

PHYSICAL FITNESS OF YOUNG SOUTH AFRICANS

by

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"It is a commonplace nowadays to observe that fitness can have no meaning except in relation to a specific task. The fitness required by the foundry worker differs from that of the ballet dancer or the long-distance runner. Yet the idea of a general condition of fitness which will be reflected in performance of any task involving strenuous physical work has always been accepted by active people. It may be of secondary importance to the highly specialized performer whose existence is organized for maximum efficiency at one type of activity, but it is essential to the man who wishes to give a good account of himself in varied and unforeseen circumstances and to enjoy a wide variety of active pursuits."

Morgan, R.E. and Adamson, G.T.
(1961) Circuit Training, 2nd ed.
London: G. Bell & Sons. p.13

"Pulse rate does not represent a complete test of circulatory-respiratory fitness but the pulse is the easiest to measure and is the most reliable of the physiological variables which reflect the internal bodily efficiency in response to exercise."

Cureton, T.K. (1947) Physical
Fitness Appraisal and Guidance.
St. Louis, C.V. Mosby Company.
p.162

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PREFACE

This thesis is a record of the tests of physical fitness which I have carried out during the last eight years on university and other college students and during the last four years on high school children. The early work has already been published; reprints of these papers are included as an appendix.

The title, 'Physical Fitness of Young South Africans', has been selected to convey the best general impression of the subject matter but the scope of the thesis is in some respects narrower, and in others broader, than the title suggests. The investigation has been restricted to adolescents and young adults (aged 12-27 years). The South Africans tested were at high schools or colleges in or near Cape Town and are representative of the main racial groups in the southern part of the Western Cape Province. I took the opportunity to compare their performance of the fitness tests with the performance of the same tests by children and young adults in the United States of America and in Great Britain.

In the first sets of tests on adults, (Chapters 6 and 7) I worked in collaboration with Dr. E.N. Keen, who performed the anthropometric measurements. Dr. E.N. Keen, who was at the time Senior Lecturer in Anatomy at the

University of Cape Town, is now Professor of Anatomy at the University of Natal. I personally conducted these and subsequent fitness tests on young adults.

The tests on high school children (Chapters 11 and 12) were carried out under my general supervision by the physical education staff of the schools concerned. I instructed staff and pupils in the performance and scoring of the tests and personally supervised many of the tests at each school in order to achieve uniformity.

For the statistical analyses involved in these investigations I have been guided by members of the Department of Mathematics of the University of Cape Town and have been assisted by my secretary, Mrs. C. Meyer. The principal methods used were the 't' test and the correlation coefficient, 'r' (Fisher, 1946). For the analysis of the athletic tests on high school children an I.C.T. computer (Model 1301) was employed.

Because the concept of physical fitness is capable of a variety of interpretations, an attempt is made to define criteria of physical fitness. Tests of various aspects of physical fitness are described and their relative merits assessed. The Harvard step test, which I have used for most of the investigations on young adults, is discussed at length. The other tests which I have employed are the 7 tests of athletic fitness recommended by the American Association for Health,

Physical Education, and Recreation (AAHPER), two of which I modified for the later investigations.

The Harvard step test was applied to young men to ascertain the influence of selected anthropometric parameters on physical fitness as determined by this test. The influence of physical training was studied by comparing physical education students with other students, and athletes were tested before and after training. A modified AAHPER test battery was used in one investigation to assess other aspects of fitness and the results of these tests were compared with those of the Harvard step test.

A modified Harvard step test was developed for young women, such that the results would be comparable to those of young men on the original test. Employing this modified test, the influence of anthropometric parameters was studied and the physical fitness of athletic and non-athletic groups of women students was compared. The effect of physical training was assessed also by testing women students of physical education and other women students at the beginning, middle, and end of the academic year. Some performed also a modified AAHPER test battery for comparison of the results with those of the Harvard step test.

A year of study leave spent in the United States of America and in England enabled me to carry out a comparative study of physical fitness on men and women students in these countries and in South Africa.

The AAHPER test battery was used also to assess the physical fitness of more than 6,000 high school children in and around Cape Town. The schools selected included White, Coloured, and African high schools and represented upper, middle, and lower income groups of the White and Coloured communities. The results of these tests were used for an inter-racial comparison and also for comparison with results of the same tests conducted by other investigators in Great Britain and in the United States of America.

In a further investigation of high school children in Cape Town each child performed a modified Harvard step test as well as the AAHPER tests. White and Coloured children were compared and the results of the Harvard step test were compared with those of the AAHPER test battery.

On the basis of these investigations some general conclusions are drawn on the physical fitness of different groups of young South Africans and on their fitness compared with corresponding groups overseas.

PART I

ASSESSMENT OF PHYSICAL FITNESS

Chapter 1

Significance of physical fitness

The concept of physical fitness

Although the term, 'physical fitness', is in common use, and each of us has a personal interpretation of its significance, the concept is difficult to define. Physical fitness implies not only freedom from disabling deformity or disease but also the capacity to perform our daily tasks without limitations imposed by poor function of any of the systems of the body. Physical educationists would set a higher standard and claim that physical fitness is a state of health in which active exercise can be undertaken efficiently, without undue fatigue, and with a sense of well-being (Abrahams, 1958).

The fitness of the athlete is measured in competitive sport but the physical fitness of a sedentary individual is more difficult to assess as there is no uniform standard. A man who is physically fit to walk a short distance between his home and his place of work, or an even shorter distance between his house and his garage, may not be fit to climb a mountain, run 5 miles across country, or play a game of rugby. In the absence of

disease or deformity the limiting factors are muscular strength and endurance and cardiac and respiratory efficiency. A satisfactory standard of fitness is one at which the individual has sufficient strength, muscular endurance, and cardiorespiratory efficiency to undertake all the activities which are required of him, or in which he wishes to take part, and which are reasonable for his age and occupation. This minimum standard must vary very widely from one individual to another and is difficult to assess unless by the observed deterioration of performance of physical tasks, or by the subjective feeling of discomfort on undertaking them, which usually follows prolonged inactivity.

Requirements for physical fitness

In order to maintain muscle tone and to enable the individual to deal with the sudden demands for physical effort which occur even in a sedentary existence, a degree of physical fitness above the minimum outlined above is desirable. There seems to be no doubt that a certain minimum amount of regular physical activity is essential for the maintenance of a desirable degree of fitness (Kraus & Hirschland, 1954; Feurig, 1964) and also for protection against the diseases associated with a too

sedentary existence (Morris et al., 1953; Leading article, 1955; Brown et al., 1957; Clarke, 1958; Morris & Crawford, 1958; Karvonen, 1959; Raab, 1960, 1962; Davies et al., 1963; Feurig, 1964). Although college athletes do not live longer than other college graduates (Rook, 1954; Montoye et al., 1956; Montoye, 1960; Davies et al., 1963) there is evidence that individuals who continue to be physically active in later life live longer than the more sedentary (Kahn, 1963; Joint Committee, 1964). In urban life supplementary physical activity is usually desirable and should be in a form which the subject enjoys (Abrahams, 1958; Guild, 1963).

An important parameter related to physical fitness is nutritional status (leanness or fatness). This depends on the balance of dietary intake and energy requirements. When more food is absorbed into the body than is eliminated or utilized to produce energy the surplus is stored as fat. When the energy expended is greater than that obtained from the diet the stores of fat are used up and, in severe under-nutrition, other body tissues are used up as well to provide energy. Obesity is usually associated with diminished physical activity rather than with increased intake of food (Thomson et al., 1961; Wenzel et al., 1962; Brožek et al., 1963; Davies

et al., 1963; Drysdale, 1964).

The usual practice of assessing obesity directly from body weight, or from body weight and height, is unsatisfactory since the extra weight of a heavy individual may be due to better development of bone or of muscle (Welham & Behnke, 1942) but it is usually sufficient to give a rough indication of nutritional status. Even allowing for the inaccuracy of assessment of body fat from body weight, some interesting correlations have been observed between body weight and health. Heavy individuals are more liable to develop coronary artery disease, arterial hypertension, or diabetes mellitus (Metropolitan Life, 1937; Meiklejohn, 1959) and their average expectation of life is shorter than that of lighter people (Metropolitan Life, 1937; Newburgh, 1942; Davidson et al., 1959; Brožek, 1961; Lew, 1961; Editorial, 1963). At the other end of the dietary scale, extreme undernourishment not only reduces the supply of energy for physical work (Keys, 1943; Brouha, 1960a; Mayer & Bullen, 1960) but also reduces resistance to disease and hinders recovery (Davidson et al., 1959). A meagre diet is likely to be lacking in animal protein and in vitamins and so may result in any of the diseases due to deficiency of these dietary con-

stituents.

Other factors which may affect physical fitness are the social habits of drinking alcohol and smoking tobacco. Even moderate consumption of alcohol impairs neuromuscular coordination (Goodman & Gilman, 1955; Sollman, 1957) but prior cigarette-smoking does not impair the performance even of strenuous muscular work (Juurup & Muide, 1946; Henry & Fitzhenry, 1950; Reeves & Morehouse, 1950), and habitual smokers have about the same work capacity as non-smokers (Schilp, 1951; Parker, 1954; Hernberg, 1964; Krumholz et al., 1964). Excessive consumption of alcohol often leads to disease of the alimentary and nervous systems (Wortis, 1963) and even moderate smoking of cigarettes significantly increases the liability to lung cancer (Royal College, 1962).

Public health measures promote fitness by reducing the liability to infective diseases. The considerable increase in average life-span in civilized communities during the twentieth century is attributable, at least in part, to the practice of immunizing individuals, and even whole communities, against specific diseases and to other measures taken to prevent the spread of epidemics. Physical exercise does not affect immunological resistance to disease (Jokl, 1964).

Social significance of physical fitness

Not only is physical fitness important to the individual in the avoidance of disease, in the ability to perform physical tasks, and in the creation of a positive sense of well-being, but it is also of fundamental importance to the community in which he lives. Many everyday tasks in agriculture demand a high standard of physical fitness. This is true also of the mining industry, the main source of South Africa's wealth, and of other heavy industries. The use of a machine does not necessarily reduce the physical demands on the worker. Often a machine is designed, not to reduce the effort required for some simple task, but rather to accomplish a much heavier task with the same degree of effort. The operator's physical fitness may still be the limiting factor in the efficient working of the machine.

Few communities can afford to carry a large load of individuals who are unfit for physical work. Nowadays, with a progressively increasing proportion of old people in the population, it is more than ever necessary that young men and women should be fit for active work and should not be an unnecessary burden on medical and nursing services.

Military significance of physical fitness

In war, even more than in peace, the survival of a nation may depend on the physical fitness of its young men and women. Modern war, for all its mechanization, imposes severe physical strain on members of the armed forces. Without modern weapons an army would be ineffective but, if both the opposing forces are equipped with modern weapons, the deciding factor may be the physical endurance of the fighting men. In the United States of America concern has been expressed about the low standard of physical fitness of young men (Erskine, 1940; Cureton, 1943, 1956; Kiphuth, 1956) and women (Amateur Athletic Union, 1955). Nearly half of the young men called up to the United States armed forces during the Korean war were found to be unfit for military service (Kennedy, 1960).

With an increasing proportion of young South African men being called up for military service it becomes increasingly important to achieve satisfactory standards of physical fitness during childhood and to maintain these during young adult life. Provided a reasonable degree of fitness is reached prior to military service, subsequent training can build on this to turn out a physically well-equipped soldier.

Categories of physical fitness

Gallagher and Brouha (1943b, 1944), who carried out much original research on physical fitness tests, considered physical fitness as falling into three categories: static fitness, dynamic fitness, and motor skills fitness. Static or medical fitness is the absence of disabling deformity or disease, dynamic or functional fitness is the ability to perform strenuous physical work, and motor skills fitness is the ability to perform particular co-ordinated movements. It is useful to be able to assess the standard of fitness in each of these categories and to know how to maintain and, if necessary, improve each type of fitness.

Static fitness is assessed by routine medical examination; if no evidence of disease or deformity is found the individual is considered to be medically fit. There are, of course, degrees of fitness in this category as in any other and our concept of what constitutes health is quite arbitrary. Some of the factors involved in static fitness have been considered above.

Dynamic fitness, the capacity for strenuous physical exertion, is the principal theme of this thesis. Assuming that an individual is medically fit, the limiting factor in dynamic fitness is the ability of the heart and

lungs to supply the active muscles with oxygen. Details of some tests of dynamic fitness are given in Chapters 2 and 3.

Motor skills fitness depends on the co-ordination of groups of muscles to perform purposive movements. This is achieved by the nervous system and improves with practice (Gray, 1962). The development of motor skill usually permits a given task to be performed with less effort by reducing unnecessary movements and so contributes to dynamic fitness. Motor skills are assessed in competitive athletics as well as by special tests and are important in all activities which depend on a high degree of muscular co-ordination.

Although the object of the investigations reported here has been to assess physical, not mental fitness it would be unrealistic to ignore the influence of mental state on physical performance. The completion of any exhausting test depends on the will to complete it in spite of progressively increasing discomfort, but the circulatory and respiratory adaptations to severe exercise depend on the work output and on physical fitness and are little influenced by the mental state (Åstrand et al., 1960).

Other aspects of physical fitness are dealt with in Chapters 4 and 5. Apart from endurance, which corresponds closely to dynamic fitness, speed, strength, power, flexibility, agility, balance, and co-ordination can all be assessed by appropriate tests. An estimate of athletic fitness can be obtained by the use of a battery of appropriate tests, and an index of athletic fitness by combining appropriately the results of the various tests.

The results of such tests and test batteries are useful not only in comparing the physical fitness of individuals and of groups of people and in establishing norms but also in following the effects of particular regimes on particular aspects of physical fitness.

Summary

Physical fitness implies the capacity to perform one's daily tasks without limitations imposed by poor function of any of the systems of the body and with some reserve to deal with unforeseen demands for physical exertion. It is not only of personal but also of national importance.

The maintenance of physical fitness requires regular physical activity, which confers some protection also against degenerative diseases and may prolong life. Prolonged inactivity is often associated with obesity

and with some of the many complications of that condition.

It is convenient to consider physical fitness as falling into three categories: static, dynamic, and motor skills fitness. Static fitness is determined by medical examination. Dynamic, motor skills, and other aspects of fitness are assessed by appropriate tests.

Chapter 2

Tests of dynamic fitness

Principles

Tests of dynamic fitness are based on the hypothesis that a distinction can be made between the fundamental physiological adaptations common to fitness for all types of exertion and the special skills necessary for the successful performance of particular physical tasks (Johnson, 1946).

The exertion must be strenuous to distinguish the fit from the less fit; it should employ large muscle groups, so that the limiting factor is not local fatigue of the muscles involved in the exercise, and it should be uncomplicated so that the element of motor skills fitness is minimal. It is convenient if the test can be performed in the laboratory.

If the test is severe and continued to exhaustion the duration of performance is itself a measure of dynamic fitness, but a more sensitive index is the degree of physiological response to submaximal exercise. Since the limiting factor is usually the capacity of the circulatory and respiratory systems to supply the active muscles with

oxygen some measure of the changes induced in these systems by exercise is adopted. Circulatory efficiency may be estimated from the changes in heart rate or arterial blood pressure induced by some standard exercise or by the time taken for these parameters to return to normal after the exercise. The respiratory rate may be counted or the pulmonary ventilation, the rate of oxygen absorption, or the oxygen debt may be estimated. As a measure of the efficiency of oxygen absorption, transport, and utilization the concentration of lactic acid in the blood may be determined. Less direct evidence of physical fitness may be sought from the renal excretion of metabolites during active exercise, which shows less change in physically fit individuals than in others (Parke Davis, 1958).

Circulatory and respiratory changes will be less for any particular task in the fit than in the unfit, partly because of more efficient use of muscles so that less oxygen is required for a given task and partly because of greater efficiency of circulatory and respiratory systems so that the additional oxygen required for strenuous exertion is supplied with less disturbance of the normal resting state. By this more efficient action a greater

maximum performance can be achieved.

Increased cardiac efficiency is associated with increased stroke volume and more complete emptying of the ventricles. Since each cardiac contraction is more efficient the required increase in minute volume is achieved with fewer heart beats and less expenditure of energy. The maximum minute volume which can be achieved is correspondingly increased. The greater respiratory efficiency which results from physical training is associated with greater depth of respiration so that more air is taken in with each respiration and a greater proportion of it reached the respiratory part of the lungs. This permits an increased oxygen intake when the venous oxygen tension is reduced during exercise.

Exercises used in tests of dynamic fitness

The exercises used in these tests are those which have been widely employed in investigations of work physiology for many years. The most popular are level walking on a treadmill, walking up an inclined treadmill, pedalling a bicycle ergometer and stepping on and off a bench. With appropriate modifications these exercises are suitable for both sexes and for all age groups. Measurements of circulatory or respiratory function, or both, are made either during or after exercise.

Other forms of exercise, unsuitable for laboratory studies, but more closely related to everyday situations have been used for tests of dynamic fitness. These include running (Boas, 1931; Cluver et al., 1942; Cureton et al., 1945a; Skubic & Hilgendorf, 1964), skiing (Christensen & Högberg, 1950), swimming (Faulkner et al., 1963), mountain climbing (Durnin, 1955), lifting and lowering a heavy box (Edholm et al., 1962), and loading, pushing and emptying trucks of coal (Wyndham, 1963).

Tests based on circulatory function

Most of the tests based on circulatory function depend on the changes which take place in the pulse rate and arterial blood pressure during strenuous exercise or on the time taken for these measurements to return to the resting level after a standard exercise.

The maximum pulse rate reached during strenuous exertion is usually between 180 and 190 beats per minute in young men (Gillespie et al., 1925; Koff et al., 1963; Åstrand et al., 1964) and about 10 beats per minute higher in young women (Åstrand & Ryhming, 1954; Åstrand, 1956, Åstrand et al., 1964). Maximum heart rates over 200 have been recorded in schoolboys (Boas, 1931; Christensen & Högberg, 1950; Knuttgen & Steendahl, 1963; Kramer &

Lurie, 1964) and in schoolgirls (Christensen & Högberg, 1950; Kramer & Lurie, 1964; Skubic & Hilgendorf, 1964). The maximum pulse rate does not depend on the nature of the exercise (Åstrand & Saltin, 1961b) or on the physical fitness of the subject (Maritz et al., 1961; Kramer & Lurie, 1964), but the physically fit individual performs more work to attain this maximum and his pulse rate returns more rapidly to the resting level after the exercise (Milic-Emili, 1959; Brouha, 1960b). Although systematic physical training lowers the resting pulse rate (Hunt & Pembrey, 1921; Hambly et al., 1922; McKensie, 1942; Cullumbine, 1949a; Henry, 1954; Fletcher, 1958a; Karvonen, 1958; Brouha, 1960), a low resting pulse rate is not in itself a reliable indication of physical fitness (Brouha & Heath, 1943; Sloan & Keen, 1959b; Maneke, 1964).

Hunt and Pembrey (1921) and Hambly et al. (1922) assessed physical fitness in terms of the pulse ratio (PR) as follows:

$$PR = \frac{\text{pulse beats for 2 min. after exercise}}{\text{pulse beats for 1 min. before exercise}}$$

The physical fitness of an unfit subject was assessed from the fraction of a standard exercise which gave the same pulse ratio as that of a fit individual performing

the whole standard exercise.

Tuttle (1931a, b) used a stool 13 inches high for the test and found the number of steps on to and off the stool which must be performed in 1 minute to give a PR of 2.5. In practice the subject was tested at 18 and at 40 steps a minute; the rate which would give a PR of 2.5 was then estimated by interpolation and could be checked by repeating the test at the estimated speed of stepping. Taking 50 steps per minute as 100% the result could be expressed in terms of per cent efficiency. Tuttle and Dickinson (1938) simplified the test but Henry and Farmer (1938) found that it had such a low coefficient of reliability that it could not satisfactorily predict individual scores on retesting. Flanagan (1935) calculated an 'endurance ratio' from the pulse ratios at 18 and 45 steps per minute and considered it a reliable criterion of endurance.

To calculate the 'progressive pulse ratio', Cureton (1951b) counted the resting pulse and the pulse after stepping on to a 17-inch stool 12, 18, 24, 30, and 36 times in one minute; for each rate of stepping the pulse count for the period 10-130 seconds after the exercise divided by the 1-minute resting count gave the progressive pulse ratio.

Johnson et al. (1942), using a motor-driven treadmill, evolved an index of physical fitness from three pulse rates after a standard exercise. The subject ran uphill at 7 m.p.h. on a gradient of 8.6% for as long as he could up to a maximum of 5 minutes. Thereafter his pulse was counted from 1 to 1½, 2 to 2½, and 4 to 4½ minutes after stopping the exercise. The fitness index (FI) was derived from the duration of exercise and the pulse rates thereafter:

$$FI = \frac{\text{duration of exercise (sec.)} \times 100}{2 \times \text{sum of the 3 half-min. pulse counts}}$$

On an arbitrary scale a FI below 41 was considered poor, 41 to 75 average, and above 75 good. Balke (1952) devised a test in which the subject walked on a treadmill at 3.4 m.p.h., the gradient being increased each minute until the pulse rate reached 180 per minute; the degree of fitness was indicated by the duration of the exercise or by the corresponding gradient. This test or a modification of it has been employed by Billings et al. (1960), Naughton et al. (1963), Dempsey (1964), Hollman (1964), Howell et al. (1964) and Rasch and Wilson (1964).

