration of 0,06 second. His sleeping heart rate was 43 beats/min. There were rare multiform premature ventricular contractions which appeared an average of three times per hour and frequent premature atrial contractions. It was concluded that these were not significant arrhythmias.

Results from rest and exercise radionuclide studies showed an ejection fraction (EF) at rest of 69% which did not change significantly at 75 watts of exercise (70%); however, at a maximal workload of 200 watts, it decreased slightly to 62%. Since the standard error of measure for this technique in our hands is ± 6%, this was considered significant. Regional left ventricular wall motion remained normal in all three studies. Previous reports have indicated

TABLE II. PHYSIOLOGICAL MEASURES: WALLY HAYWARD

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Value</th>
</tr>
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<tr>
<td>Age yrs</td>
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<td>70</td>
</tr>
<tr>
<td>Height cm</td>
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<tr>
<td>Weight kg</td>
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<tr>
<td>Lean body weight* kg</td>
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<td>58.45</td>
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<td>Fat weight* kg</td>
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<td>9.20</td>
</tr>
<tr>
<td>Relative fat* %</td>
<td></td>
<td>13.6</td>
</tr>
<tr>
<td>Total skinfolds mm</td>
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</tr>
<tr>
<td>Heart rate, rest Beats/min</td>
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<td>52</td>
</tr>
<tr>
<td>Blood pressure, rest</td>
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<tr>
<td>Systolic mmHg</td>
<td></td>
<td>108</td>
</tr>
<tr>
<td>Diastolic mmHg</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>VO\textsubscript{m} max l/min</td>
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<td>3.84</td>
</tr>
<tr>
<td>VE\textsubscript{m} max (BTPS)</td>
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<td>125.2</td>
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<tr>
<td>Heart max Beats/min</td>
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<td>165</td>
</tr>
<tr>
<td>R</td>
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</tr>
<tr>
<td>Lactate max mg/dl</td>
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</tr>
<tr>
<td>Blood pressure max</td>
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<td></td>
</tr>
<tr>
<td>Systolic mmHg</td>
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<td>155</td>
</tr>
<tr>
<td>Diastolic mmHg</td>
<td></td>
<td>65</td>
</tr>
<tr>
<td>Ejection fraction, \textsuperscript{18}Tc</td>
<td>%</td>
<td>69</td>
</tr>
<tr>
<td>Rest</td>
<td>%</td>
<td>70</td>
</tr>
<tr>
<td>Exercise, 75 watt</td>
<td>%</td>
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</tr>
<tr>
<td>Exercise-max, 200 watt</td>
<td>%</td>
<td>82</td>
</tr>
<tr>
<td>Slow twitch skeletal muscle fibres</td>
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<td>82</td>
</tr>
<tr>
<td>Serum cholesterol mg/dl</td>
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<td>247</td>
</tr>
<tr>
<td>Serum triglycerides mg/dl</td>
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<td>44</td>
</tr>
<tr>
<td>High density lipoproteins mg/dl</td>
<td></td>
<td>58.5</td>
</tr>
<tr>
<td>Haemoglobin mg/dl</td>
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<td>14.8</td>
</tr>
<tr>
<td>Haemocrit %</td>
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<td>42.2</td>
</tr>
<tr>
<td>Uric acid mg/dl</td>
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<td>5.4</td>
</tr>
<tr>
<td>Glucose mg/dl</td>
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<td>90.0</td>
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<td>Vital capacity, BTPS l</td>
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</tr>
<tr>
<td>Residual volume, BTPS l</td>
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</tr>
<tr>
<td>Total lung capacity, BTPS l</td>
<td></td>
<td>7.13</td>
</tr>
<tr>
<td>% Vital capacity,\textsuperscript{0.9}</td>
<td>%</td>
<td>73</td>
</tr>
<tr>
<td>% Vital capacity,\textsuperscript{0.9}</td>
<td>%</td>
<td>87</td>
</tr>
<tr>
<td>RV/TLC</td>
<td>%</td>
<td>33.6</td>
</tr>
</tbody>
</table>

* Hydrostatic weighing.  † Anthropometric determination. Jackson and Pollock\textsuperscript{14} equation using the sum of chest, abdominal and thigh skinfolds, and gluteal girth (cm)