For field work or when a treadmill is not available the 'Harvard pack test' may be substituted (Consolazio et al., (1951). In this test the work comprises stepping on and

off a platform 16 inches high 30 times a minute for as long as possible up to 5 minutes, carrying a haversack loaded to approximately one third of the body weight; a handrail is provided at a convenient height for the subject to grasp. The fitness index is derived as for the treadmill test and the results of the two tests show close agreement. Ladell and Kenney (1955) modified the test by using different heights of platform and different rates of stepping. Patterson et al. (1964) used a 20-inch step for the pack test and exercised their subjects to exhaustion.

The same fitness index was derived by Gallagher and Brouha (1943c) from the response to work on a bicycle ergometer, which the subject pedalled at 20 m.p.h. against a friction load of 5 lb. for as long as possible up to a maximum period of 5 minutes. Similar tests were employed by Clarke (1943), Maxfield and Brouha (1963), and Sexton (1963).

The simplest and most popular of the tests of circulatory efficiency is the Harvard step test (Brouha et al., 1943). This test and the various modifications of it which have been employed are described in Chapter 3. Elbel et al. (1958) found a significant correlation between the pulse ratios of the Tuttle test and the fitness

indices of the Harvard step test for the same group of subjects.

Sj6strand (1947) assessed dynamic fitness from the rate of work which could be maintained on a bicycle ergometer with a constant pulse rate during the exercise and a return to near the resting pulse rate within 10 minutes after stopping the exercise. Adams et al. (1961a, b), testing children on a bicycle ergometer, expressed the working capacity as the load which corresponded to a steady pulse rate of 170 per minute. Milic-Emili (1959) measured the time taken for the pulse rate to return half-way to the resting level after walking to exhaustion at 5.5 km./hr. on a treadmill with an upward gradient of 20%.

The Schneider index (Schneider, 1920; Schneider & Truesdell, 1922) is derived from the changes that take place in pulse rate and systolic blood pressure on changing from the recumbent to the erect posture and after stepping on to a bench 18 inches high 5 times in 15 seconds. Abrahams (1928) found that changes in heart rate and blood pressure on standing up are not a satisfactory index of physical efficiency. Master and Oppenheimer (1929) found for each of their subjects the maximum rate of stepping up and down 2 steps each 9 inches high for $1\frac{1}{2}$ minutes

which permitted the pulse rate and systolic blood pressure to return to the resting levels 2 minutes after completion of the exercise. Other workers (Brouha & Heath, 1943; Cullumbine, 1949b) found the arterial blood pressure after exercise a less reliable index of physical fitness than the pulse rate. The accuracy of assessment of fitness from the post-exercise pulse rate is diminished rather than increased by including in the calculation another factor, such as the arterial blood pressure, which is less closely related to dynamic fitness.

Tests based on respiratory function

Hartwell and Tweedy (1913) measured pulmonary ventilation at rest and after running up and down a flight of stairs. Wahlund (1948) measured respiratory rate and pulmonary ventilation during work on a bicycle ergometer. Milic-Emili (1959) based an assessment of fitness on the time taken after exercise to exhaustion on a treadmill for the pulmonary ventilation rate to return half-way to the resting level. Durnin (1955) measured ventilation while climbing on different gradients and Pugh (1958) while performing a step test at different altitudes. Henry and Berg (1950) measured oxygen debt and carbon dioxide production during and after exercise. The very numerous

investigators who have estimated oxygen consumption during work as a measure of physical fitness include Taylor (1944), Wahlund (1948), Bruce et al. (1951), Durnin (1955), Pugh (1958), Wyndham et al. (1959), Åstrand et al. (1960a,b) Durnin et al. (1960), Åstrand and Saltin (1961a,b), Maritz et al. (1961), Williams et al. (1962), and Grimby and Söderholm (1962). The maximum oxygen intake of which the subject is capable may be taken as a measure of his work capacity (Simonson & Enser, 1942; Taylor et al., 1955; Mitchell et al., 1958; Balke, 1963; Luft et al., 1963; Newton, 1963; Kramer & Lurie, 1964). The maximum oxygen intake is probably the best single measurement for estimating physical fitness (Linde, 1963) but is difficult to measure under field conditions; it may however be calculated from the heart rate and oxygen consumption (Åstrand & Ryhming, 1954; Wyndham et al., 1959; Andersen et al., 1960; Maritz et al., 1961; Seaward et al., 1964) or from the heart rate (Åstrand & Ryhming, 1954; Hettinger et al., 1961; Borg & Dahlström, 1962; Maggio et al., 1963; Wyndham et al., 1963), during exercise. Prediction of the maximum oxygen intake from the pulse rate during exercise can lead to serious under-estimation, especially in sedentary subjects (Rowell et al., 1964).

Malhotra et al. (1963) found a linear correlation between pulse rate and rate of energy expenditure for each of their subjects but the slope of the regression line was different for each; the range of error between measured and predicted values of oxygen consumption was 0.6 - 7.0%. In the investigation reported by Tabakin et al. (1964) both the heart rate and the oxygen intake varied with the work load but the relationship between them was seldom strictly linear.

In general the degree of dynamic fitness is assumed to be inversely proportional to the increase in ventilation and in oxygen intake induced by a standard exercise and directly proportional to the maximum oxygen intake.

Other respiratory measurements which have been related to dynamic fitness include the vital capacity (Cullumbine & Williams, 1949; Elbel et al., 1958; Stuart & Collings, 1959), breath-holding time (Cullumbine & Williams, 1949; Montoye, 1951), expiratory force (Cullumbine & Williams, 1949), and maximum breathing capacity (Harris, 1958; Stuart & Collings, 1959).

Tests based on circulatory and respiratory function

In most of the investigations of respiratory function noted above, the heart rate also was recorded and was

found to vary with the ventilation and with the rate of oxygen consumption. Bruce et al. (1949, 1951) devised a physical fitness index (PFI) from the respiratory and circulatory responses to walking at 1.73 m.p.h. on a treadmill tilted to 10% upgrade for as long as possible up to a maximum of 10 minutes.

$$\text{PFI} = \frac{\text{duration of exercise (min.)} \times \text{average respiratory efficiency during exercise} \times 100}{\text{sum of heart beats for 3 min. after exercise}}$$

Respiratory efficiency was expressed as the difference in oxygen concentration between inspired and expired air. Rasch et al. (1959) found a poor correlation between the results of the Bruce test and of the Harvard step test on the same group of healthy young men; they concluded that the Bruce test gives a less satisfactory indication of physical fitness as well as requiring more complex apparatus. Davies and Harris (1964) expressed the pulse deficit as the ratio of mean heart rate during the 5th and 6th minutes of treadmill walking to the mean heart rate during the first 4 minutes. Measuring oxygen intake at increasing work loads, the pulse deficit index (PDI) was the rate of oxygen intake at which the pulse deficit showed a decided upward swing. The PDI had a high correlation with maximum oxygen intake.

Tests depending on estimation of blood lactate

Dill et al. (1930) considered that the concentration of lactate in the blood after a standard exercise is a satisfactory measure of physical efficiency but Lorentzen (1962) found wide individual variations. Bock et al. (1928), Brouha and Heath (1943), Taylor (1944), Åstrand et al. (1960a), and Billings et al. (1960) estimated the concentration of lactate in the blood as well as the respiratory and circulatory changes after a standard exercise. Johnson and Brouha (1942) derived a 'work index' from the duration of running up an inclined treadmill, the maximum pulse rate during the exercise, and the blood lactate concentration immediately after it. Gallagher and Brouha (1943c) found little correlation between blood lactate levels and fitness indices on the bicycle ergometer test, though higher lactate levels tended to accompany lower fitness indices.

Huckabee (1958) observed that under aerobic working conditions the proportion of lactate to pyruvate in the blood remained constant. In hypoxia the lactate/pyruvate ratio increased, the 'excess lactate' being a measure of the degree of hypoxia. Knuttgen (1962), Wyndham et al. (1962), Williams et al. (1962) and Margaria (1964) took excess

lactate as a measure of anaerobic work and related it to maximum oxygen intake and work capacity.

Thomas et al. (1964) found that patients with subnormal cardiac output had higher blood lactate concentrations and higher lactate/pyruvate ratios during moderate exercise than healthy subjects on the same work load. Presumably, for any standard amount of exertion, a high degree of cardiac and respiratory efficiency permits a greater proportion of the work to be performed aerobically, with correspondingly less accumulation of lactic acid in the blood.

Summary

Dynamic fitness, the capacity for strenuous physical exertion, may be assessed from the maximum duration of performance of an exhausting task or from the physiological responses to submaximal exercise.

Most tests of dynamic fitness are based on changes in the circulatory or respiratory systems or both during a standard exercise. Some other tests involve determination of the blood lactate concentration during or after exercise. The physiological changes during a standard exercise are less marked and the return to the resting state after exercise is more rapid in the fit than in the unfit.

Chapter 3

The Harvard step test

The Harvard step test, which was employed for most of the investigations described in this thesis, was developed during the second world war in the Fatigue Laboratory of Harvard University. It is a simple test which yet fulfils the criteria for a satisfactory test of dynamic fitness. The subject works at a constant rate which is proportional to his body weight, large muscle groups are used, and the exercise requires no unusual skill. Another advantage is simplicity of the apparatus required, only a bench, platform or stool, a metronome, and a stop-watch.

Technique

In the original test (Brouha et al., 1943) the subject steps up and down from a 20-inch platform 30 times a minute for 5 minutes or until fatigue compels him to desist (Fig. 1). Immediately after the exercise he sits down, and his pulse rate is counted for the periods 1-1½, 2-2½, and 3-3½ minutes after the exercise. The fitness index (FI) is then calculated as follows:

$$FI = \frac{\text{duration of exercise (sec.)} \times 100}{2 \times \text{sum of 3 half-min. pulse counts during recovery}}$$

On the results of the test, individuals are arbitrarily classified into several categories:

Fitness index < 50	-	poor
" "	50-64	- low average
" "	65-79	- high average
" "	80-89	- good
" "	> 89	- excellent

In order to achieve valid comparison of different individuals and of different groups, the test conditions must be standardised as far as possible. The environment should not be uncomfortably hot or humid and the test should not be performed within three hours after a heavy meal. Light gymnastic costume and tennis shoes are worn.

Stepping up and down should be in time with a metronome beating 120 times a minute, the subject stepping up with one leg on the first beat, up with the other leg on the second beat, down with the first leg on the third beat, and down with the other leg on the final beat of the cycle. It is permissible to change step from time to time.

During the test the observer calls out the time at intervals of 1 minute, and encourages the subject to continue if there is any indication that he may fail to complete the test. After the test the subject sits down

and relaxes until the last pulse count has been taken.

The subject must stand erect on the bench; if he crouches or fails to keep up with the metronome the investigator should encourage him to do better and, if the faulty posture or timing is maintained for 15 seconds, the exercise is stopped and the duration to the time of stopping is taken for calculation of the fitness index. Faulty posture is inevitably a subjective assessment on the part of the observer so, for strict comparison, series of tests should be supervised by the same observer or by observers trained to accept similar standards. With standardized conditions and an experienced observer Cureton et al. (1945a) found a high test-retest reliability for this test.

Theoretical background

The height of the stool and rate of stepping are such that about one-third of normal subjects fail to complete the period of 5 minutes. Since the test is an exhausting one, an increasing effort of will is required to keep going as fatigue develops. Hardy et al. (1943) pointed out that some women students will not exert a maximum effort from laziness, from feminine dislike of appearing untidy, or from fear of physical injury; these individuals

are recognised by a short work period and a slow pulse during recovery. Although the element of willpower involved means that the test is not of physical fitness only, it is still a valuable test of dynamic fitness because strenuous exertion demands both physical and mental qualities for its achievement.

From the three pulse counts after exercise the pulse rate throughout the recovery period may be calculated. The curve of pulse rate during recovery is found to fit an exponential equation and can be drawn when any three values are known (Johnson et al., 1942). Gallagher et al. (1943) found that fitness indices calculated from three heart rates during the first $3\frac{1}{2}$ minutes after exercise agreed closely with those for which the third reading was taken 1 or 2 minutes later. Hence there is no advantage in taking the final pulse reading any later than $3-3\frac{1}{2}$ minutes after the cessation of exercise; much time would be wasted if later readings were taken on many subjects.

The arbitrary correlation of duration of exercise with post-exercise pulse rates has been criticised (Insull et al., 1955) and some investigators have preferred to allocate an arbitrary fitness index on the basis of time of exercise alone to those who fail to complete 5 minutes

(Brouha et al., 1943; Johnson et al., 1943). I see no reason to believe that the standard method of calculating fitness index, though arbitrary, is less precise than this modification and the double criterion has the merit of giving a wide scatter of fitness indices. The least fit individuals have a short exercise period with a rapid pulse thereafter; those of average fitness complete the exercise but with a rapid post-exercise pulse; the fittest complete the exercise without any considerable increase in pulse-rate. Brouha and his colleagues found a range of fitness index of 15-120 in Harvard students. The range in my own investigations over several years has been 18-118. Both Zatopek and Bannister, when in training, had fitness indices of 172 (Cureton, 1956)

The rapid fitness index

A useful time-saving modification of the original calculation, recommended by Montoye (1953) requires only one pulse count 1-1½ minutes after exercise. From this the rapid fitness index (RFI) is calculated as follows:

$$\text{RFI} = \frac{\text{duration of exercise (sec.)} \times 100}{5.5 \times \text{pulse count 1-1½ min. after exercise}}$$

The classification of fitness recommended on the basis of RFI is as follows (Weiss & Phillips, 1954; Morehouse & Miller, 1959):

RFI < 50	-	poor
" 50-80	-	average
" > 80	-	good

Fitness indices calculated by the two methods show very close agreement (Karpovich, 1953; Sloan, 1963), and the rapid method saves much time when many subjects are to be tested.

Other modifications

Most modifications of the test, introduced by various investigators, involve reduction in the height of the step or in the duration or tempo of stepping. Karpovich et al. (1944) reduced the rate to 24 steps a minute for young men convalescing from acute respiratory infections, and Jung (1951) reduced it to 15 steps a minute. The height of the step has been reduced to 18 inches (Cureton et al., 1945a) or 17 inches (Cureton, 1951a,b). Brockett et al. (1956a,b) reduced the duration of stepping to 3 minutes. Michael and Gallon (1959) used a 17-inch step on to which their subjects stepped at a rate of 36 steps per minute for 1 minute. Miller and Elbel (1946) and Elbel (1948) reduced the height of the step to 16 inches and the duration of the test to 1 minute; the rate varied from 18 to 42 steps per minute. Ryhming (1954) used a

40 cm. step at 22.5 steps per minute. Rovelli and Aghemo (1963) used bench heights of 30, 40, 45, and 50 cm. and stepping rates of 10, 20, and 30 per minute; the duration of stepping was 5 minutes. Hettinger and Rodahl (1960) adjusted the height of step for each individual to give a standard degree of flexion of hip and knee; the test was performed for 2 minutes at a rate of 25 steps per minute. A disadvantage of reducing the severity of the test is that emotional effects on the pulse, which are minimal during the response to severe exercise, may exert considerable influence at lower work levels (Taylor et al., 1963). The sole exception to the trend of diminishing effort is Fletcher (1958a,b, 1960) whose subjects stepped on to a 22-inch bench 30 times a minute until exhausted.

For testing men none of the above modifications has any conspicuous advantage over the original pattern of the test but there is fairly general agreement that a less strenuous test is desirable for women and children. For women the height of the step has been lowered to 18 inches (Hardy et al., 1943; Weld, 1946; Skubic & Hodgkins, 1963), 15 inches (Cullumbine, 1949b), 14 inches (Careton, 1947), or even 13 inches (Eyming, 1954). The period of exercise has been reduced to 4 minutes (Hardy et al., 1943; Weld, 1946) or 3 minutes (Skubic & Hodgkins, 1963).

Skubic and Hodgkins also reduced the rate to 24 steps per minute. Ryhming (1954) reduced it to 22.5 steps per minute. Sloan (1959) found that healthy young women stepping 30 times a minute for up to 5 minutes on a 17-inch step had fitness indices of the same order as healthy young men performing the same test on a 20-inch step.

Various arbitrary modifications of the test have been employed for boys and for girls (Sloan & Keen, 1959a). Cureton (1947) recommended a step 13 - 14 inches high for preadolescent boys and girls. Cullumbine (1949b) used a 20-inch step for males aged 14 years and over and a 15-inch step for younger boys. Weld (1946) used an 18-inch step for boys and reduced the period of exercise to 4 minutes. Karvonen (1964) recommended a 17-inch step and a 3-minute exercise period for boys. Gallagher and Brouha (1943d), Johnson et al. (1943), Gallagher (1944), and Weiss and Phillips (1954) used a 4-minute exercise period and a step 20 inches high for boys whose surface area was 1.85 square metres or more; for smaller boys the step was 18 inches high. High school girls have been tested on an 18-inch step at 24 steps a minute for 3 minutes (Skubic & Hodgkins, 1963, 1964) and on a 16-inch step at 30 steps a minute for 4 minutes (Brouha & Gallagher, 1943; Gallagher & Brouha,

1943a). As an arbitrary standard I have tested both boys and girls (aged 14 years and over) at 30 steps a minute for 5 minutes, using an 18-inch step for boys and a 16-inch step for girls. For testing different age and sex groups it is convenient to have an adjustable bench, such as one I have designed which can be set at heights of 16, 17, 18, 19, or 20 inches (Fig. 2).

Applications

During the second world war the Harvard step test was used in the selection of combat officers (Woods et al., 1943). Since the war the original test, or some modification of it has been applied to soldiers (Reedy, 1953, 1954; Reedy & Saiger, 1954; Insull et al., 1955; Brockett et al., 1956a,b), sailors (Cook & Wherry, 1950), airmen (Seltzer, 1946; Evrard, 1959), lumbermen (Fortier, 1946a,b), and athletes (Cullumbine, 1949a; Cullumbine & Williams, 1949; Cureton, 1951; Michael & Gallon, 1959). Numerous investigators have tested students, and Cullumbine (1949c,d,e) tested whole populations (men, women, and children) in Ceylon.

Correlation with other tests

Most investigators have found poor correlation between FI on the Harvard step test and the results of other tests

of work capacity (Eichna et al., 1944; Cureton et al., 1945a; Cullumbine & Williams, 1949; Cook & Wherry, 1950; Montoye, 1953; Maggio et al., 1963; Rasch & Wilson, 1964) but Ryhming (1954) found good agreement between the pulse rates after a modified step test and after equivalent work on a bicycle ergometer, and Martin (1957) found no significant difference between the pulse rates after a 5-minute step test, a 3-minute step test, and 100 standing jumps.

Hodgson et al. (1946) found that the FI calculated from the Harvard step test showed little relation to rate of oxygen consumption, pulmonary ventilation, or resting heart rate. Cullumbine and Williams (1949) found no significant relation between FI, vital capacity, breath-holding time, or expiratory force. Hettinger et al. (1961) and Rodahl et al. (1961) showed good correlation between FI and maximum oxygen intake. Rovelli and Aghemo (1963), employing a range of heights and rates of stepping, found a linear correlation between rate of oxygen consumption and the calculated energy expenditure; on a 50 cm. bench at 30 steps per minute this corresponded to the maximum oxygen intake for a young non-athletic subject.

Reedy (1953, 1954) included the Harvard step test in a

test battery for army recruits, and Brockett et al. (1956b) combined a modified step test with the U.S. Army physical training tests. Cureton (1956) found that the Harvard step test had the best correlation of any individual fitness test with a 22-item test battery but had a low correlation with other individual tests of fitness for strenuous work.. Brožek et al. (1953), assessing the reliability of a number of exercise tests, found that the Harvard step test gave the most consistent results.

Although the blood lactate level after exercise shows poor correlation with the results of fitness tests, high blood lactate levels tend to be associated with low fitness indices (Gallagher & Brouha, 1943c).

Summary

The technique of the Harvard step test is described.

The original test is a satisfactory test of dynamic fitness of young men but, in order to achieve valid comparisons, the conditions of testing must be carefully standardised. The rapid fitness index, based on one post-exercise pulse count instead of three, is satisfactory and time-saving.

Different investigators have modified the test in different ways, altering the height of the step, the rate

of stepping, and the duration of stepping. For men the modifications confer no advantage over the original test. For women and children a lower step is desirable than for men but the tempo and duration of stepping need not be altered.

Opinions differ widely on the correlation between fitness index, as determined by the Harvard step test or one of its modifications, and other measures of physical fitness. In general the fitness index correlates fairly well with maximum oxygen intake and with the composite results of batteries of athletic tests.

Chapter 4

Tests of athletic fitness

Categories of physical fitness

Although most of the investigations reported in this thesis have been concerned with the determination of dynamic fitness as defined by Gallagher and Brouha (1943b), and static fitness, which is determined by routine medical examination, is not discussed here, there are other aspects of physical fitness which must be considered in achieving a general assessment. Stansbury (1943) gave these as speed, strength, endurance, agility, and co-ordination. The New York State Physical Fitness Test (University, 1958) substituted accuracy for co-ordination and added posture and balance. Cureton (1947), from an extensive analysis of a 14-item test battery, extracted 6 principal factors, viz.: endurance, strength, balance, agility, power, and flexibility. Local factors which have been investigated include abdominal strength, arm strength, and foot strength (Mohr, 1944) and arm and shoulder co-ordination (Barrow, 1954). Nicks and Fleishman (1962) subdivided the strength factor into explosive, dynamic, and static strength, and added speed and co-ordination. Ismail and Cowell (1962)

substituted cardiovascular efficiency for endurance, and added accuracy. Ponthieux and Barker (1963) considered 3 categories of physical fitness, viz.: circulorespiratory endurance, gross body co-ordination, and explosive strength; the test battery, which I have employed, is a useful measure of these factors.

The most satisfactory test of fitness for a particular task is performance of the task (Tegner, 1945; Abrahams, 1956) but a general assessment of fitness for physical activity may be achieved by the groups of tests described below.

Tests of athletic fitness of men

The oldest tests of physical fitness, those based on athletic performance, have been employed in competitive athletics for more than 2,000 years. Whereas any one type of athletic performance may depend to a considerable extent on a particular motor skill it is possible, with a suitable combination of tests, to assess the several factors involved. The raw scores of different tests may be converted to T-scores and the total T-score is taken as a criterion of physical fitness (Powell & Howe, 1939; O'Connor & Cureton, 1945; Cureton, 1947; Brown, 1954; Barrow, 1954; Landiss, 1955; Cousins, 1955; Arnett, 1962),

The range, 0-100, on a T-score corresponds to the mean ± 3 standard deviations of the raw scores for the test. To obtain a composite criterion of fitness for an individual his T-scores for the several tests in one test battery are added together. They may be given equal weight or each test result may be multiplied by a factor based on its value in predicting the criterion. For practical purposes, if large groups are to be tested, the minimum number of tests should be employed which will give a reasonable prediction of the score of the more comprehensive test batteries.

Larson's test of motor ability (Larson, 1941) consists of baseball throw for distance, pull-ups, vertical jump, and bar-snaps. Kistler (1944) employed a 5-minute run for distance, an obstacle race for time, push-ups, chinning, and sit-ups. The JCR test battery (Phillips, 1947a,b) comprises a vertical jump, chinning, and a shuttle run of 20 5-yard lengths with bankboards at each end.

Cureton's short classification test (Cureton et al. 1945b), comprising dive and roll, medicine ball put, bar vault, chinning, leg lift, sit-ups, breath holding, and man lifting, can be performed indoors on 10 men in 30 minutes by one instructor. A shorter battery (Cureton et

al. 1945a) comprises the mile run, chinning, and sitting tucks. The United States Army Air Force employs a battery of 3 tests (chinning, sit-ups, and 300-yard shuttle run), the scores of which correlate well with the total score of 15 tests of speed, strength, endurance, agility, and coordination (Stansbury, 1943). The United States Army test battery includes these and squat jumps and press-ups (Department of the Army, 1950). These tests might be combined with the Harvard step test, and obstacle race, and a 5-mile speed march (Reedy, 1953, 1954) or with a modified Harvard step test (Brockett et al., 1956b). The United States Navy fitness test (Loveless, 1952), comprising squat thrusts, sit-ups, push-ups, squat jumps and pull-ups, has the advantage that it does not require outdoor facilities.

Cullumbine (1949d,e) combined weight-lifting and a 100-yard sprint with the Harvard step test. Henry and Berg (1950) combined a modified Harvard step test with an endurance index (EI) derived as follows:

$$EI = \frac{\text{time taken to run 300 yards}}{\text{time taken to run 75 yards}}$$

Other short test batteries which have proved satisfactory include: sit-ups, squat jumps, squat thrusts, push-ups,

pull-ups, 100-yard pick-a-back, and 300-yard run (Siger-
seth, 1951); standing broad jump, shot-put, squat twists
and leg raising (McHone et al., 1952); 60-yard dash,
shuttle run, standing broad jump, softball throw for
distance, straddle chinning, and trunk flexion (Barrow,
1954); and push-ups, squat jumps, sit-ups, standing broad
jump, 75-yard dash, and 220-yard dash (Riendeau et al.,
1958). The test battery employed by Hebbelinck and
Postma (1963) comprises a 60-yard dash, chinning, dipping,
standing vertical jump, standing broad jump, and putting
a 16 lb. shot. That of Mellerowitz (1964) includes broad
jump, 100-metre and 1,000-metre runs and an exercise
tolerance test with a hand ergometer. That of Kukushkin
(1964) comprises 100-metre and 1,500-metre runs, running
long jump, and chinning.

Other measurements may be added to tests for motor
fitness to obtain a comprehensive picture of physical
condition. Cureton (1947) included constitutional body
type, metabolic rate, and nutritional status.

Tests of athletic fitness of women

A 3-item test battery for women which shows good corre-
lation with a 35-item composite criterion (Scott, 1939)
comprises 4-second dash for distance, basketball throw for

distance and vertical jump. A 6-item battery which includes tests of strength and endurance (Mohr, 1944) is the following: modified step test, sit-ups, arm strength by dynamometer, modified push-ups, squat-jumps, and obstacle race. Powell (1947) employed an 8-item test battery comprising standing broad jump, potato race, basketball throw for distance, push-ups, sit-ups, pull-ups, 10-inch squat thrust, and 30-inch squat thrust. Scott and Wilson (1948) used only 5 tests, viz., obstacle run, vertical pull, sit-ups, bounce, and chair stepping. McCue (1953) assessed flexibility by measurement of joint movements and Harris (1963) by the Kraus-Weber tests (vide infra). Hart and Shay (1964) applied the New York State physical fitness test battery (vide infra). Kukushkin (1964) tested women on 100-metre and 800-metre runs, running long jump, and push-ups.

Tests of athletic fitness of high school children

Most adult tests of physical fitness are applicable also to high school children but some modifications may be required, particularly for the younger age-groups. The modifications of the Harvard step test which have been found appropriate are described in Chapter 3. Other laboratory tests of dynamic fitness which have been performed

on children include bicycle ergometry (Gallagher & Brouha, 1943c; Gallagher et al., 1943; Adams et al., 1961a,b; Redahl et al., 1961; Sexton, 1963; Maggio et al., 1963; Knuttgen & Steendahl, 1963; Hollman, 1964; Kramer & Lurie, 1964), treadmill running (Balke, 1963), and running up and down stairs (Boas, 1931). Heart rates have been recorded during running on the level (Boas, 1931; Skubic & Hilgendorf, 1964) and during swimming and gymnastic activities (Faulkner et al., 1963).

The Kraus-Weber tests (Kraus & Hirschland, 1953, 1954; Phillips et al., 1955) lay particular emphasis on flexibility; they involve prone trunk and leg raising, supine trunk and leg raising, and trunk flexion. Burley et al. (1961) added to flexibility tests the basketball throw for distance, standing broad jump, and 50-yard dash.

A short battery of athletic tests which has been applied to many children from 6 to 18 years of age comprises 100-yard run, 600-yard run, and putting a 12 lb. shot (Jokl & Cluver, 1941; de Jongh et al., 1942; Cluver et al., 1942; Botha et al., 1945). Another test battery which has been used for both boys and girls consists of a 60-metre run, high jump, and throwing an 80-gram ball (Milicer & Denisiuk, 1964b).

The New York State Physical Fitness Test (University, 1958) comprises a posture rating, target throw, pull-ups (modified pull-ups for older girls and modified push-ups for younger boys and girls), side-steps, 50-yard dash, squat stand, and 'treadmill' (in push-up position, jump change of alternate legs from full extension to full flexion with thigh against chest). From the results of the 7 tests a composite physical fitness score is derived. After many thousands of children had been tested a shorter screening test was devised, comprising sit-ups, side-steps, 50-yard dash, and squat thrusts (University, 1964).

Other test batteries which have been used for schoolboys include: vertical jump, rope climb, standing broad jump, fence vault, and a swimming test (Johnson et al., 1944), straddle chinning, push-ups, squat thrusts, and vertical jump (Bookwalter, 1952), and hand-grips, back lift, leg lift, pull-ups, push-ups, and lung capacity (Clarke & Carter, 1959). Ismail and Cowell (1962) derived from 18 tests and groups of tests on boys a 3-item test battery comprising the standing broad jump, softball throw for distance, and pull-ups. Baacke (1964) derived a composite criterion of physical fitness for boys from height, weight, leg length, and 8 athletic tests; a combination of 2

tests (standing broad jump and 50-yard dash) correlated well with the criterion. Karvonen (1964) combined his step test (vide supra) with the vertical jump, chinning, push-ups, side leg raising, squat jumps, and forehead-knee touching.

O'Connor and Cureton (1945) employed 6-item and 12-item motor fitness test batteries to assess balance, flexibility, agility, strength, power and endurance of high school girls; the tests of strength and endurance had the highest correlation with the total criterion. Short test batteries which have been used for schoolgirls include; standing broad jump, hurdle race, and scramble (Powell & Howe, 1939), 'through-the-stick', pull-ups, curl-ups, squat thrusts, and agility run (Fox, 1959), and modified pull-ups, 600-yard run-walk and standing broad jump (Arnett, 1962). All three short batteries correlate well with more complex criteria of fitness.

The AAHPER test battery (American Association, 1958) comprising 7 tests of athletic fitness, has now been applied to many thousands of children both in the United States and in other countries. This battery, which I have used for most of my tests of athletic fitness and a number of modifications of it, are described and discussed in

Chapter 5.

The performance of athletic tests by children varies with age and sex. At tests involving strength or endurance boys are usually better than girls of the same age and the boys' performance improves progressively with age, whereas the endurance of girls tends to deteriorate after puberty (Cluver et al., 1942; de Jongh et al., 1942; Hunsicker, 1958; Espenschade, 1960; University, 1963).

Summary

A general assessment of the physical fitness of subjects who are free from disease or deformity may be achieved by the use of a test battery which measures selected aspects of athletic fitness. The main factors are endurance (the main feature of dynamic fitness), coordination (motor skills fitness), strength, speed, agility, flexibility, and balance. Some investigators include anthropometric data in the assessment of physical fitness.

Appropriate tests of each of these factors have been devised and a composite criterion of fitness may be calculated for each individual from his T-scores on the several tests. A good test battery is one which requires only simple equipment and can be applied by one trained observer to many subjects in a short time. It should



Fig. 1: Harvard step test.



Fig. 2: Adjustable bench for Harvard step test.

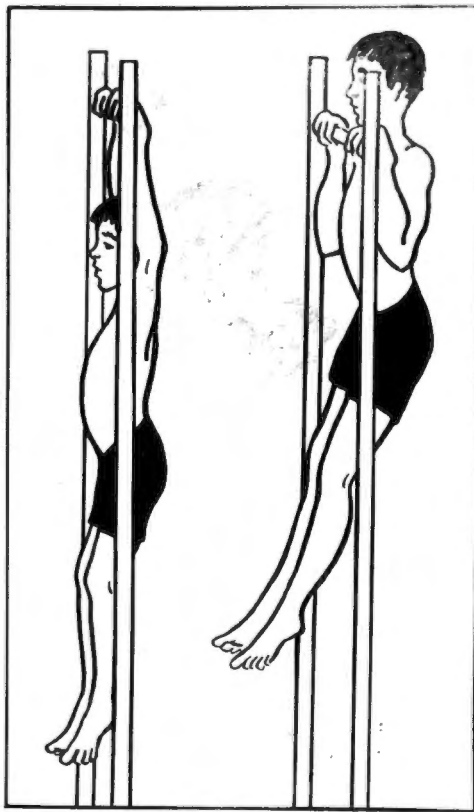


Fig. 3: Pull-up

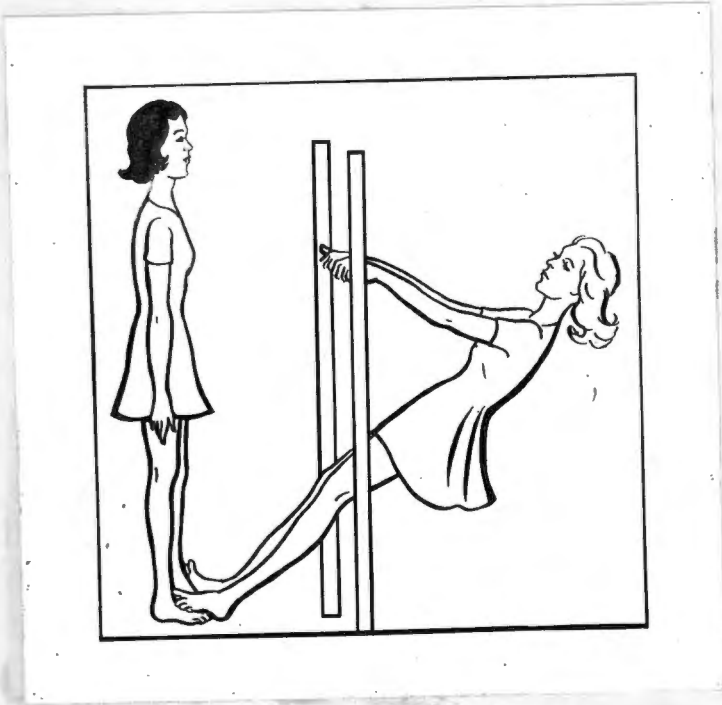


Fig. 4: Modified pull-up

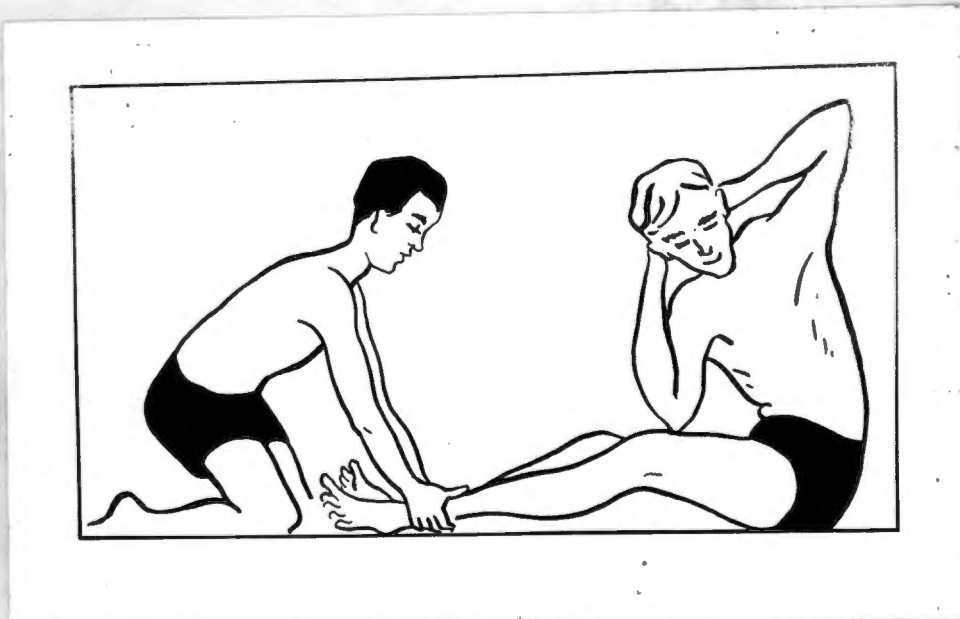


Fig. 5: Sit-up

employ the minimum number of tests required to give a general assessment of physical fitness and should have a high test-retest reliability.

Many test batteries are suitable for men, women, and children although some require modification, particularly for young children, and different standards of performance must be set for the two sexes and for different age-groups of boys and of girls.

Chapter 5

The AAHPER test battery

In 1958 the American Association for Health, Physical Education and Recreation recommended a battery of 7 tests to assess the physical fitness of high school children, viz.: pull-up, sit-up, shuttle run, standing broad jump, 50-yard dash, softball throw for distance, and 600-yard run-walk. The first 4 tests are normally performed in the gymnasium during one school period and the remaining 3 are performed out of doors in one school period. Detailed instructions are given for the performance and scoring of each test (American Association, 1958). All the tests are reliable, as indicated by a highly significant test-retest correlation (Stein, 1964).

Details of tests

1(a). Pull-up - The pull-up for boys is performed hanging from a bar high enough for the feet to be clear of the floor when the arms are fully extended. The overhand grasp is used (Fig. 3). The subject raises his body by his arms until his chin is above the bar and then lowers himself to the starting position. No swinging of the body or kicking of the legs is permitted. The exercise is repeated as

often as possible and the score is the number of complete pull-ups achieved.

2(b). Modified pull-up - For girls the modified pull-up is used. A horizontal bar, set at about nipple level, is grasped with both hands, using an overhand grasp. The subject extends her legs under the bar and extends her arms fully (Fig. 4). The arms should form an angle of 90 degrees with the body line and the body line should form an angle of 45 degrees with the floor. The heels should be braced to prevent slipping, for instance against the scorer's feet. From this position, keeping her body straight, the subject raises her body by the arms until the chest touches the bar and then lowers herself to the starting position. No resting is permitted. The score is the number of completed pull-ups to a maximum of 40.

2. Sit-up - The sit-up is performed with the subject supine on the floor with legs extended and feet about 2 feet apart. The hands are placed on the back of the neck with the fingers interlaced and the elbows against the floor. A partner holds the ankles down and acts as scorer (Fig. 5). To perform the test the subject sits up turning the trunk to the left and touching the right elbow to the left knee, returns to the starting position, and then sits up turning

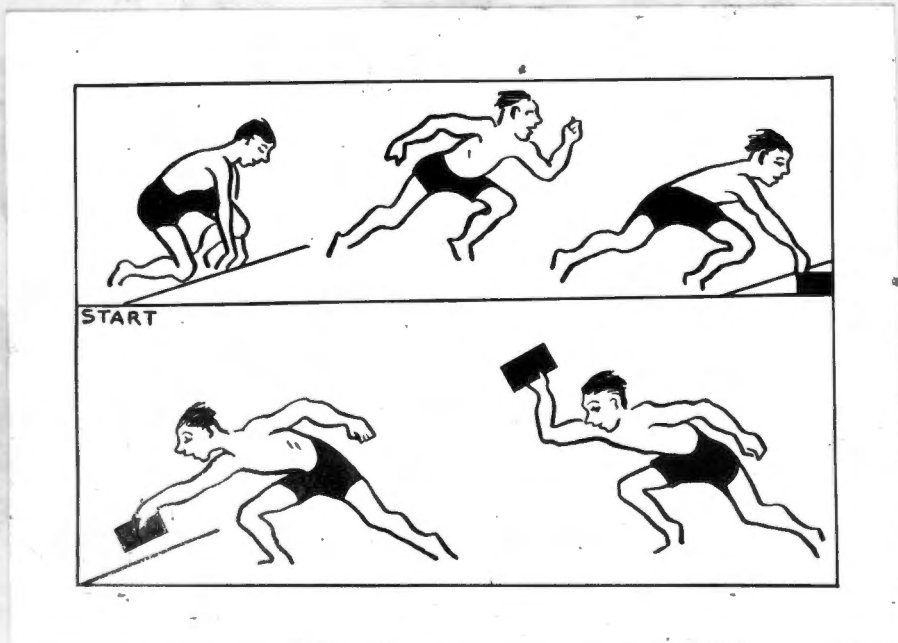


Fig. 6: Shuttle-run

the trunk to the right and touching the left elbow to the right knee. The exercise is repeated, alternating sides. In scoring, one point is given for each complete movement of touching elbow to knee. No score is counted if the fingertips do not maintain contact behind the head, if knees are bent when the subject lies on his back or when he begins to sit up, or if he pushes up off the floor with an elbow. The maximum score in number of sit-ups is restricted to 50 for girls and 100 for boys.

3. Shuttle run - For the shuttle run, two parallel lines are marked on the floor 30 feet apart and two small blocks of wood (2 in.x 2 in.x 4 in.) are placed beyond one of the lines. Starting from behind the other line the boy or girl runs to the blocks, picks one up, runs back to the starting line, and places the block behind the line, runs back and picks up the second block, and runs back with it across the starting line (Fig. 6). At least 2 scorers should be available with stop-watches so that at least 2 subjects can run at the same time. Two trials are allowed with a rest between. The score is the shorter of the two times to the nearest tenth of a second.

4. Standing broad jump - For the standing broad jump the boy or girl stands with feet apart and toes just behind

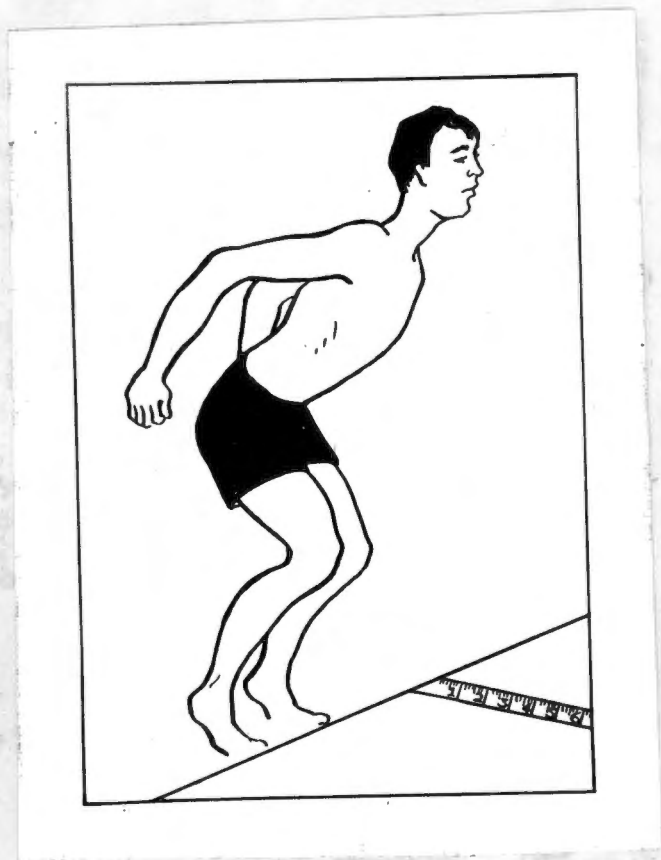


Fig. 7: Standing broad jump

the take-off line. Preparatory to jumping the subject swings the arms backwards and bends the knees (Fig. 7). The jump is accomplished by simultaneously extending the knees and swinging forward the arms. The jump is measured to the heel or other part of the body that touches the floor nearest the take-off line. Three trials are allowed and the score is the longest of the three jumps measured to the nearest inch.