13.6% is below average for runners his age and is comparable to that of a champion cyclist. Elite young runners average 4.7% fat. The number of kilometres he trains per week would account for much of the difference between him and runners of comparable age, but does not account for his difference from younger elite runners. Although Hayward is considered quite lean, one might expect his body fat percentage to be similar to that of the younger elite runners. Hayward's anthropometric assessment of percentage fat was 8.1%, which is more in line with what would be expected of a runner of his capability and training load. This same equation for predicting body fat showed the elite runners to be 4.8% fat, while for runner TR and the cyclist (Table III) the values were 12.9% and 10.8% fat respectively. Wilmore et al. noted a similar divergence between the measure of body fat determined by underwater weighing and that determined by anthropometric techniques. The authors agree with Wilmore et al. and question the validity of the underwater weighing technique with older subjects. These equations were developed from cadaver work based on much younger samples. If lean body mass is underestimated owing to a decrease in bone density with age, a higher fat value may result. Nevertheless, the data from Hayward and the other trained endurance athletes showed them to be significantly leaner than the sedentary population in their eighth decade of life. Hayward's resting heart rate and blood pressure were considered lower than average sedentary values, and comparable to elite runners and to 2 of 5 mentioned older athletes (Table III). VO\textsubscript{m}ax and VE\textsubscript{m}ax were considered exceptionally high when compared to those of sedentary men in their eighth decade of life, and, with the exception of the cyclist, significantly higher than those of endurance athletes of similar age (see Table III). It is difficult to estimate whether a lifetime of endurance training has decreased the slope of regression in VO\textsubscript{m}ax with age, because no earlier laboratory tests are available.
that only a rise in EF from rest to exercise can be considered a normal response; however, recent work would seem to contradict these findings as long as the fall in EF was still within the normal range (approximately 55%) and no regional wall motion dysfunction occurred.

Results of maximal exercise were not considered abnor-
mal, because of the subject's high working capacity, the
fact that regional wall motion remained normal during
maximum effort, and his apparent lack of other significant
abnormalities during maximal stress.

Echocardiographic analysis showed a normally func-
tioning heart with mild concentric left ventricular hyper-
trophy. The end-diastolic diameter (EDD) was 5.5 cm
and posterior wall thickness 1.3 cm. Specifically, there
was no left atrial dilatation, but the left ventricular EDD
(and volume) was minimally increased. The end-diastolic
wall thickness was proportionally increased. Mild hyper-
trophy of this nature has been shown to be common in
endurance runners.

Results of all blood studies were considered within the
normal range. Hayward's serum cholesterol level of 245 mg/dl seemed high. Recent popu-
larization norms show this to be higher than average for his
age. However, the subject's higher than average high-
beats/min) compared to other endurance athletes his age (see
data from Pollock et al.29) and generally negative results of musculoskeletal examina-
tion show that 52 years of continuous training and com-
petition have had no significant deleterious effect on his
health and free from clinical signs of coronary heart
disease and had a low risk factor profile for its develop-
mint. Evaluation of skeletal muscle fibre composition showed 82% slow-twitch fibres. This finding is consistent with those in other outstanding endurance runners. No muscle biopsy data were available for the other endurance athletes of similar age.

The subject's musculoskeletal history revealed no com-
plaints of pain, swelling or instability. Further examination showed excellent joint alignment, stability, mobility, and
muscular development. Vascular examination revealed
strong peripheral pulses. Radiographic analysis showed
some degenerative changes with osteophyte formation in
the mid-lumbar, L3-L4 region, but with the total absence
of pain these were not considered to be of clinical sig-
nificance (Fig. 1). Standing knee radiographs showed
excellent joint alignment, stability, mobility, and
anomalous changes with osteophyte formation in the
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Results of all blood studies were considered within the
normal range. Hayward's serum triglyceride level was
considered slightly high, his RV /TLC ratio was found
to be favourable in comparison with normal values for his
age.

Results of pulmonary function studies were normal and
comparable to other endurance athletes his age (see
Table III). Although the subject's residual volume was
considered slightly high, his RV/TLC ratio was found
to be favourable in comparison with normal values for his
age.

That only a rise in EF from rest to exercise can be considered a normal response; however, recent work would seem to contradict these findings as long as the fall in EF was still within the normal range (approximately 55%) and no regional wall motion dysfunction occurred. Results of maximal exercise were not considered abnormal, because of the subject's high working capacity, the fact that regional wall motion remained normal during maximum effort, and his apparent lack of other significant abnormalities during maximal stress.