5. 50-yard dash - This test is performed by two or more subjects at a time, depending on the number of timers with stop-watches available. The starter drops his arm on the command, 'go', to give the timer a visual signal. This test is performed once only and the score is the time taken to run 50 yards, measured to the nearest tenth of a second.

6. Softball throw for distance - A standard (12-inch circumference) softball is used. Starting from in front of a line 6 feet behind the take-off line the boy or girl throws the softball overhand from behind the take-off line as far as possible. The throw is measured from the point of landing to the nearest point on the take-off line. Three throws are allowed and the score is the longest of the three throws, measured to the nearest foot.

7. 600-yard run-walk - From a standing start the boy or girl runs 600 yards. If unable to run the whole distance he intersperses running with walking but the object is to cover the distance in the shortest possible time. It is convenient to have from 6 to 12 subjects running together; each runner has a partner who notes the time called out by the timer as that runner crosses the finishing line. The test is performed once only and the score is the time taken to cover 600 yards, measured to the nearest second.

Significance of the AAHPER tests

In the original publication, results of the tests were expressed as raw scores and percentiles for each annual age-group from 10 to 17 years of boys and of girls and in terms of an index derived from age, height, and weight for each sex. Espenschade (1963), from analysis of a similar test battery, concluded that age alone is a better basis for establishing test norms than is a combination of age, height, and weight. In secondary school children Gross and Casciani (1962) found that age, height, and weight bore little relation to the results of the tests; they recommended that junior high school boys, junior high school girls, high school boys, and high school girls should each be regarded as a homogeneous group for purposes of classification.

O'Connor and Cureton (1945) took sit-ups as a test of strength. Cureton (1947) considered pull-ups a test of endurance and the standing broad jump a test of power. Fowler and Gardner (1963) considered pull-ups as testing dynamic strength, the 50-yard dash and broad jump explosive strength, sit-ups dynamic flexibility, and the 600-yard run endurance.

From multiple correlations of the results of the 7 AAHPER tests Ponthieux and Barker (1963) extracted 3 categories of physical fitness, viz.: (1) circulo-respiratory endurance (pull-up, sit-up, 600-yard run-walk), (2) gross body coordination (softball throw), and (3) explosive strength (standing broad jump, 50-yard dash, shuttle run). Knuttgen and Steendahl (1963) contend that the softball throw depends predominantly on acquired skill and so is of questionable validity as a test of physical fitness.

In my opinion the main factors measured by the AAHPER tests are as follows:

- (1) Pull-up and modified pull-up: arm strength
- (2) Sit-up: trunk strength and flexibility
- (3) Shuttle-run: agility
- (4) Standing broad-jump: power (explosive strength)

- (5) 50-yard dash: speed
- (6) Softball throw: power and coordination
- (7) 600-yard run-walk: endurance

An important factor not specifically tested by this battery is balance.

Modifications of the AAHPER test battery

Arnett (1962) found good correlation ($r=.892$) between the AAHPER tests and a short test battery consisting of modified pull-up, 600-yard run, and standing broad-jump. The best single test was the standing broad-jump. Ismail and Cowell (1962) employed a 3-item battery comprising standing broad-jump, softball throw, and pull-up. A total score was calculated as follows:

$$\text{Score} = 3.319A + 1.596B + 15.371C + 188.64$$

where A = broad jump (feet)

B = softball throw (feet)

C = pull-ups (number)

In my later tests of athletic fitness I have modified two of the tests in order to obtain more satisfactory T-scores for a total criterion of fitness. Having found the modified pull-up an unsatisfactory test of fitness for girls since nearly all the subjects tested achieved the maximum score with little effort and since it has a

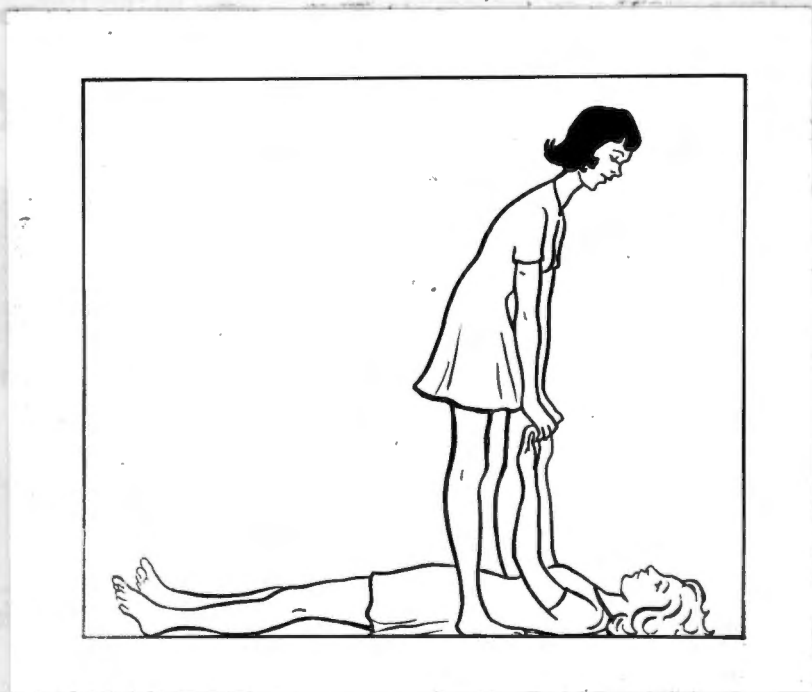


Fig. 8: Straddle chinning

restricted maximum score, I substituted straddle chinning (Cureton et al., 1945a) as a test which would distinguish the fit from the less fit girls and avoid an arbitrary maximum score. To avoid the skew distribution imposed on the results of the sit-ups by the restricted maximum for boys and for girls I substituted for the original test timed sit-ups (Havlicek, 1944), counting the maximum number which could be performed in one minute. The details of these tests are as follows:

Straddle chinning - The subject lies supine with her arms by her sides while her partner stands astride of her with her feet against the subject's elbows. The subject then grasps the partner's hands, each flexing the fingers with the palms of the hands towards her own body (Fig. 8). Keeping her body rigid she pulls herself up by her arms until her body touches the inside of her partner's thighs and then lowers herself to the starting position. At the top of the lift the subject's arms should be in line with her trunk and lower limbs. No resting is allowed and the partner must be motionless and avoid contributing to the lift. The exercise is repeated as often as possible and the score is the number of complete straddle chinings achieved.

Timed sit-up - The pattern of movement for the timed sit-up is the same as for the original sit-up test, but the score is the maximum number of complete sit-ups performed in one minute. The test is the same for boys and for girls.

Summary

The AAHPER test battery measures all the main factors involved in athletic fitness except balance. It comprises 7 tests, viz.: pull-up (modified pull-up for girls), sit-up, shuttle run, standing broad jump, 50-yard dash, softball throw for distance, and 600-yard run-walk. The modified pull-up is not a satisfactory test for girls and may be replaced by straddle chinning. For both boys and girls, timed sit-ups (maximum 1 minute) are preferable to the original untimed test with an arbitrary maximum for boys and for girls.

PART II

PHYSICAL FITNESS OF COLLEGE STUDENTS

Chapter 6

Influence of anthropometric parameters on the physical fitness of young men

In view of the discrepancy between the findings of different users of the Harvard step test on the relation between fitness index (FI) and anthropometric parameters of young men I investigated this problem, in collaboration with Dr. E.N. Keen, in 1957. Since then I have performed further investigations on my own in this field and have also applied the AAHPER test battery to young men.

A number of anthropometric factors might be expected to influence the FI of young men subjected to the Harvard step test. Of these the most obvious are weight and height. The work done is directly proportional to the body weight and one might expect that taller subjects would achieve more easily the stepping on to a high bench.

Seltzer (1946), testing aviation cadets and college students, found a positive correlation between FI and the reciprocal ponderal index ($\text{height}/\sqrt[3]{\text{weight}}$) in untrained but not in trained subjects. In the military recruits tested by Reedy and Saiger (1954, 1958) the FI was not related to height and weight or to height alone but the performance of heavier men was significantly poorer.

Brockett et al. (1956b) and Fletcher (1960) found no correlation between FI and height, weight, or leg length, but Elbel et al. (1958) found a positive correlation with each of these parameters. Monod and Bouisset (1964) demonstrated a low, but significant correlation between FI and an index derived from height, weight, and mean thoracic circumference.

Seltzer and Brouha (1943) assessed the 'masculine component' of freshmen at Harvard University from general appearance, approximation of thighs with heels together, carrying angle, hip-shoulder ratio, hair distribution, and breast development. In general, individuals with a low masculine component had a low FI, and the highest FIs were achieved only by individuals with a strong masculine component.

Other anthropometric measurements have been studied in relation to the FI. Fortier (1946b) found that a high bi-acromial/bi-iliac ratio was significantly related to a high FI. Cullumbine (1949c) found that the FI was significantly related to the bi-iliac diameter and to the ratios, bi-iliac diameter/height and chest-circumference/height; FI was not, however, related to the degree of obesity (Cullumbine et al., 1950).

Kireillis and Cureton (1947) found only a low negative correlation between obesity (expressed as the total of 6 skinfold measurements) and physical performance (assessed by a 23-item test battery); there was however a significant negative correlation between obesity and an endurance criterion derived from the times taken for 4 long-distance runs.

There is no evidence of reduced muscular efficiency in obese subjects at arm flexion tests (Gessler, 1927a,b; McKee & Bolinger, 1960) or on climbing stairs (Kommerell, 1931). On treadmill tests, however, obese subjects are less efficient (Miller & Blyth, 1955; Alexander, 1964; Turell et al., 1964). On a bicycle ergometer too there is a lower mechanical efficiency in the obese (Åstrand et al., 1960b) and they have less endurance (Josenhans, 1962) than subjects of average build.

In healthy individuals the maximum oxygen intake is closely related to the lean body mass (Baskirk & Taylor, 1957; Luft et al., 1963). Obesity limits the capacity for strenuous effort (Welch et al., 1957; Balke & Ware, 1959). Using batteries of athletic tests Loveless (1952) and Best and Kuhl (1955) found reduced fitness in obese or heavy subjects and Riendeau et al. (1957, 1958) found

that obesity was a limiting factor in most motor fitness tests.

Cureton (1947) recommended the inclusion of somatotypes (Sheldon, 1940) in a general assessment of physical fitness. Willgoose and Rogers (1949) found a positive correlation between FI and mesomorphy, a negative correlation with endomorphy and no correlation with ectomorphy. Miller (1952) found poor correlation between assessments of body build and the results of individual athletic tests or the total scores of test batteries. Sills (1950) and Hebbelinck and Postma (1963) found that mesomorphs were superior to endomorphs and ectomorphs in a number of motor fitness tests. Finnish jumpers, throwers, sprinters, and long-distance runners do not differ anthropometrically from each other (Pere et al., 1954). Endomorphs tend to have a poor athletic performance (Sills, 1950, 1960) and ectomorphs are prone to injury (Sills, 1960).

Cullumbine et al. (1949) found a significant difference in fitness indices between different races in Ceylon, but these could be ascribed to inadequate nutrition of the groups with the poorer performance. Best and Kuhl (1955) found no significant difference in performance of fitness tests between white and black subjects.

All these investigations, except those of Cullumbine (1949c,d,e) were restricted to young men. Robinson (1938), Åstrand (1956), Simonson (1957), Norris and Shock (1960), Andersen (1964), and Hollman (1936, 1964) reported on the progressive reduction in dynamic fitness in middle and old age.

Anthropometry

Sheldon's original method of assessing body build in terms of mesomorphy, ectomorphy, and endomorphy (Sheldon, 1940) requires specialised equipment and a trained observer although some investigators have claimed to be able to assess these parameters reliably by direct observation of their subjects without recourse to photography or measurements (Postma & Berens, 1962). A rough assessment of the predominance of mesomorphy, endomorphy, or ectomorphy can be derived from the reciprocal ponderal index (RPI) (Sheldon, 1940; Sills, 1960) or from the RPI and the body fat as estimated from skinfold measurements (Hunt, 1952). Mesomorphs and endomorphs have a low RPI compared with ectomorphs (Parnell, 1954; Dupertuis & Emanuel, 1956) and can be distinguished from each other by the relatively lower proportion of body fat usually found in mesomorphs than in endomorphs (Dupertuis et al., 1950; Parnell, 1954).

In my investigations skinfolds were measured with the United States Army Medical Nutrition Laboratory caliper (Best, 1953). The specific gravity (SG) of young men was calculated from 3 skinfold measurements by the formula of Brožek and Keys (1951) as follows:

$SG = 1.1017 - 0.000282A - 0.000736B - 0.000883C$, where

A = horizontal abdominal skinfold (mm.) half-way between the umbilicus and the right mid-axillary line.

B = chest skinfold (mm.) half-way between the nipple and the anterior axillary fold on the right side, taken across this line.

C = vertical skinfold (mm.) on the back of the right arm midway between acromion and olecranon processes.

From the SG the proportion of fat in the body (by weight) is calculated as follows (Keys & Brožek, 1953):

$$\% \text{ fat} = 100 \left(\frac{4.201}{SG} - 3.81 \right)$$

In 1964 I acquired in the Physiology Department of the University of Cape Town equipment for underwater weighing (Behnke et al., 1942; Sloan et al., 1962) and for determination of pulmonary residual volume by the open circuit nitrogen-dilution method (Cournand et al., 1941; Comroe et al., 1962; Consolazio et al., 1963), and so was able to determine body specific gravity directly. As before,

the formula of Keys and Brozek (1953) was used to calculate the proportion of body fat from the specific gravity.

Tests of fitness

Dynamic fitness was assessed by the standard Harvard step test (Chapter 3). For the first investigation the subjects wore shorts and tennis shoes and the FI was calculated from 3 half-minute post-exercise pulse counts. In the second and third investigations the subjects were given the choice of wearing tennis shoes or of performing the test barefoot and the RFI was calculated from a single post-exercise pulse count.

The subjects of the second investigation also performed the modified AAHPER test battery (Chapter 5), in which timed sit-ups (maximum number in 1 minute) were substituted for the original untimed test limited to a maximum of 100 sit-ups. To obtain a composite criterion of athletic fitness T-scores were constructed for each test as described in Chapter 4. All raw scores were converted to T-scores, the T-scores being "inverted" for the 3 runs (shuttle run, 50-yard dash, and 600-yard run) so that the shortest time corresponds to the highest T-score. The composite criterion for each individual is the sum of his 7 T-scores divided by 7 to express it as a percentage.

Subjects and methods of investigation

The subjects of the first investigation (Keen & Sloan, 1958; Sloan & Keen, 1959a) were 75 healthy young men, aged 17-27 years, of whom 51 were medical students at the University of Cape Town and 24 were physical education (PE) students at Paarl Training College. Prior to analysis of the results 2 PE students were excluded because they had performed the Harvard step test barefoot and 5 medical students because they were unable to keep proper time or had paused during the test. We measured height, weight, leg length (the height of the iliac crest from the ground in the erect posture), bi-iliac diameter, and resting pulse. The FI was derived as in the original Harvard step test.

In 1964 I investigated the physical fitness of 76 healthy young men, aged 17-26 years, of whom 47 were White students at Paarl Training College and 29 were Coloured students at Hewat Training College in Athlone. All the PE students at each college (20 White and 5 Coloured) were tested as well as control groups of students (27 White and 24 Coloured) not specializing in PE, although all had at least one weekly period of gymnastics as part of their general training. Height and weight were measured and the RPI calculated. Body fat was estimated from skinfold

**Table 1. Anthropometric and physiological parameters
of 68 young men**

Parameter or Test	Medical Students	Physical Education Students	Significance of Difference
N	46	22	
Height	176.6 [±] 5.7	176.6 [±] 4.0	-
Weight	63.3 [±] 8.3	75.1 [±] 8.0	M<PE (P<.01)
Leg length	107.4 [±] 4.3	107.4 [±] 2.9	-
Bi-iliac diam.	28.5 [±] 1.4	28.8 [±] 1.0	-
Resting pulse	83.5 [±] 12.1	74.4 [±] 9.3	M<PE (P<.01)
Fitness index	62.0 [±] 15.7	85.6 [±] 10.2	M<PE (P<.001)

In the tables in this chapter:

N = number of subjects

Height, leg-length, and bi-iliac diameter are measured in centimetres and weight in kilograms.

Resting pulse is expressed in beats per minute.

x[±]y represents mean [±] standard deviation.

Fitness index refers to Harvard step test.

M = medical students

PE = physical education students

- indicates no significant difference.

measurements. The RFI was calculated for the Harvard step test and the modified AAHPER test battery was performed.

The third investigation, also performed in 1964, was on 50 healthy White male students, aged 18-26 years at the University of Cape Town. These students performed the Harvard step test and their body fat was estimated from specific gravity, determined by underwater weighing.

Results

The results of the first investigation are given in Table 1. The mean stature and leg length of the two groups were the same and the mean bi-iliac diameters very similar but the PE students were significantly heavier. The PE students had a significantly lower mean resting pulse than the medical students. (The effect of physical training on the resting pulse will be discussed in Chapter 7.) In spite of their heavier weight the PE students had a much higher mean FI than the medical students. Height, weight, leg length, and bi-iliac diameter showed no significant correlation with FI in either group or in the series as a whole.

The results of the second investigation are shown in Table 2 and the significance of differences between the

Table 2. Anthropometric parameters and results of fitness tests on 76 young men

Parameter or Test score	White students		Coloured students	
	PE	Control	PE	Control
N	20	27	5	24
Height	178.8 [±] 7.6	179.0 [±] 5.4	166.6 [±] 3.4	169.5 [±] 4.6
Weight	75.4 [±] 9.0	74.9 [±] 6.0	62.6 [±] 5.6	62.9 [±] 6.5
RPI	42.4 [±] 1.0	42.5 [±] 1.1	40.8 [±] 1.5	42.7 [±] 1.7
Fat*	3.5 [±] 0.8	4.6 [±] 1.7	3.6 [±] 0.7	3.5 [±] 1.4
RFI	84.5 [±] 10.4	79.9 [±] 7.9	78.8 [±] 3.6	79.1 [±] 12.6
<u>AAHPER:</u>				
Pull-ups	9.8 [±] 2.5	6.3 [±] 2.0	11.2 [±] 1.5	8.4 [±] 2.2
Sit-ups	34.2 [±] 3.0	33.9 [±] 2.7	32.8 [±] 4.3	29.8 [±] 5.2
Shuttle	9.2 [±] 0.3	9.8 [±] 0.4	9.0 [±] 0.2	9.3 [±] 0.4
Jump	97.4 [±] 8.1	89.1 [±] 5.5	88.6 [±] 4.8	92.9 [±] 5.3
50-yard	6.1 [±] 0.3	6.5 [±] 0.3	7.1 [±] 0.7	6.7 [±] 0.4
Softball	190.0 [±] 23.6	167.0 [±] 22.2	176.0 [±] 14.6	182.3 [±] 25.0
600-yard	93.6 [±] 6.5	97.3 [±] 6.4	97.6 [±] 6.8	104.1 [±] 6.5
Criterion	60.5 [±] 6.4	45.4 [±] 11.5	50.6 [±] 11.1	47.3 [±] 7.5

In the tables in this chapter:

RPI = reciprocal ponderal index

RFI = rapid fitness index (Harvard step test)

Results of AAHPER tests are raw scores as described in text; criterion is derived from sum of T-scores for each test as described in text.

*These figures (representing the percentage by weight of fat in the body) were derived by the formula of Brozek and Keys from skinfold measurements and are unnaturally low. They should not be taken as valid except for comparison between the groups (see text).