Echocardiographic analysis showed a normally functioning heart with mild concentric left ventricular hypertrophy. The end-diastolic diameter (EDD) was 5.5 cm and posterior wall thickness 1.3 cm. Specifically, there was no left atrial dilatation, but the left ventricular EDD (and volume) was minimally increased. The end-diastolic wall thickness was proportionally increased. Mild hypertrophy of this nature has been shown to be common in endurance runners.

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The subject's musculoskeletal history revealed no complaints of pain, swelling or instability. Further examination showed excellent joint alignment, stability, mobility, and muscular development. Vascular examination revealed strong peripheral pulses. Radiographic analysis showed some degenerative changes with osteophyte formation in the mid-lumbar, L3-L4 region, but with the total absence of pain these were not considered to be of clinical significance (Fig. 1). Standing knee radiographs showed excellent alignment and no degenerative changes (Fig. 2). Thickened heel pads and a slight sclerosis of the subtalar joint were noted. The relative lack of degenerative changes in the hip, knee, ankle, and foot joints were remarkable considering the subject's age and long-term involvement in long distance running. This would support the fact that stable, well-aligned joints do not degenerate with years of competitive running.

In summary, the subject was found to be in excellent health and free from clinical signs of coronary heart disease and had a low risk factor profile for its development. His VO2max of 56.8 ml/kg/min is one of the highest on record for a person 70 years old. The subject, in physical fitness and performance capacity, was superior to other endurance runners of similar age, which is partially attributable to his volume of training. Lack of symptoms and generally negative results of musculoskeletal examination show that 52 years of continuous training and competition have had no significant deleterious effect on his musculoskeletal system. Although the data suggested a

### Table III. Comparison of Wally Hayward with Other Athletes and Untrained Men of Similar Age and Elite Young Runners

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hayward</th>
<th>Other runners (Wilmore et al.)</th>
<th>Webb</th>
<th>Cyclists (Faria)</th>
<th>Elite</th>
<th>Normal sedentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>26</td>
<td>70-79</td>
<td></td>
</tr>
<tr>
<td>Ht, cm</td>
<td>179</td>
<td>179</td>
<td>177</td>
<td>177</td>
<td>172±2</td>
<td></td>
</tr>
<tr>
<td>Wt, kg</td>
<td>75</td>
<td>68,6</td>
<td>79,0</td>
<td>63,1</td>
<td>73±2</td>
<td></td>
</tr>
<tr>
<td>RFI (%)</td>
<td>23,2</td>
<td>17,6</td>
<td>17,6</td>
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<td>17,6</td>
<td></td>
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<tr>
<td>RH (%)</td>
<td>1</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td></td>
</tr>
<tr>
<td>RHR (%)</td>
<td>157</td>
<td>56,8</td>
<td>56,8</td>
<td>56,8</td>
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<td></td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>161</td>
<td>161</td>
<td>161</td>
<td>161</td>
<td>161</td>
<td></td>
</tr>
<tr>
<td>Triglycerides (mg/dl)</td>
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<td>124</td>
<td>124</td>
<td>124</td>
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<td></td>
</tr>
<tr>
<td>HDL (mg/dl)</td>
<td>32,1</td>
<td>32,1</td>
<td>32,1</td>
<td>32,1</td>
<td>32,1</td>
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<tr>
<td>LDL (mg/dl)</td>
<td>44</td>
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<td>44</td>
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<tr>
<td>V02max (ml/kg/min)</td>
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<td>156</td>
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<tr>
<td>V02max (ml/kg/min)</td>
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<td>156</td>
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<td>Pleural pressure (mmHg)</td>
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<td>Ht, cm</td>
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<td>Wt, kg</td>
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<td>68,6</td>
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<td>Triglycerides (mg/dl)</td>
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<td>V02max (ml/kg/min)</td>
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<td>Pleural pressure (mmHg)</td>
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reduction in the rate of decline in VO2max with age, no final conclusion as to the effect of 52 years of strenuous physical activity on the ageing process can be drawn.

The authors wish to thank the subject, Wally Hayward, for his co-operation and friendship during his visit to our laboratory.

REFERENCES