Table 3. Significance of differences in anthropometric parameters and fitness tests on 76 young men

Parameter or test score	White PE v. Con.	Coloured PE v. Con.	PE W v. C	Con. W v. C
Height	-	-	W>C (P<.001)	W>C (P<.001)
Weight	-	-	W>C (P<.001)	W>C (P<.001)
RPI	-	PE<Con. (P<.05)	-	-
Fat	-	-	-	-
RFI	-	-	-	-
<u>AAHPER:</u>				
Pull-ups	PE>Con. (P<.001)	PE>Con. (P<.01)	-	W<C (P<.01)
Sit-ups	-	-	-	-
Shuttle	PE>Con. (P<.05)	-	-	W<C (P<.01)
Jump	PE>Con. (P<.001)	-	W>C (P<.01)	-
50-yard	-	-	W>C (P<.05)	-
Softball	PE>Con. (P<.01)	-	-	W<C (P<.05)
600-yard	-	-	-	W>C (P<.001)
Criterion	PE>Con. (P<.001)	-	-	-

Con. = Control

W = White

C = Coloured

In the AAHPER tests A>B indicates a better performance by A, i.e. a shorter time for the runs or a higher score for the other tests.

groups in Table 3. These tables are based on raw scores, so a lower score for the runs indicates a better performance. T-scores for each of the AAHPER tests on young men are given in Table A1 (Appendix). White students were significantly taller and heavier than Coloured students, and Coloured PE students had a lower RPI (less ectomorphy) than other Coloured students. The results of the Harvard step test showed no significant difference between the groups. On the AAHPER tests of White students the PE group was superior to the control group at pull-ups, shuttle-run, broad jump, and softball throw and in the total criterion; in the Coloured groups PE students were superior only at pull-ups. In the inter-racial comparison of PE students the White were superior at the broad jump and the 50-yard dash. White controls were superior to Coloured only at the 600-yard run; at pull-ups, shuttle run, and softball throw the Coloured students were superior. Assessed on the total criterion of AAHPER fitness tests there was no significant difference between White and Coloured PE students or between White and Coloured controls.

Considering the 4 groups as one the RFI had no significant correlation with RPI ($r=.018$) but a low negative correlation with body fat ($r=.291$; $P<.05$). The total criterion had

Table 4. Correlations of individual AAHPER test results with AAHPER criterion and with RFI in 76 young men.

Test	Correlation with criterion	Correlation with RFI
AAHPER criterion	-	.211
Pull-ups	.575	.093
Sit-ups	.466	.045
Shuttle run	.546	.107
Broad jump	.733	.057
50-yard dash	.727	.147
Softball throw	.521	.147
600-yard run	.535	.267

Table 5. Anthropometric characters and fitness index of 50 young men.

Height	177.3 ± 6.22
Weight	70.6 ± 6.86
RPI	42.9 ± 1.64
Body fat	9.38 ± 4.62
RFI	75.1 ± 15.33

a positive correlation with RPI ($r=.625$; $P<.001$) and a low negative correlation with body fat ($r=-.258$; $P<.05$).

The AAHPER criterion had a highly significant correlation ($P<.001$) with each of its individual tests, the best being with the standing broad jump (Table 4). The correlation of RFI with the AAHPER criterion and with the individual AAHPER tests was poor, the only significant correlation being with the 600-yard run-walk ($P<.05$).

To assess the influence of body build on RFI and on total criterion the 76 students were divided into 3 groups. The 26 with the highest RPI were classed as ectomorphs, the 26 of the remainder with the least body fat as mesomorphs, and the remaining 24 as endomorphs. On this basis mesomorphs were significantly better at the Harvard step test than ectomorphs ($P<.01$) and than endomorphs ($P<.05$); the difference between ectomorphs and endomorphs was not significant. In terms of total AAHPER performance mesomorphs were superior to endomorphs ($P<.01$) but not to ectomorphs.

In the third group of subjects, young White men, the mean RFI was 75 and the mean body fat 9.4% (Table 5). There was no significant correlation between RFI and height, weight, or RPI but a highly significant negative correlation

between RFI and proportion of body fat ($r=-.520$; $P<.001$). Grouping the subjects as ectomorphs, mesomorphs, and endomorphs, as in the previous investigation, the mesomorphs were the fittest but not significantly better than the ectomorphs; both mesomorphs and ectomorphs were significantly better than endomorphs ($P<.05$).

Discussion

The results of the first investigation demonstrate the superiority of PE students over medical students at a test of physical endurance. The finding that neither height nor leg-length is significantly correlated with FI suggests that no modification of the test is necessary for individuals of varying stature. The absence of correlation between weight and FI contrasts with the finding of Reedy and Saiger (1954) that lighter men attain significantly higher FI scores than heavier men. Since this might be due to the additional weight in their subjects being adipose tissue and in ours muscle, the opportunity was taken in later investigations to seek any correlation between FI and body build. We failed to substantiate a correlation between FI and bi-iliac diameter established by Cullumbine (1949c) on what was, admittedly, a much larger series of observations.

The only marked anthropometric differences between groups

in the second investigation were the greater height and weight of the White students, differences which were not associated with any marked difference in physical performance from that of the Coloured students.

The figures for body specific gravity derived from skinfold measurements by the formula of Brožek and Keys (1951) are unreasonably high, as Pascale et al. (1955, 1956) and I have observed in other investigations; consequently the figures for percentage body fat derived from this skinfold formula are too low; they are, however, useful for comparative purposes within the series and in the division of the series into groups based on somatotypes.

The similarity of performance of the Harvard step test by all the groups in the second series may be attributable to the fact that all the students in this series had regular physical training in their curriculum. In the AAHPER tests, PE students had more arm strength as evidenced by their better performance of pull-ups and, in the White groups, they showed more agility (shuttle run), power (broad jump, softball throw) and coordination (softball throw). White PE students had more power (broad jump) and speed (50-yard dash) than Coloured but, in the control groups, White students excelled only in endurance (600-yard

run) and were inferior in arm strength, agility, and coordination. One would expect the White students with their greater weight, not in this case attributable to obesity, to have more muscle power, but this is manifested only in the comparison of broad jumps in the PE groups. The superiority of PE students over controls in the total criterion is significant only in the White group, possibly because of the very small number of Coloured PE students.

The high correlation of the AAHPER criterion with each of its constituent tests indicates that this is a well-balanced test battery. The RFI has a surprisingly poor correlation with the AAHPER criterion and with the individual AAHPER tests; the highest correlation, as might be expected, is with the test of endurance (600-yard run-walk).

The mean body fat (9.4%) estimated by underwater weighing in the third series of young men, agrees reasonably well with the findings of 10.6% (von Döbeln, 1956), 8% (Le Bideau, 1959), and 10.7% (Macmillan et al., 1965) in European subjects. American observers have reported higher figures, 13.3% (White, 1961) and 16% (Behnke, 1961). This is indirect support for the hypothesis that lack of correlation between RFI and body weight in young men in Cape Town, whereas a negative correlation has been reported

in young American men (Reedy & Saiger, 1954; Elbel et al., 1958), is due to the heavier South Africans being less obese than the heavy Americans.

In the second and third investigations the RPI was inversely related to the proportion of fat in the body, as was indicated also by the poor performance of subjects classed (on the basis of RPI and fat) as endomorphs. While the mean performance of endomorphs was below that of mesomorphs in both series the difference just failed to reach significance in the third. The advantage of muscularity is less obvious than the disadvantage of obesity.

Summary

The influence of anthropometric parameters on physical fitness, assessed by the Harvard step test, was studied on 3 series of healthy young men, one of which also performed the AAHPER test battery. Height and weight were measured in every case. In one series leg length and bi-iliac diameter were measured; in the others RPI was calculated from height and weight, and the proportion of fat in the body was estimated from selected skinfold measurements or from specific gravity, determined by underwater weighing. Subjects were classified in groups of relative ectomorphy, mesomorphy, and endomorphy on the

basis of RPI and body fat.

There was no significant correlation between height and weight and physical fitness, as assessed by the Harvard step test or by the AAHPER test battery. Physical education students were fitter than others, but there was no consistent difference in performance between White and Coloured subjects although the White were much taller and heavier. There was no significant correlation between FI (or RFI) and RPI, leg length, or bi-iliac diameter, but a negative correlation with obesity. The AAHPER criterion had a positive correlation with RPI (ectomorphy) and a negative correlation with obesity. There was a high correlation between the AAHPER criterion and the individual AAHPER tests but very poor correlation between the RPI and the AAHPER criterion or the AAHPER tests, except the 600-yard run-walk.

The more mesomorphic subjects were the best at the Harvard step test and the AAHPER tests; the more endomorphic were the worst at the Harvard step test.

Chapter 7

Influence of physical training on the physical fitness of young men

The influence of physical training on physical fitness may be assessed from the difference in performance of tests of physical fitness by athletic and non-athletic groups or, better, by longitudinal studies on the same group of men during a prolonged period of physical training.

Assessing dynamic fitness by the Harvard step test Brouha et al (1944) found significantly higher mean FIs in oarsmen (87) and in cross-country runners (86) than in an unselected group of students (75). Taddonio and Karpovich (1951) found the following mean FIs in particular groups of young men; cross-country runners, 112; marathon runners, 99; sprinters and hurdlers, 86; sedentary, 62. Keen and Sloan (1958) found a higher mean FI in PE than in medical students (Chapter 6). During World War II, Kark et al. (1947) in South East Asia observed higher FIs on a step test and on a pack test in soldiers whose work and training were vigorous than in those who were less active.

Athletic men achieve better performances than sedentary

men on treadmill tests (Milic-Emili, 1959; Koff et al., 1961) and on a bicycle ergometer test (Andersen, 1964). Overweight men have less endurance than normal men on a bicycle ergometer test, a difference which may be attributable to a lower level of physical activity in the former group (Josenhans, 1962).

Athletes have a longer breath-holding time (Montoye, 1951) and a greater vital capacity (Stuart & Collings, 1959) than non-athletes.

The performance of the Harvard step test by young men at intervals during periods of from 3 weeks to 6 months of systematic physical training shows consistent improvement (Seltzer & Brouha, 1943; Seltzer, 1946; Evrard, 1959; Cureton, 1963). Similar findings have been obtained, using modified step tests (Henry & Berg, 1950; Fletcher, 1958a,b, 1960; Michael & Gallen, 1959) and the Harvard pack test (Graybiel & West, 1945). The FI is not affected by cigarette smoking immediately prior to the test (Reeves & Morehouse, 1950; Schilpp, 1951).

Training for running causes progressive improvement in efficiency of movement and progressive increase in maximal oxygen intake, (Knehr et al., 1942) as well as greater toleration of oxygen debt (Hemingway, 1959). Work capacity

is increased by a long-term programme of gymnastics and cross-country running once or twice a week for several months and also by a short-term programme of daily skiing for 8-10 days (Holmgren et al., 1960). The maximum oxygen intake of champion skaters improves with training (Jongblood, 1962). Work efficiency and pulmonary gas exchange improve progressively with physical training (Balke, 1952; Naughton et al., 1963) and deteriorate during bed rest (Taylor, 1945; Balke, 1952). Soldiers improved at 7 tests of athletic fitness with 12 weeks of regular physical training (Sigerseth, 1951) and students improved in muscular strength, muscular endurance, and muscular power during 8 weeks of circuit training (Adamson, 1959).

Kistler (1944) applied 5 tests of athletic fitness to 1650 healthy young men before and after an intensive 8-week course of physical training; the greatest improvement was at sit-ups and the least at a 5-minute run (maximum distance covered in 5 minutes). Bell (1948), testing male athletes, found a greater improvement in the time for a 300-yard run than in the times for shorter runs or the results of other tests of endurance. Reedy (1954) applied the U.S. Army Physical Fitness test battery (Chapter 4) and other tests, including the Harvard step test, to more than 1000 army

recruits before and after basic infantry training; an interesting finding was that a group participating in additional physical training showed no greater improvement than the rest, which suggests that the basic infantry training was itself more strenuous than the additional formal physical training. During a year of military training of Swedish army recruits the work capacity of some who had been fittest at the beginning declined and the work capacity of some of the least fit improved (Borg & Dahlström, 1962). Some of these recruits were lumbermen, for whom the military regime may have been less strenuous than their previous employment.

Influence of physical training on body fat

Active physical training causes diminution in body weight and in waist girth (Suk, 1929) and in total body fat (Cureton, 1958, 1963; Parísková et al., 1962). In both sexes and in all age-groups after puberty physically active people have less body fat than sedentary ones (Parísková, 1964).

Influence of physical training on resting pulse rate

According to Hunt and Pembrey (1921): "There is definite evidence to show that in any particular person the pulse rate is slower the better his physical condition".

This view is supported by McKenzie (1924). The mean resting pulse rate of trained athletes is slower than that of sedentary men (Cook & Pembrey, 1913; Hambly et al., 1922; Campbell, 1925; Henderson et al., 1927; Cotton, 1932; Schneider & Karpovich, 1948; Cullumbine, 1949a) and systematic physical training lowers the resting pulse rate (Dawson, 1919; Schneider et al., 1927; Jokl et al., 1941; Karvonen, 1959; Brouha, 1960b; Fletcher, 1960; Raab, 1960; Parízková et al., 1962; Holmgren et al., 1960). Montoye et al. (1960) noted that the resting pulse rate returned to its original level when training was abandoned. In contrast to these observations Cogswell et al. (1946) failed to detect any progressive decrease in resting pulse rate with training.

The slow resting pulse of the trained athlete has been attributed to an increase in the stroke volume of the heart (Henderson et al., 1927; Bock et al., 1928; Henry, 1954) with a corresponding increase in cardiac efficiency (Karvonen, 1958). The slower resting pulse allows of a greater increase with exercise up to the maximum rate of about 180 beats per minute for the healthy human heart (Maritz et al., 1961). An individual with a slow resting pulse rate will have a slower pulse rate

during and after moderate exercise than an individual with a faster resting pulse (Campbell, 1925; Tuttle & Salit, 1945; Schneider & Karpovich, 1948; Cullumbine, 1949d). With severe exercise the maximum rate is approached in every case so the absolute pulse increase is greater in the individual with a slow resting pulse (Tuttle & Salit, 1945; Schneider & Karpovich, 1948).

In general the resting pulse rate is an unsatisfactory measure of physical fitness, since it is influenced by so many factors besides physical fitness. Brouha and Heath (1943) failed to find any correlation between resting pulse rates and capacity for strenuous exertion.

Subjects and methods

The first investigation performed by Dr. Keen and myself (Keen & Sloan, 1958; Sloan & Keen, 1959a) gave a direct comparison of physical fitness between two groups of young men, comparable in most other respects, one of which was undergoing systematic training in physical education whereas the other group, although it included individuals who participated in various sports, had no systematic physical training. This investigation is described in Chapter 6.

In order to achieve a longitudinal study of the effect of training on physical fitness Dr. Keen and I next proceeded to investigate University oarsmen and rugby

players before and after a period of active physical training (Sloan & Keen, 1959b). Our subjects were 100 healthy male students, aged 17 to 24 years, at the University of Cape Town; of these 35 were members of the rowing club, 45 were members of the rugby club, and 20 (controls) were medical students who were not undergoing systematic training for any sport, although some of them played games such as golf, tennis, or squash racquets. Resting pulse rates were counted and the Harvard step test was performed, as in the first investigation. The subjects were tested at the beginning of the academic year and the tests were repeated after 2-4 months, during which the members of the rowing and rugby clubs had been undergoing intensive training for their respective sports.

A considerable number of subjects dropped out of the investigation after the first test. Eight members of the rowing club gave up rowing before the second tests were due and 3 failed to return for a second test. Four members of the rugby club stopped training and 10 were incapacitated by illness or injury before the second tests were due; 13 failed to attend for the second tests, the dates of which unfortunately coincided with examinations. Those rugby players who, for various reasons, did not perform

Table 6. Initial mean fitness indices and resting pulse rates of oarsmen, rugby players and controls

Group	N	Fitness Index	Resting Pulse
Rowing	35	80.2 [±] 12.0	79.5 [±] 14.4
Rugby	45	75.0 [±] 13.5	79.1 [±] 12.0
Control	20	56.0 [±] 19.9	84.8 [±] 10.1

In the tables in this chapter:

N = number of subjects

x[±]y represents mean [±] standard deviation

Table 7. Changes in mean fitness index of oarsmen and rugby players and controls after period of training

Group	N	Initial	Final	Significance of Change
Rowing	24	81.1 [±] 12.6	91.8 [±] 11.4	P<.001
Rugby	18	81.3 [±] 13.1	92.6 [±] 11.8	P<.001
Control	16	58.4 [±] 17.8	59.6 [±] 15.6	-

a second test represent a fair cross-section of the group on the basis of physical fitness and resting pulse at the first test. Only 4 of the controls failed to return, one of them owing to injury.

Results

As described in Chapter 6 and summarized in Table 1, a group of physical education students had a significantly higher mean FI and a significantly lower mean resting pulse than a comparable group of medical students. The absolute pulse increase also was significantly lower for the PE students (means 44.5, 51.7; $P < .05$) but the ratio of pulse increase to resting pulse was almost identical in the two groups (PE = 0.61; Med. = 0.62).

For the longitudinal study, Table 6 gives the mean FI and resting pulse of each of the athletic groups and of the control group at the beginning of the academic year. Analysis of variance revealed no significant difference in resting pulse rates between the groups but the mean FIs of the rowing and rugby groups were significantly higher than that of the control group ($P < .001$). There was no significant difference in FI between oarsmen and rugby players.

Table 7 gives the initial and final readings of FI

Table 8. Changes in mean resting pulse rates of oarsmen, rugby players, and controls after period of training

Group	N	Initial	Final	Significance of Change
Rowing	24	78.8 [±] 13.8	71.5 [±] 9.2	P<.01
Rugby	18	77.6 [±] 12.3	66.8 [±] 8.4	P<.01
Control	16	86.2 [±] 10.4	80.4 [±] 10.2	P<.05

for the members of each group who were re-examined at the end of the training period. There was a highly significant improvement in both the athletic groups but no significant change in the controls. Table 8 gives the corresponding results for the resting pulse. At the beginning of the investigation there was no significant difference in mean resting pulse rate between the three groups but all groups showed a significant reduction at the second set of tests, the fall being greater in the athletic groups. By the end of the investigation the mean resting pulse rates of the athletic groups were significantly lower than those of the controls ($P < .001$).

Discussion

The higher FI of the PE students in the first investigation has already been discussed (Chapter 6). The lower mean resting pulse and lower absolute pulse increase in this group have been noted. This investigation did not show whether the slower resting pulse rates of the athletic group were due to individuals with slow pulses choosing physical education as a career or to the effect of their physical training; both factors could be involved and their relative importance was studied in the next investigation. The lower absolute pulse increase of

the PE students performing the same test as the controls shows their greater efficiency; probably better muscle coordination puts less load on the heart and the trained heart, having a greater stroke volume, meets its requirements with a less prolonged increase in rate.

In the investigation of college athletes there was no significant difference in FI between the oarsmen and the rugby players either at the beginning or at the end of the period of investigation but both these groups had consistently higher mean FIs than the control group. It may be assumed that individuals proposing to compete for places in University teams take steps to achieve a high standard of fitness before the start of the academic year, but their resting pulse rates prior to training were not significantly lower than those of the control group.

After training the FIs were significantly higher than before in each of the athletic groups but not in the controls; this suggests that the change was due to the training since the academic and social background of the athletic and control groups was in other respects comparable. The similarity of response of the two athletic groups supports the contention that the Harvard step test is a valid test of fitness for strenuous effort. The training

of the rowing and rugby clubs was dissimilar except that, in both training schedules, the circulatory and respiratory systems were subjected to prolonged stress; the effects of training on FI, however, were very similar in the two groups. From this observation it may be concluded that the Harvard step test does not merely measure the individual's ability to perform the Harvard step test but has a wider significance as a measure of dynamic fitness.

The fall in mean resting pulse rate with exercise in each of the athletic groups during the training period was highly significant but a significant fall occurred also in the control group. The high resting pulse rates before the first attempt may have been due to apprehension since none of the subjects had previous experience of the test. Again, a change in environmental temperature may have been involved, since the initial tests were held during the hot months of February and March and the final tests during the cooler month of June, but this factor is probably unimportant since the tests were performed in a laboratory sheltered from direct sunshine. The fact that resting pulse rates of the athletic groups were significantly slower at the end of the training period than those of the controls supports the view that strenuous physical

training slows the resting pulse rate.

Summary

The much better performance of the Harvard step test by students of physical education than by other students, noted in Chapter 6, is evidence of the effect of systematic physical training on physical fitness.

In a longitudinal study, oarsmen, rugby players, and other, more sedentary, male students performed the Harvard step test at the beginning and end of a 2-4 month period, during which the athletes were training for their respective sports. The athletes had much higher FIs than the controls at the beginning of the investigation and their FIs showed a highly significant increase with training, whereas the FIs of the controls did not change significantly.

Physical education students had a lower mean resting pulse rate than others and a lower absolute pulse increase with the standard work of the Harvard step test. At the start of the longitudinal study there was no significant difference in resting pulse rate between athletes and non-athletes but, after training, the resting pulse rates of the athletes were much lower than those of the controls.

Chapter 8

Influence of anthropometric parameters on the
physical fitness of young women

During the past 8 years I have subjected numerous groups of young women to a modified Harvard step test. In 1964 4 such groups performed also a modified AAHPER test battery so that other aspects of fitness than endurance could be tested and any correlation between fitness index (FI) and the AAHPER criterion could be ascertained.

In general the same tests, sometimes with minor modifications, are suitable for women as for men, but different standards must be applied. The athletic performance of women is usually 10-30% below that of men, presumably because of the lower proportion of muscle in the female body (Nöcker & Böhlau, 1956). The athletic performance of trained women, however, equals or surpasses that of untrained men (Noack, 1954; Amateur Athletic Union, 1955) and, with the current secular improvement in athletic performances, some leading women athletes today outclass the leading men athletes of a few years ago (Jokl, 1964; Jokl et al., 1964). Sports injuries, however, are commoner in women (Klaus, 1964).

The mechanical efficiency of men and of women is very similar both on a step test and on a bicycle ergometer (Ryhming, 1954) but women usually have a faster pulse rate at rest (Hambly et al., 1922) and after exercise (Noack, 1954; Nöcker & Böhlau, 1956; Brouha & Harrington, 1957; McDonald, 1959; Brouha & Radford, 1960). The pulse rate after exercise takes longer to return to the resting level in women than in men (Brouha & Harrington, 1957; Hettinger & Rodahl, 1960; Brouha & Radford, 1960). The maximum cardiac output (Åstrand et al., 1964) and the maximum oxygen intake (Nöcker & Böhlau, 1956; Hollman, 1963, 1964) are usually lower in women than in men.

Master and Oppenheimer (1929) held that taller women have a greater exercise tolerance but Cullumbine et al. (1950) found no significant correlation between FI and either height or weight. Obese women, tested on a bicycle ergometer, have a lower mechanical efficiency (Wang et al., 1930a; Åstrand et al., 1960b) and less endurance (Wang et al., 1930b) than lean women. On treadmill tests obese women have a higher cardiac output (Alexander, 1964) and oxygen consumption (Turell et al., 1964) for the same work load.

Cullumbine et al. (1950) found that the mean FI of

women on a modified Harvard step test did not vary significantly with different physiques. Perbix (1954), applying standard somatotyping and 4 tests of motor fitness to 183 women students, found a significant positive correlation between mesomorphy and strength or power and a significant negative correlation between endomorphy and strength or agility.

Anthropometry

The same criteria for assessment of somatypes were employed in this investigation as in the investigation of men (Chapter 6), the series being divided into 3 more or less equal groups on the basis of relative ectomorphy, mesomorphy, or endomorphy.

Body fat was estimated from two skinfolds by the formula of Sloan et al. (1962) as follows:

$$SG = 1.0764 - 0.00081A - 0.00088B$$

A = vertical skinfold (mm.) over the right iliac crest in the mid axillary line

B = vertical skinfold (mm.) on the back of the right arm midway between acromion and olecranon processes.

From the specific gravity (SG) the proportion of fat (by weight) in the body was calculated as for men

(Chapter 6) by the formula of Keys and Brožek (1953).

Tests of fitness

The subjects of my first investigation on women (1958-59) performed a modified Harvard step test in which the step was 18 inches high instead of the 20 inches adopted for men (Chapter 3). The subjects wore leotards or shorts and tennis shoes, and the FI was calculated from 3 half-minute post-exercise pulse counts.

For the second investigation (1964) the height of the step was reduced to 17 inches, at which level the FIs of women performing the test are very similar to those of comparable groups of men using a 20-inch step (Sloan, 1959). The subjects of this investigation performed also the AAHPER test battery with two modifications, viz.: straddle chinning was substituted for modified pull-ups and timed sit-ups for the original untimed test with an arbitrary maximum of 50 sit-ups (Chapter 5). A composite criterion of fitness was derived from the results of the 7 AAHPER tests as for young men (Chapter 6).

Subjects and methods of investigation

For the first investigation 56 White women students performed the modified Harvard step test. Sixteen were

students of medicine and 15 students of physiotherapy at the University of Cape Town, and 25 were students of physical education (PE) at Cape Town Training College. Most of the physiotherapy students studying physiology in 1958 and the 2nd year women medical students in 1959 were tested and all the physical education students in 1958 and 1959. Their ages ranged from 17 to 21 years and all were medically fit. The heights, weights, and FIs of the medical and physiotherapy students (taken as one group) were compared with the same parameters for the PE students. Correlation coefficients were calculated between FI and height and FI and weight for the series as a whole.

For the second investigation 68 women students performed the modified Harvard step test (17-inch bench) and the modified AAHPER test battery (vide supra). Thirty-seven were White students at Cape Town Training College (13 PE and 24 controls) and 31 were Coloured students at Wesley Training College (7 PE and 24 controls). All the PE students at both colleges were tested and enough randomly selected other students to constitute control groups. Their ages ranged from 16 to 21 years and all were medically fit. Height and weight were measured and the RPI calculated. Body fat was estimated from skinfold measurements.

Table 11. Significance of differences in anthropometric parameters and fitness tests on 68 young women

Parameter or test score	White PE v. Con.	Coloured PE v. Con.	PE W v. C	Con. W v. C
Height	-	-	W>C (P<.001)	W>C (P<.01)
Weight	PE>Con. (P<.05)	-	W>C (P<.01)	W>C (P<.01)
RPI	-	-	-	-
Fat	-	-	-	W>C (P<.05)
RFI	PE>Con. (P<.001)	-	-	-
<u>AAHPER:</u>				
Pull-ups	-	PE<Con. (P<.05)	W>C (P<.05)	-
Sit-ups	PE>Con. (P<.01)	PE>Con. (P<.001)	-	-
Shuttle	PE>Con. (P<.001)	-	W>C (P<.05)	-
Jump	PE>Con. (P<.001)	PE>Con. (P<.001)	-	W<C (P<.05)
50-yard	PE>Con. (P<.001)	PE>Con. (P<.05)	-	-
Softball	PE>Con. (P<.001)	PE>Con. (P<.05)	-	W<C (P<.05)
600-yard	PE>Con. (P<.001)	PE>Con. (P<.001)	-	-
Criterion	PE>Con. (P<.001)	PE>Con. (P<.001)	-	W<C (P<.05)

PE = Physical education students; Con. = Control
W = White; C = Coloured
In the AAHPER tests A>B indicates a better performance by A, i.e. a shorter time for the runs or a higher score for the other tests.

Table 10. Anthropometric parameters and results of fitness tests on 68 young women

Parameter or Test score	White students		Coloured students	
	PE	Control	PE	Control
N	13	24	7	24
Height	166.2 [±] 3.8	164.8 [±] 5.7	158.9 [±] 4.4	159.0 [±] 5.8
Weight	62.8 [±] 5.8	58.7 [±] 6.0	54.3 [±] 6.6	51.1 [±] 6.1
RPI	41.9 [±] 1.1	42.3 [±] 1.6	42.0 [±] 1.0	43.0 [±] 2.1
Fat	21.1 [±] 3.4	21.3 [±] 4.1	20.0 [±] 2.4	19.0 [±] 3.8
RFI	73.3 [±] 9.2	57.1 [±] 15.7	74.7 [±] 6.8	60.9 [±] 20.5
<u>AAHPER:</u>				
Pull-ups	29.9 [±] 13.1	24.3 [±] 11.6	19.6 [±] 7.5	28.1 [±] 10.6
Sit-ups	25.9 [±] 5.9	19.6 [±] 4.0	25.3 [±] 1.5	18.5 [±] 4.1
Shuttle	10.0 [±] 0.5	10.8 [±] 0.7	10.4 [±] 0.4	10.6 [±] 0.7
Jump	81.0 [±] 8.9	65.8 [±] 8.7	79.9 [±] 7.1	70.1 [±] 4.1
50-yard	7.5 [±] 0.8	8.6 [±] 0.7	7.7 [±] 0.6	8.2 [±] 0.5
Softball	106.1 [±] 25.3	67.7 [±] 12.6	115.4 [±] 24.5	89.5 [±] 14.1
600-yard	135.1 [±] 8.7	172.9 [±] 24.9	131.1 [±] 6.4	163.3 [±] 18.3
Criterion	63.6 [±] 11.9	41.6 [±] 10.0	59.9 [±] 7.0	47.7 [±] 7.6

In the tables in this chapter:

RPI = reciprocal ponderal index

RPI = rapid fitness index (modified Harvard step test)

Fat = percent by weight of fat in the body

Pull-ups are straddle chinning

Results of AAHPER tests are raw scores as described in text; criterion is derived from sum of T-scores for each test as described in text.

Table 9. Height, weight, and fitness index of 56 young women

Parameter	Medical & Physiotherapy Students	Physical Education Students	Significance of Difference
N	31	25	
Height	164.6 [±] 6.77	163.9 [±] 4.41	-
Weight	59.0 [±] 6.92	59.8 [±] 7.93	-
FI	56.4 [±] 17.20	75.2 [±] 10.91	M<PE (P<.001)

In the tables in this chapter:

N = number of subjects

FI = fitness index on modified Harvard step test

Height is measured in centimetres and weight in kilograms

$\bar{x} \pm y$ represents mean \pm standard deviation

- indicates no significant difference

Physical fitness was assessed by the modified Harvard step test and the modified AAHPER test battery.

Results

The results of the first investigation on women are given in Table 9. There was no significant difference in height or weight between the two groups but the PE students had a much higher mean FI. In the series as a whole there was a low but significant positive correlation between FI and height ($r=.32$; $P<.05$) and between FI and weight ($r=.28$; $P<.05$). Excluding from the series one exceptionally heavy young woman (92.5 kg.) with a high FI (93) the correlation of FI with weight failed to reach significance.

The results of the second investigation are shown in Table 10 and the significance of difference between the groups in Table 11. As in the corresponding investigation on men (Chapter 6) the tables are based on raw scores so a lower score for the runs indicates a better performance. White students were significantly taller and heavier than Coloured students and White PE students heavier than White controls. White controls had more body fat than Coloured controls. There was no significant racial difference in RFI but, in the White group only the PE students had a significantly higher mean RFI than the controls. On the

Table 12. Correlations of individual AAHPER test results with AAHPER criterion and with RFI in 68 young women.

Test	Correlation with criterion	Correlation with RFI
AAHPER criterion	-	.616
Pull-ups	.516	.275
Sit-ups	.693	.409
Shuttle run	.787	.505
Broad jump	.861	.533
50-yard dash	.853	.512
Softball throw	.729	.352
600-yard run	.823	.670

AAHPER tests of White students the PE group was significantly superior to the controls in every test except the pull-ups (straddle chinning) and in the total criterion. Coloured PE students were significantly superior to their controls in every test except the shuttle run and in the total criterion. In the inter-racial comparison of PE students the White women were superior at pull-ups (straddle chinning) and shuttle run; in the inter-racial comparison of the control students the Coloured women were superior at the standing broad jump, the softball throw, and the total criterion. The T-scores from which the AAHPER criteria were derived are given in Table A₂ (Appendix).

In the second series as a whole the RFI had no significant correlation with height but a low negative correlation with weight ($r = -.250$; $P < .05$) and with body fat ($r = -.345$; $P < .01$) and a low positive correlation with RPI ($r = .249$; $P < .05$). The AAHPER criterion had a low negative correlation with body fat ($r = -.331$; $P < .01$). There was fair correlation between RFI and AAHPER criterion ($r = .616$; $P < .001$). The AAHPER had a highly significant correlation ($P < .001$) with each of its constituent tests, the best being the standing broad jump (Table 12). The

RPI had lower but significant correlations with the AAHPER tests, the poorest ($P < .05$) being with pull-ups and the best ($P < .001$) with the 600-yard run-walk.

In women the ectomorphs had the highest mean RPI and the endomorphs the lowest but the differences were not significant. The mean AAHPER criterion was slightly higher for mesomorphs than for ectomorphs, both of which were higher than endomorphs but none of the differences was significant.

Discussion

Both these investigations demonstrate the greater physical fitness of PE than of other women students. The taller subjects showed little superiority at the Harvard step test and none at the AAHPER tests, although the more ectomorphic (high RPI) achieved a higher AAHPER criterion. Weight was not an important factor but a high proportion of body fat proved a handicap both in the Harvard step test and in the AAHPER tests, as others have found it in tests with bicycle ergometer or treadmill (vide supra).

The high correlation between AAHPER criterion and each of its individual tests shows, as in men, that this is a well-balanced test battery. The highly significant correlation between AAHPER criterion and RPI in women, is

easier to understand than the very poor correlation in men, since both parameters are measures of physical fitness. In women, as in men, the RFI, which is an endurance test, had a higher correlation with the AAHPER endurance test (600-yard run-walk) than with the total criterion, and its lowest correlation was with the test of arm strength (pull-ups).

Although the White women were taller and heavier than the Coloured there was no consistent difference in performance between the two racial groups, the White PE students showing slight superiority in tests of strength and agility and the Coloured control students some superiority in tests of power and coordination and in the total criterion. These results suggest that the differences are sociological rather than physiological, the White PE course being more strenuous than the Coloured and the Coloured control students more physically active than the White control students.

The proportion of fat in the bodies of these young women was 20.32% for the series as a whole, which is very close to the figures of 20.06% for young women in North Carolina reported by Sloan et al. (1962) and 20.3% for young women in Stockholm (von Döbeln, 1956). Young et al.

(1961) gave higher figures (corresponding to a mean of 24.9% by the Keys-Brošek formula) for young American women at Cornell University.

The lack of significant correlation between somatotypes and the results of the fitness tests, in spite of the negative correlation established between obesity and fitness, indicates that body shape, except in so far as it is influenced by obesity, is not an important factor in the physical fitness of these young women.

Summary

The influence of anthropometric parameters on physical fitness, assessed by the modified Harvard step test, was studied on 2 series of healthy young women, one of which also performed the AAHPER test battery. Height and weight were measured in every case. In the second series, which included White and Coloured groups, the RPI was calculated from height and weight, body fat was estimated from skinfold measurements, and a rough classification of somatotypes was based on RPI and body fat.

The only parameter which consistently influenced the performance of the Harvard step test and of the AAHPER test battery was the proportion of body fat, the more obese subjects being less fit. Although the White women were

much taller and heavier than the Coloured there was little difference in physical fitness between the two groups.

There was a highly significant correlation between the two estimates of physical fitness (FI or RFI and AAHPER criterion), and between the criterion and each of its constituent tests. The highest correlation of RFI with an AAHPER test was with the 600-yard run-walk.

The body build of the young women, apart from obesity, did not significantly influence their performance of the tests.

Chapter 9

Influence of physical training on the physical fitness
of young women

In 1959, at the request of the Principal of Cape Town Training College, I tested the physical fitness of different groups of women students at intervals during the year, in order to establish whether the physical training programmes in which some of them participated produced any measurable change in physical fitness.

After exercise the pulse rate returns to the resting level more quickly in athletic than in non-athletic women (Hartwell & Tweedy, 1913) and the FIs on a modified Harvard step test are higher in physically active than in sedentary women (Skubic & Hodgkins, 1963). Salit and Tuttle (1944) found that the pulse count 2 minutes after a standard exercise was lower in women who took regular active exercise than in others; blood pressure measurements failed to distinguish between the groups.

The FIs of women are raised by physical training (Hardy et al., 1943; Weld, 1946) and 2 45-minute periods of outdoor sports per week are sufficient to cause a significant increase (Clarke, 1943). Young women studied by

Maxfield (1964) showed a reduction in heart rate during and after standard work as a result of systematic training on a bicycle ergometer; also their work capacity increased. In women as in men work capacity is increased by systematic physical training (Hollman, 1963; Holmgren et al., 1960). Mohr (1944) found no consistent change in the results of endurance tests after systematic physical training but strength and agility increased. McCue (1963) demonstrated increased flexibility in women after appropriate exercises.

The resting pulse rate is slower in athletic than in non-athletic women (Hartwell & Tweedy, 1913) and slower in fitter women, fitness being assessed on a bicycle ergometer test (Tuttle & Salit, 1945).

The traditional ideas that menstruation is a contra-indication for physical activity and that strenuous exertion is likely to cause menstrual disturbances have been challenged by several investigators. Clow (1932) and Ryde (1957) affirmed that dysmenorrhoea can often be cured by active exercise. Bausenwein (1954) advised that competitive sport and strenuous training should be avoided shortly before and during menstruation but Ingman (1953) and Abrahams (1958) found no evidence of menstrual

disturbances arising from competitive sport. Both Ingman (1953) and Bausenwein (1954) reported that many champion female athletes performed better during menstruation than at other times.

There is no evidence that competitive sport causes subsequent complications of pregnancy or of labour (Niemieneva, 1953; Amateur Athletic Union, 1955).

Subjects and methods

The subjects of this investigation (Sloan, 1961) were 66 women students, aged 17 to 20 years, at Cape Town Training College. Of these students, one group in the 3rd year of training was specializing in physical education; their weekly programme included 2½ hours of gymnastics, 2 hours of dancing and at least 2 hours of games. A second group of 3rd year students was specializing in infant-school teaching (IST); they spent 40 minutes a week at gymnastics and participation in games was not obligatory. The remaining students were all in their 1st year of general training; one group had gymnastics for 40 minutes each week and obligatory games; the other group had neither.

The height and weight of each subject were measured at the beginning of the investigation and a menstrual history

was obtained at each test to ascertain whether the subject was menstruating or about to menstruate at the time. The modified Harvard step test with an 18-inch step, was employed and the subjects were dressed in light gymnastic costume and tennis shoes. The tests were performed in an unheated room usually between 9 a.m. and 12.30 p.m. and room temperatures were recorded. The first set of tests was performed at the beginning of the scholastic year, in January and February, and the tests were repeated 4 months and 9 months later. All the PE students performed the 3 tests. Three IST students and 2 others were absent from the 2nd and 3rd tests, so have not been included in the series.

In addition to the FI the resting pulse rate was determined, usually between 2 and 3 p.m. To avoid the effect of excitement in anticipation of the test, or any residual effect of exercise, the resting pulse was counted either several hours after the test or on a different day. The subjects were seated and relaxed for at least 5 minutes before the resting pulse was counted and the pulse rate per minute was calculated from 3 half-minute readings taken at half-minute intervals.

Table 13. Changes in fitness index of 61 women students during the academic year

Group	No.	1st test	2nd test	3rd test
Physical education	13	61.2 [±] 15.5	73.0 [±] 11.7	76.8 [±] 4.7
Infant school	18	46.8 [±] 18.4	48.2 [±] 18.2	48.1 [±] 19.3
General course:				
With gymnastics	19	51.1 [±] 17.9	53.8 [±] 18.4	52.3 [±] 18.5
Without gymnastics	13	41.1 [±] 18.3	37.9 [±] 17.8	36.6 [±] 12.7

In the tables in this chapter:

$\bar{x} \pm y$ represents mean \pm standard deviation

Results

There was no significant difference in height or weight between the groups and no correlation was found between FI and height or weight, except in the case of IST students, where the heavier subjects did less well. In this group there was a wider anatomical range of size and shape than in the other groups. In the series as a whole there was practically no difference between the average performance of those who were menstruating at the time and those who were not, the mean FIs being 49.8 and 50.0 respectively.

Room temperatures during the first set of tests varied between 19 and 24°C, except on one very hot day (29.5°C) when the PE students were being tested. The second tests were carried out during the cool season at temperatures of 14.5-16.5°C and the third tests at 18.5-23.5°C.

Table 13 shows the mean fitness index of each group at each test. The students who were about to specialize in PE had a higher FI than the IST students ($P < .05$) or the general course students who did not propose to do gymnastics ($P < .01$). There was no significant difference between the FIs of the other groups. At the second tests the PE students had higher fitness indices than at the first tests ($P < .001$); this improvement was maintained

Table 14. Changes in resting pulse rate of 61 women students during the academic year

Group	No.	1st test	2nd test	3rd test
Physical education	13	88.7[±] 9.5	73.8[±] 7.7	80.6[±]10.0
Infant school	16	80.5[±] 9.6	86.7[±] 4.3	86.7[±]15.7
General course;				
With gymnastics	19	79.6[±] 8.7	86.8[±]12.4	78.9[±] 8.6
Without gymnastics	13	89.4[±]11.0	87.7[±] 9.2	82.3[±] 8.6

without further significant change at the third tests. Although no significant change in FI occurred in any other group, at the second tests there was a significant difference in FI between the general course students who did gymnastics and those who did not ($P < .05$); this difference was maintained at the third tests.

Table 14 summarizes the resting pulse rates at each stage of the investigation. At first the mean resting pulse rates of PE and of general course students who did not propose to do gymnastics were significantly higher than those of the other 2 groups ($P < .05$). The mean resting pulse rate of the PE students fell during the first 4 months ($P < .001$) but rose again during the ensuing 5 months ($P < .05$). The IST and general course students doing gymnastics showed a significant increase in resting pulse at the end of 4 months ($P < .01$), which was maintained by the IST but not by the other students. The students doing no gymnastics showed a significant fall in pulse rate over 9 months ($P < .05$).

At the first set of tests there was no correlation between FI and resting pulse. At the second tests, although no individual group showed such correlation, in the whole series a high FI was associated with a low resting pulse

($P < 0.05$). This correlation no longer held at the third tests.

Discussion

The lack of correlation between fitness indices and height or weight in this investigation agrees with previous observations on men (Chapter 6) and with some previous observations on women (Chapter 8). The absence of any adverse effect of menstruation on the performance of strenuous physical work is to be expected in view of modern opinion on this topic.

It is not surprising that the students who intend to make physical education their career should have higher FIs than the others; presumably they are more physically active. The highly significant increase in FI of these students during the year is evidence of the efficacy of their strenuous programme of physical training, since no such change occurs in any other group. Even the much less strenuous gymnastic programme of the general course, however, seems to have some beneficial effect. The general course students who did gymnastics were significantly fitter after 4 months than those who did not; the latter showed a steady though not significant fall in FI. This suggests that at least a certain minimum amount of regular physical training is advisable to counteract the tendency

to physical deterioration of the more sedentary students.

The PE students had unexpectedly high resting pulse rates at the beginning of the investigation. Since these were recorded on an exceptionally hot day they may have been influenced by the environmental temperature. The resting pulse rates of these students were lower after a period of training but rose again while the training was still in progress. No comparable changes occurred in other groups, and the students doing no gymnastics showed a steady fall in resting pulse rate during the period of investigation. It may be that the effect of a little physical activity is to increase the resting pulse rate, presumably by stimulating metabolism, whereas greater activity reduces it again by a compensatory increase in cardiac efficiency. This hypothesis would explain all the observations except the final rise in pulse rate of the PE students.

The lack of correlation between FI and resting pulse rate is surprising. One would expect a slow resting pulse to be associated with a slow post-exercise pulse but the resting pulse is influenced by so many extraneous factors, not connected with muscular activity, that it is a much less reliable measure of physical fitness than is the

Harvard step test.

Summary

To ascertain the effect of physical training on young women, 4 groups were subjected to a modified Harvard step test at the beginning of the academic year and again 4 and 9 months later. One group, specializing in physical education, had a very active programme of gymnastics, dancing, and games; two other groups had a much less active programme; a fourth group had no regular physical training. In the series as a whole there was no correlation between FI and either height or weight and no evidence that menstruation influenced performance of the test. At the beginning of the investigation the PE students had higher FIs than the others and they improved with training. Lesser degrees of physical training caused no significant increase in FI but counteracted a tendency to deterioration observed in the group that had no physical training. Changes in the resting pulse were less consistent and resting pulse rates showed little correlation with FIs.

Chapter 10

Comparison of the physical fitness of young adults
in South Africa, North Carolina, and England

In comparing the athletic performance of different groups of men or women a major difficulty is the standardization of test conditions and of interpretation of results. This is the case particularly when different national groups are being tested, each in their own country, and the only satisfactory solution is for the same investigator or team of investigators to visit and supervise the tests in each of the countries concerned. In 1960 and 1961 I was fortunate in having the opportunity to test the physical fitness of college students in Cape Town and Paarl (Cape Province, South Africa), Greensboro and Chapel Hill (North Carolina, U.S.A.) and London and Exeter (England).

Although international comparisons of the physical fitness of champion athletes are made regularly at Olympic Games and other events (Cureton, 1951a; Jokl et al., 1964), similar studies on non-athletes are rare. Andersen et al. (1960) observed that the maximum oxygen intake (MOI) of healthy male Yukon Indians, on a bicycle ergometer test,

was lower than that of either athletic or sedentary Scandinavian men; in terms of body weight the MOI of the Indians was lower than that of the athletic but higher than that of the sedentary Scandinavians. Hettinger et al. (1961) found the mean MOI of a group of healthy but untrained American men much lower than that of a comparable group of Swedes tested by Åstrand.

Subjects and methods of investigation

The subjects for my international comparison were 114 healthy white men and 122 white women aged 18-25 years, including physical education (PE) and other students in each country (Sloan, 1963). The PE students, except the English women, were in their third year at college but in their first year of specialized training as teachers of physical education; the English women were second-year students of physical education. All the non-athletic students were in their second year at college. There was no selection of PE students, the whole class at each place being tested, but individuals in active training for competitive sport were excluded from the control groups.

Each subject was questioned about sporting activities and previous medical history, and a menstrual history was obtained from each woman to relate the date of performance

of the test to the time in her menstrual cycle. The height and weight of each subject, wearing light gymnastic costume without shoes, were measured.

Every attempt was made to standardize the test conditions. The tests were performed between 8.30 a.m. and 1 p.m. during the cool season of the year, June in South Africa, February in North Carolina, and November in England. In South Africa the room was unheated, with open windows, and the range of temperatures was 14-22°C; in North Carolina no unheated room was available but, with windows open, the range of temperature was 15-23°C; in England the women were tested in a heated room with open windows (17-19°C) but the men in a very cold gymnasium (9-11°C). All barometric pressures were within the range 743-769 mm.Hg. but relative humidities varied widely.

Since the performance of an exhausting test depends on motivation as well as on physical fitness each group of students was told that the investigation was an international comparison of fitness and that their performance was a matter of national prestige. Each subject was actively encouraged to complete the test if he or she showed any sign of failing to do so.

The students performed the Harvard step test, dressed in

**Table 15. Number of students in each group in
South Africa, North Carolina, and
England**

Subjects	S. Africa	N. Carolina	England
PE Men	15	16	18
Control Men	20	23	22
PE Women	14	15	21
Control Women	28	22	22

. In the tables in this chapter:

PE = physical education students

Table 16. Height of students in South Africa, North Carolina, and England

Subjects	S. Africa ¹	N. Carolina ²	England ³	Significant Differences
PE Men	175 [±] 6.6	182 [±] 8.0	173 [±] 4.1	2>3 (P<.001) 2>1 (P<.01)
Control Men	181 [±] 6.8	178 [±] 6.7	176 [±] 5.4	1>3 (P<.05)
PE Women	166 [±] 6.8	164 [±] 5.1	165 [±] 6.3	-
Control Women	166 [±] 6.4	164 [±] 6.5	162 [±] 5.9	1>3 (P<.05)

In the tables in this chapter:

Height is measured in centimetres and weight in kilograms

x[±]y represents mean ± standard deviation

- indicates no significant difference

Table 17. Weight of students in South Africa, North Carolina and England

Subjects	S. Africa ¹	N. Carolina ²	England ³	Significant Differences
PE Men	74.7 [±] 9.1	86.7 [±] 11.0	73.2 [±] 5.3	2>3 (P<.001) 2>1 (P<.01)
Control Men	70.9 [±] 7.8	71.2 [±] 9.7	69.8 [±] 8.3	-
PE Women	61.9 [±] 10.5	57.1 [±] 6.4	60.0 [±] 6.5	-
Control Women	61.4 [±] 8.5	55.8 [±] 12.0	56.4 [±] 6.2	-

light gymnastic costume and wearing rubber-soled canvas shoes. The bench was 20 inches high for men and 17 inches high for women and standard test conditions were applied (Chapter 3). As well as the fitness index (FI) calculated from 3 post-exercise counts, the rapid fitness index (RFI) was calculated from the first post-exercise pulse count in each case.

The curriculum of each college was studied to ascertain the number of hours of PE and of compulsory games laid down for each group of students and I watched some PE classes at each college to get an impression of the strenuousness of the course.

Results

Table 15 gives the number of subjects in each group and Tables 16 and 17 the heights and weights of the several groups. The male PE students in North Carolina were taller and heavier than other PE students. The South African non-athletic men were taller than the English but not significantly taller than the Americans. There was no significant difference in weight between the control groups of male students. Within the national groups the PE men were heavier than the controls in North Carolina ($P < .05$) and the controls were taller than the PE men in South Africa ($P < .05$). In the women there was no significant

Table 18. Fitness index of students in South Africa, North Carolina, and England

Subjects	S. Africa ¹	N. Carolina ²	England ³	Significant Differences
PE Men	85.0 [±] 4.9	66.0 [±] 16.6	95.8 [±] 15.5	<u>3</u> > <u>2</u> (P<.001) <u>3</u> > <u>1</u> (P<.01) <u>1</u> > <u>2</u> (P<.001)
Control Men	64.2 [±] 15.6	68.3 [±] 19.9	82.1 [±] 14.5	<u>3</u> > <u>2</u> (P<.05) <u>3</u> > <u>1</u> (P<.01)
PE Women	67.1 [±] 12.4	57.2 [±] 18.6	70.2 [±] 16.7	<u>3</u> > <u>2</u> (P<.05)
Control Women	40.1 [±] 16.9	41.4 [±] 17.6	61.0 [±] 16.0	<u>3</u> > <u>2</u> (P<.001) <u>3</u> > <u>1</u> (P<.001)

Table 19. Hours allocated to physical training in South African, North Carolinian and English curricula

Subjects	S. Africa ¹	N. Carolina ²	England ³
PE Men	10.25	18.00	11.00
Control Men	nil	2.00	nil
PE Women	8.00	6.00	4.50
Control Women	nil	2.00	0.75

difference in height or weight between the 3 nationalities of PE students. The South African controls were significantly taller than the English but not than the Americans; the differences in weight were not significant. There was no significant difference in height or weight between any group of female PE students and the corresponding control group.

In terms of FI on the Harvard step test the English PE students were the fittest of the national groups of men and the South Africans were fitter than the Americans (Table 18). In the male controls too the English were the fittest but the difference between Americans and South Africans was not significant. English and South African male PE students were fitter than the corresponding control groups ($P < .05$; $P < .001$); in North Carolina the controls had a higher mean FI than the PE students but the difference was not significant. In the international comparison of women the English PE students were fitter than the Americans but not significantly fitter than the South Africans; of the control groups of women the English were the fittest and the difference between the South Africans and Americans was not significant. In South Africa and in North Carolina

female PE students were fitter than the controls ($P < .001$; $P < .05$) but in England the difference was not significant.

Neither in any individual group nor in the series as a whole was there significant correlation between FI and weight. There was no significant correlation between FI and height in any individual group but, taking the men students as a whole, there was a low negative correlation between FI and height ($r = -.211$; $P < .05$). There was no significant correlation between FI and height in women. There was no significant difference in FI between the women who performed the test during a menstrual period or within the 2 days prior to menstruation and other women.

In the whole series the correlation between the FI used in this investigation and the RFI was very high ($r = .996$).

Table 19 gives the allocation of time to physical training (including compulsory games) for each group. More time was allotted to physical activity in the curriculum of male PE students in North Carolina than in that of any other group. The highest allocation of physical training time for women was in South Africa. In the control groups men and women in South Africa and men in England had no physical training in their curricula.

Discussion

Working single-handed with many other commitments it was impossible for me to test a large and representative cross-section of college students in each nation. Although each of the colleges where the tests were performed has a high reputation in its own community it would be unreasonable to interpret my findings as representing systematic differences in fitness between South African, American, and English students. The results, however, are of interest, and possible explanations will be considered.

Any influence of environmental factors on the results was minimized by standardisation of the test conditions. Since all the tests were performed under conditions to which the subjects concerned were accustomed it is unlikely that environmental factors would have much influence on the results.

Since all the subjects were of European stock, no difference in racial aptitude for this form of exertion is likely to be involved.

The significant differences in mean FI of the different groups might be due to differences of bodily habitus. Since there is no significant correlation between FI and either height or weight in any individual group the

negative correlation between FI and height in the men in this series may be attributed to the number of tall Americans with low FIs. Reedy and Saiger (1954), in the United States, found a significantly poorer performance of this test in heavier young men. In the present investigation the male PE students in North Carolina were considerably heavier than their opposite numbers in the other countries and it may be that their low FIs are attributable to the extra work done in lifting the extra weight at each step. Unfortunately, when this investigation was performed, I had not yet acquired the equipment for determination of body fat.

In North Carolina most male students were performing the Harvard step test for the first time, whereas in South Africa the male PE students and in England all the male students had performed it previously. All the female students were performing it for the first time. Previous investigations on men (Sloan & Keen, 1959b) and on women (Sloan, 1961) showed no improvement in FI as a result of previous performance of the test, although systematic practice at it results in significant improvement (Jung, 1951; Insull et al., 1955; Fletcher, 1958a,b, 1960).

The finding that neither menstruation nor the premenstrual

period impaired performance of a severe physical test supports my previous conclusion (Chapter 9) that healthy young women are capable of strenuous physical exertion at these times.

The very close agreement between the FIs calculated from 3 post-exercise pulse counts and the RFIs calculated from 1, supports the contention that the standard method may satisfactorily be replaced by the rapid (Chapter 3).

Although a detailed comparison of method and intensity of physical training between different colleges is difficult if not impossible it is of interest to compare the average time devoted to physical training during class hours by each group of students. The times given in Table 19 are those on the timetables, and include time for changing and for instruction. In South Africa and in England circuit training (Adamson & Morgan, 1954; Morgan & Adamson, 1961), which promotes strength and endurance, was an integral part of the physical training programme for male PE students and in South Africa a suitably modified version was used for female PE students, but it was not used in North Carolina. Apart from circuit training the several courses covered a wide range of physical activity, with emphasis on the national games in each country and on the development of agility and strength in men and of agility

and grace in women.

The male PE students in North Carolina, although devoting the most time of any group to physical activity, had lower FIs than the other PE students. My impression of their training was that it was less strenuous than that in South Africa or in England. The fittest control group, the English, had no compulsory physical training but many of them used the gymnasium after class hours and most of them participated actively in sport.

The female students with the highest FIs, PE students in England and South Africa and controls in England, had more strenuous physical activity in their courses than female students in North Carolina. The American female controls with two periods of not very active physical training per week were not significantly fitter than the South Africans with none.

The finding that most groups of women had lower fitness indices than the corresponding groups of men indicates that the modified test may have to be modified still further by reducing the height of the bench below 17 inches or by reducing the duration or rate of stepping to obtain comparable results in both sexes. Since 1958, when the 17-inch bench for women was found to give results

corresponding very closely to those of men on a 20-inch step (Sloan, 1959), I have observed a progressive decline in the dynamic fitness of female students in Cape Town, whereas that of male students has varied little. No explanation of this phenomenon, which has been observed also by Milicer and Denisiuk (1964b) in Poland, is apparent but it seems that no satisfactory standards for the comparison of men's and women's performance on the Harvard step test have yet been established.

Apart from physical activity in the curriculum the amount of extra-mural physical exercise performed by individuals varies so widely that it is difficult if not impossible to assess. Any difference between groups is likely to be due in part to the local attitude to physical activity. In the United States, where motor transport has largely replaced pedestrianism, even for school children, and where both school and college sports attract many more spectators than participants, the danger of young men and women taking less exercise than the minimum required to maintain physical fitness is particularly great. In South Africa, although young men and women walk less than in England, many participate in at least one active sport. This may explain why the South African controls with no compulsory

physical activity, were not significantly less fit than the Americans with two sessions a week of physical training.

Summary

The Harvard step test was performed by male PE students and by other male students in Cape Province (South Africa), North Carolina (United States of America) and England. A modified Harvard step test was performed by corresponding groups of women in these places. As far as possible the test conditions were made similar for all groups.

The American PE students were taller and heavier than the others and the South African control men were taller than the English. There was no significant difference in height or weight between the 3 groups of female PE students but South African control women were taller than the English.

The fittest male PE students were the English, and the South Africans were fitter than the Americans. Of the non-athletic men, the English were the fittest and there was no significant difference in fitness between South Africans and Americans. English female PE students were not significantly fitter than South Africans but were fitter than the Americans. Of the non-athletic women the English

were the fittest and there was no significant difference in fitness between South Africans and Americans.

With one minor exception no significant correlation was found between FI and height, weight, or time devoted to organized physical training. Differences in dynamic fitness may be partly explained by different degrees of physical activity in the curricular training and by different amounts of extra-curricular physical activity.

Menstruation did not impair the performance of female students on the modified Harvard step test.

The rapid method of calculating fitness index gave results almost identical with those obtained from the original method.

PART III

PHYSICAL FITNESS OF HIGH SCHOOL CHILDREN

Chapter 11
Physical fitness of
South African high school children

The physical fitness tests appropriate for children are mentioned in Chapters 2, 3, and 4, and the AAHPER test battery, which I have used in most of my investigations on school children, is described in detail in Chapter 5.

With children, as with adults, different standards must be set for male and for female. Before puberty there is little or no sex difference in work capacity as assessed by pulse ratio (Faine & Mathews, 1951), maximum oxygen intake (Hollman, 1963), or athletic performance (McDonald, 1959; Espenschade, 1960) but girls are superior at tests of flexibility (Phillips et al., 1955). At all ages, boys are better at jumping and at throwing (McDonald, 1959; Espenschade, 1960). After puberty boys are superior in work capacity (Hettinger & Rodahl, 1960; Adams et al., 1961a, b) and at athletic tests (Fowler & Gardner, 1963; Sexton, 1963), although trained girls may equal or surpass untrained boys of the same age (Jokl, 1963, 1964; Milicer & Denisiuk, 1964b).

Although no allowance need be made for age in young adults of either sex, age is an important factor in the athletic performance of children. Most observers agree that the physical fitness of boys, estimated by tests of speed, strength, and endurance, increases progressively up to 18 or 19 years of age (de Jongh et al., 1942; Hunsicker, 1958; McDonald, 1959; Espenschade, 1960, 1963; Gross & Casciani, 1962; Fowler & Gardner, 1963; University, 1963; Mellerowicz, 1964), but Karvonen (1964) found no age trend with a step test, squat jumps, or forehead-knee touches and Cullumbine et al. (1950), using a modified Harvard step test, described a decline in the fitness index of boys at the age of 13 followed by a rise starting at 17. There is fairly general agreement that the athletic performance of girls improves with age up to puberty, after which there is either no further improvement (Hunsicker, 1958; Espenschade, 1960, 1963; Gross & Casciani, 1962) or deterioration, especially in endurance (Cluver et al., 1942; de Jongh et al., 1942; Cullumbine et al., 1950; Åstrand, 1956; McDonald, 1959; University, 1963; Jokl, 1964). Strength, as estimated by shot-put (de Jongh et al., 1942) and standing broad jump (Burley et al., 1961) show progressive improvement with age in both sexes and highly

trained girl athletes do not deteriorate, as do other girls, at the other tests (Skubic & Hodgkins, 1963). The deterioration in physical performance of girls after puberty may be due to lack of interest and motivation rather than to physical disability (McDonald, 1959; Espenschade, 1960). From analysis of AAHPER test results in more than 13,000 American children, Gross and Casciani (1962) concluded that senior high school boys, senior high school girls, junior high school boys and junior high school girls may each be regarded as a homogeneous group with respect to the effect of age on performance of the tests.

Although mesomorphs are stronger than ectomorphs of the same age (Espenschade, 1960) there is in general little or no correlation between somatotype and the results of fitness tests on children (Burley et al., 1961). The physical fitness of children is not significantly related to either height or weight (Gallagher & Brouha, 1943c; Hettinger & Rodahl, 1960; Gross & Casciani, 1962; Espenschade, 1963) but obesity is a handicap (Bookwalter, 1952; Milicer & Denisiuk, 1964a). Age alone is a better basis for establishing test norms than is a combination of age, height, and weight (Espenschade, 1963).

Inter-racial studies of the physical fitness of children have been reported from South Africa, the United States of America, and Ceylon. Cluver et al. (1942) applied 3 tests (100-yard run, 600-yard run, and 12-lb. shot-put) to 9,214 South African children, classified as European, Bantu, and Asiatic. Up to puberty the Bantu boys and girls were superior to the other groups, except at the shot-put, where European boys were better than Bantu boys. After puberty the European boys led in all the tests and European girls were better than other girls at the 100-yard run. Asian children (Chinese and Indian) were the poorest at all the tests. Botha et al. (1945), applying these tests to 1,542 European and Bantu children, found that Bantu children performed better at the runs, in spite of a high incidence of malnutrition and parasitic infestation, whereas European children were better at the shot-put, performance of which was related to body weight. Applying the Kraus-Weber tests to 2,626 White and Bantu children, Smit (1961) found greater flexibility in the Bantu. Rodahl et al. (1961), in Philadelphia, found no significant difference in work capacity between White and non-White children. Cullumbine et al. (1949c) in Ceylon, found racial differences in performance of fitness tests,

which could be attributed to different economic and nutritional circumstances.

The physical fitness of boys and girls improves significantly with systematic physical training (Parizkova et al., 1962; Hollman, 1963; Jokl, 1963; Knuttgen & Steendahl, 1963; Sexton, 1963; Fabricius, 1964; Jacobziner, 1964; Milicer & Denisiuk, 1964b). The physical fitness of high school pupils is related to the quality of the physical education programme at their schools (Rosenstein, 1963; Rosenstein & Frost, 1964) and, in the case of girls, to their participation in extra-curricular physical activity (Damez et al., 1926; Kammeyer, 1956).

Faine and Mathews (1951) reported a lower standard of physical fitness in more intelligent children, whereas Clarke (1958) found a higher scholastic performance in the more physically fit. Shaw and Cordts (1960), in a review of this problem, conclude that no significant correlation has been established between mental and physical fitness.

Subjects and methods of investigation

The subjects of my first investigation on school children were more than 6,000 boys and girls at 15 high schools in or near Cape Town. These schools serve upper,

middle, and lower income groups of the White and of the Coloured communities, and the only Bantu high school in Cape Town is included. The 'Coloured' pupils are mostly of mixed European and African stock but include a small proportion of Asians, mostly Malay or Indian. At each school every pupil, who was not exempted on medical grounds from physical activity, was subjected to the tests. Analysis was limited to the age groups 12-18 and any incomplete records were rejected, leaving 5,962 subjects in all.

The tests performed were those of the original AAHPER test battery (Chapter 5). At each school I explained the tests to the physical education staff and to the pupils and personally supervised many of the tests to ensure uniformity of scoring. Sex, age, height, and weight were recorded for each pupil, as well as the score for each of the 7 tests. Age was taken as age in years at last birthday. Height was measured to the nearest half-inch and weight to the nearest pound. Racial segregation in the schools facilitated an inter-racial comparison. The performance of the several tests by South African boys and girls of all races was later compared with the performance of British and American children at the same tests (Chapter 12).

A.A.H.P.E.R.
INTER-RACIAL
COMPARISON

BOYS	WHITE	■——■
	COLOURED	▲——▲
	AFRICAN	●——●
GIRLS	WHITE	□-----□
	COLOURED	△-----△
	AFRICAN	○-----○

Fig. 9

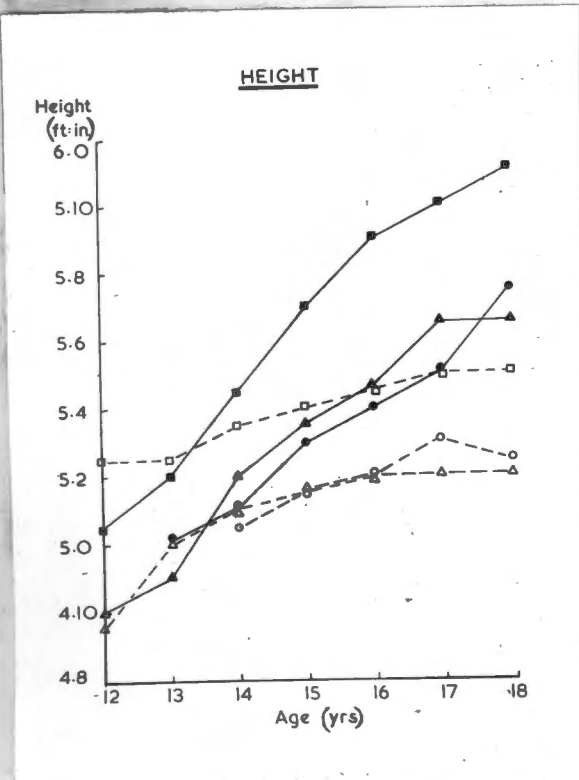


Fig. 10

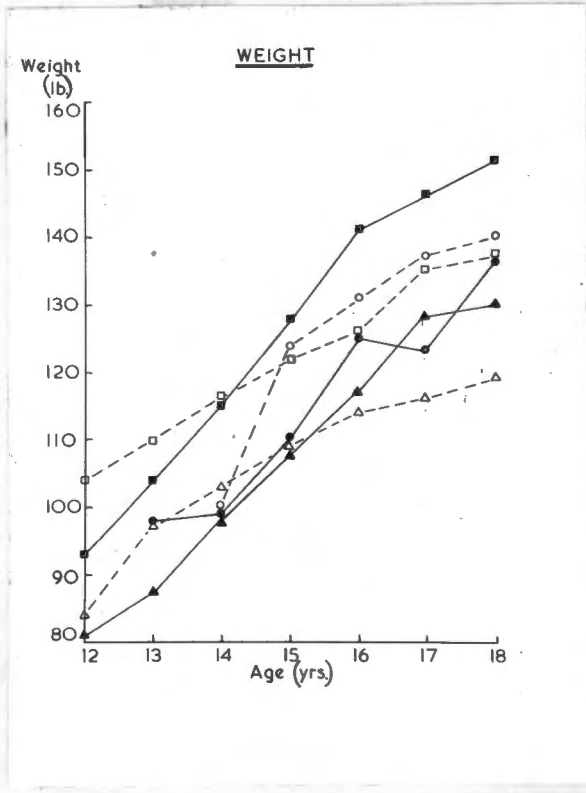


Fig. 11

In a later investigation on South African school children I tested 393 White and Coloured boys and girls in a more restricted age-group (15-17 years). The schools participating were Rondebosch Boys' High School and Rustenburg Girls' High School (White) and Alexander Sinton Secondary School (Co-educational, Coloured). The AAHPER test battery was modified, as described in Chapter 5, by substituting straddle chinning for the original modified pull-ups for girls, and by substituting for the original limited number of pull-ups, the maximum number which could be performed in 1 minute. T-scores were derived for each test for boys (Table A3) and for girls (Table A4) so that a composite criterion of fitness could be calculated. Each pupil also performed a modified Harvard step test, the bench being 18 inches high for boys and 16 inches high for girls (Chapter 3), and the rapid fitness index (RFI) was calculated. For White and for Coloured boys and for White and for Coloured girls the correlation between AAHPER criterion and RFI was calculated. For the series as a whole, correlation coefficients were calculated between the AAHPER criterion and the individual tests and between the RFI and the AAHPER criterion and individual tests.

Results

Figures 10 and 11 show the mean height and weight, and

A.A.H.P.E.R. INTER-RACIAL COMPARISON

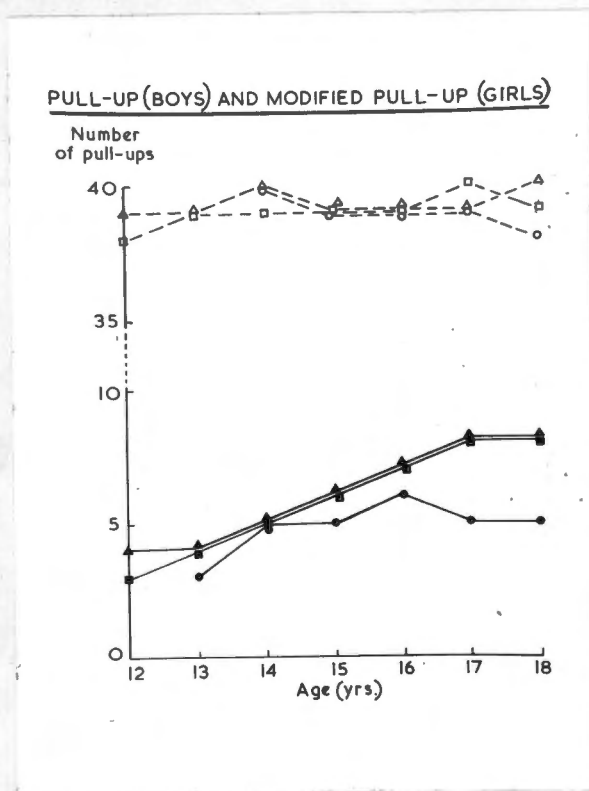


Fig. 12

Figures 12-18 the mean scores on the several AAHPER tests, of White, Coloured, and African boys and girls in each age-group studied in the first investigation. The tables giving the statistical significance of the differences, since they are rather voluminous, are relegated to Appendix A (Tables A5-A13).

White and African boys showed a progressive increase in height up to the age of 18 and Coloured boys up to the age of 17. Coloured girls ceased to gain height at 16 and White and African girls at 17 (Fig. 10). In each age-group and each sex White children were the tallest. There was no consistent difference in height between African and Coloured children (Table A5).

Boys and girls of all races gained weight up to the age of 18 (Fig. 11). White boys were heavier than Coloured or African boys and there was little difference between Coloured and African (Table A6). White girls were heavier than Coloured at every age but African girls, gaining weight rapidly from the age of 14, were significantly heavier than Coloured but not than White, in the older age-groups.

At pull-ups (Fig. 12, Table A7) White and Coloured boys improved progressively up to the age of 17 whereas African

A.A.H.P.E.R. INTER-RACIAL COMPARISON

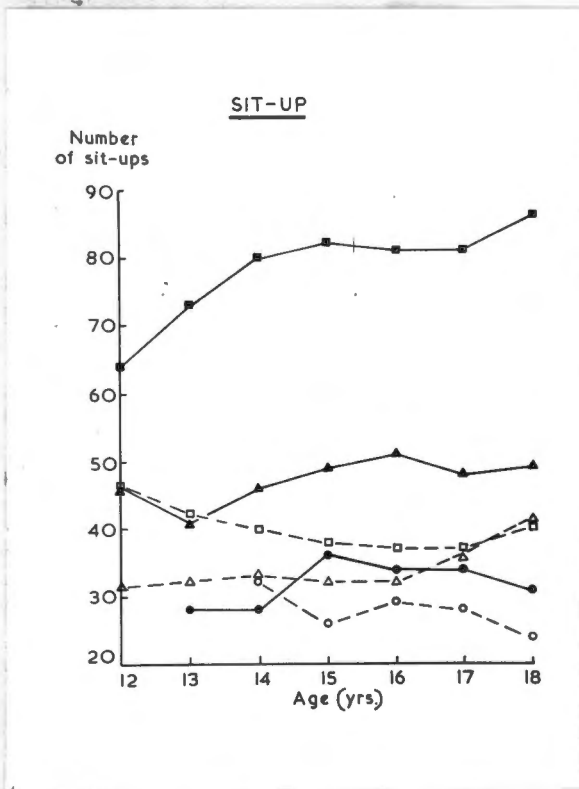


Fig. 13

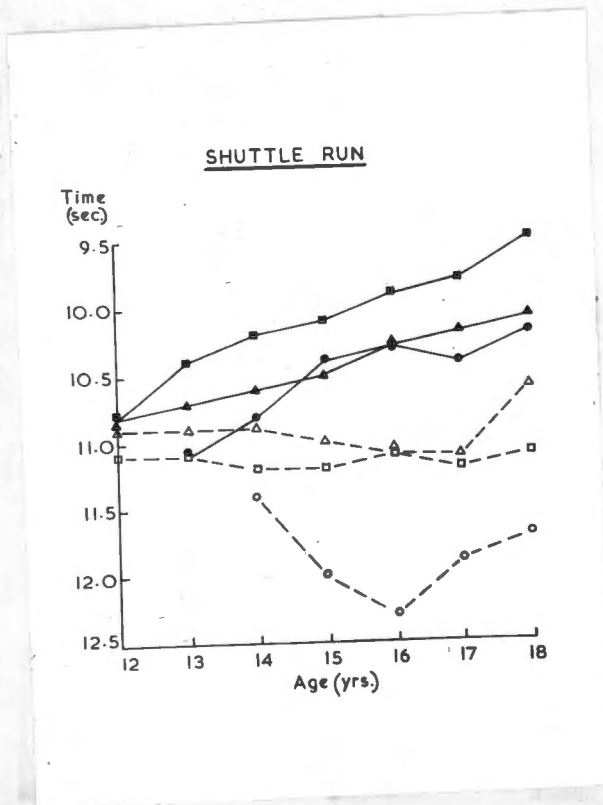


Fig. 14

boys deteriorated after 16. From 15 years of age the African boys were poorest at this test. The modified pull-up for girls (with an arbitrary maximum score of 40) showed no significant age trend in any racial group and no significant difference between the races.

At sit-ups (Fig. 13, Table A8), a tendency to improve with age was obvious only for White boys, who were better than Coloured boys, who in turn were better than African. White and African girls tended to deteriorate at this test in the older age-groups but Coloured girls showed some improvement after the age of 16. In most age-groups White girls were superior to Coloured, and Coloured were superior to African.

White and Coloured boys improved progressively and Africans irregularly with age at the shuttle run (Fig. 14, Table A9). White boys were better than Coloured and African in most age-groups and there was no significant difference between Coloured and African. The girls' performance tended to deteriorate with age. Coloured girls were superior to White and White girls superior to African in most age groups.

The performance of boys at the standing broad jump showed progressive improvement with age, except for the

highest age-group of Coloured boys (Fig. 15, Table A10). White boys were superior to Coloured and African, and Coloured boys to African in most age-groups. Girls showed no consistent age trend at this test. Coloured girls had the highest scores and White girls were better than African.

At the 50-yard dash White and Coloured boys improved progressively with age but African boys deteriorated after the age of 16 (Fig. 16, Table A11). At most ages White boys were superior to both other racial groups and Coloured were superior to African. The performance of White girls was not related to age but Coloured and African girls deteriorated from the age of 14. White girls were superior to Coloured and Coloured to African at this test.

Boys improved with age at the softball throw (Fig. 17, Table A12). White boys were superior to both other racial groups and there was no significant difference between Coloured and African. Girls showed less obvious improvement with age. Coloured and African girls were better than White at this test and, in the younger age-groups, Coloured were significantly better than African.

At the 600-yard run-walk there was progressive improvement with age in White and Coloured boys but very poor performances by African boys aged 15-17 (Fig.18, Table A13).

A.A.H.P.E.R. INTER-RACIAL COMPARISON

STANDING BROAD JUMP

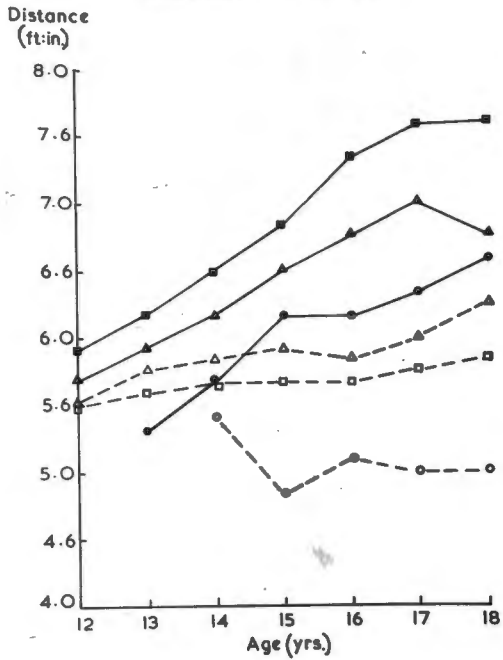


Fig. 15

50-YARD DASH

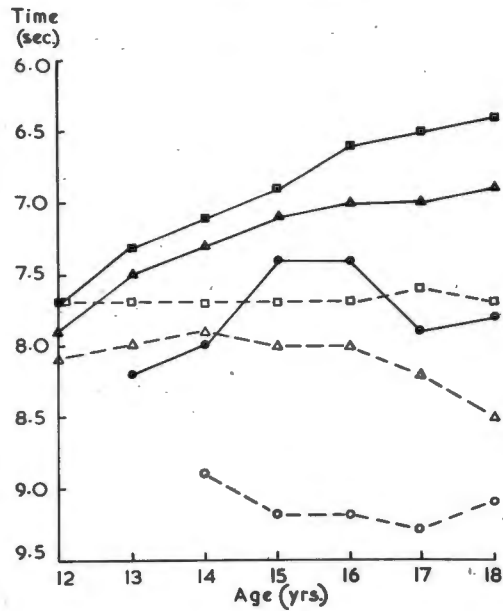


Fig. 16

SOFTBALL THROW

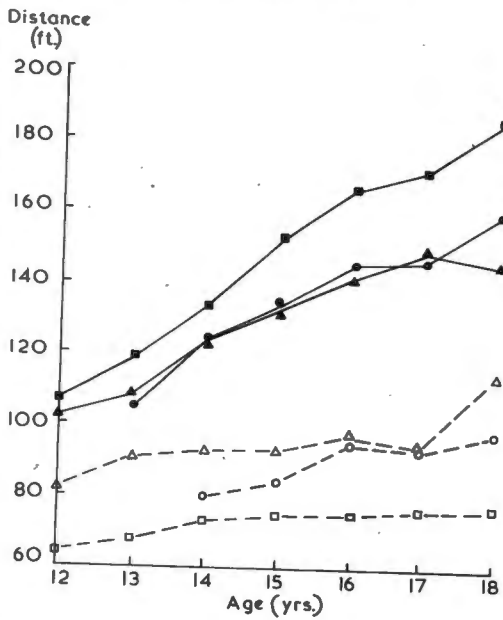


Fig. 17

600-YARD RUN-WALK

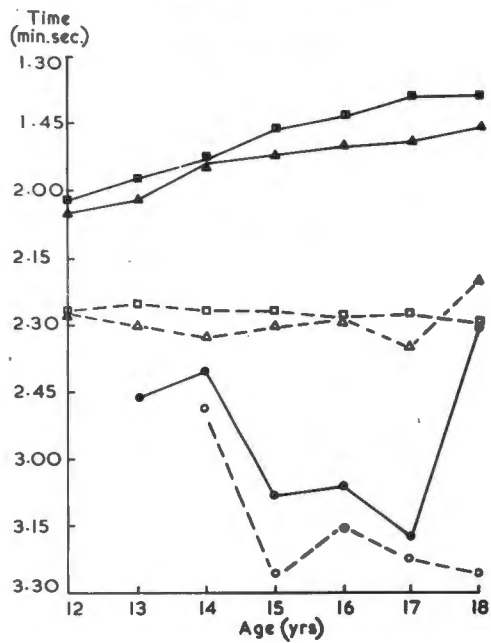


Fig. 18

Table 20. Second inter-racial comparison of South African children - boys - modified AAHPER test battery and modified Harvard step test

Parameter or Test	White Boys	Coloured Boys	Significance of Difference
N	125	99	
Height	175.2 [±] 6.7	166.1 [±] 7.9	W>C (P<.001)
Weight	64.7 [±] 8.7	53.6 [±] 7.8	W>C (P<.001)
<u>AAHPER:</u>			
Pull-ups	7.7 [±] 3.8	6.6 [±] 3.2	W>C (P<.05)
Sit-ups	38.1 [±] 5.5	27.7 [±] 6.0	W>C (P<.001)
Shuttle run	10.5 [±] 0.7	9.7 [±] 0.5	C>W (P<.001)
Broad Jump	85.6 [±] 8.8	85.8 [±] 8.1	-
50-yard	6.7 [±] 0.4	6.8 [±] 0.5	W>C (P<.01)
Softball	160.5 [±] 33.2	157.7 [±] 28.3	-
600-yard	102.0 [±] 10.8	110.5 [±] 12.0	W>C (P<.001)
Criterion	51.9 [±] 10.9	47.7 [±] 9.4	W>C (P<.01)
RFI	84.8-11.2	78.3-12.4	W>C (P<.001)

In the tables in this chapter:

N = Number of subjects

W = White

C = Coloured

Height is measured in centimetres and weight in kilograms

Criterion = composite fitness score based on T-scores for the 7 AAHPER tests

RFI = rapid fitness index (modified Harvard step test)

x[±]y represents mean [±] standard deviation

- indicates no significant difference

In the AAHPER tests A>B indicates a better performance by A, i.e. a shorter time for the runs or a higher score for the other tests.

White boys were superior in most age-groups and African boys were much worse than either of the other racial groups. There was no obvious age trend in White or Coloured girls but African girls deteriorated from the age of 14. In some age-groups White girls were significantly better than Coloured and, from the age of 15, White and Coloured girls were significantly better than African.

In the second investigation, limited to age-groups 15-17, White boys, Coloured boys, White girls, and Coloured girls were each treated as a uniform group. The heights and weights, the scores for each of the AAHPER tests, the composite criteria based on T-scores for the AAHPER tests, the RFI derived from the modified Harvard step test, and the significance of inter-racial differences are given in Tables 20 and 21.

White boys were taller and heavier than Coloured boys, were significantly better at 4 of the 7 AAHPER tests, and had a higher composite criterion of fitness and a higher RFI (Table 20). The only test at which Coloured boys were significantly better than White was the shuttle run. There was significant correlation between AAHPER criterion and RFI for White boys ($r=.292$; $P<.01$) but not for Coloured boys ($r=.160$; $P<.1$).

Table 21. Second inter-racial comparison of South African children - girls - modified AAHPER test battery and modified Harvard step test

Parameter or Test	White Girls	Coloured Girls	Significance of Difference
N	107	62	
Height	165.0 [±] 5.4	156.9 [±] 6.7	W>C (P<.001)
Weight	56.7 [±] 7.9	50.1 [±] 7.0	W>C (P<.001)
<u>AAHPER:</u>			
Pull-ups	28.3 [±] 14.8	15.0 [±] 5.9	W>C (P<.001)
Sit-ups	20.7 [±] 4.5	19.1 [±] 4.1	W>C (P<.05)
Shuttle run	11.0 [±] 0.6	11.3 [±] 0.8	W>C (P<.01)
Broad Jump	69.4 [±] 6.9	70.6 [±] 8.4	-
50-yard	8.0 [±] 0.6	8.0 [±] 0.9	-
Softball	70.1 [±] 17.8	102.2 [±] 17.5	C>W (P<.001)
600-yard	141.8 [±] 16.1	149.6 [±] 17.0	W>C (P<.01)
Criterion	50.6 [±] 9.5	48.9 [±] 11.3	-
RFI	67.5 [±] 13.2	55.7 [±] 19.2	W>C (P<.001)

Table 22. Correlations of individual AAHPER test results with AAHPER criterion and with RFI in 393 South African high school children

Test	Correlation with criterion	Correlation with RFI
AAHPER criterion	-	.321
Pull-ups	.490	.209
Sit-ups	.562	.581
Shuttle run	.546	.396
Broad jump	.744	.482
50-yard dash	.785	.591
Softball throw	.557	.467
600-yard run	.652	.660

White girls were taller and heavier than Coloured girls and were significantly better at 4 of the 7 AAHPER tests, though not on the composite criterion (Table 21). Coloured girls were better at the softball throw. White girls had a higher RFI. There was significant correlation between AAHPER criterion and RFI both for White ($r=.422$; $P<.001$) and for Coloured girls ($r=.603$; $P<.001$).

In the second series as a whole there was highly significant correlation ($P<.001$) between the AAHPER criterion and the T-scores of each of the individual tests, the highest correlation being with the 50-yard dash (Table 22). The RFI had a highly significant correlation ($P<.001$) with the AAHPER criterion and with each of the individual tests, the highest correlation being with the 600-yard run-walk and the lowest with pull-ups.

Discussion

The growth curves of height follow the usual pattern for children and adolescents (Lurie & Ford, 1958; Tanner, 1962). The apparent loss of height of African girls from 16 to 17 years of age is presumably due to the taller individuals leaving school at a younger age than the others but the numbers are small and no far-reaching conclusions should be drawn from this observation. The greater height of

White than of other children in South Africa may be due to their better nutrition (Lurie & Ford, 1958; Hansen, 1962). The dominant effect of undernutrition in children is retardation of growth (Weir, 1952). Although growth in weight is usually affected more than growth in height much smallness of stature attributed to racial factors is really due to malnutrition (Illingworth, 1953). A privileged group of Bantu children in South Africa achieved the same heights and weights as White South African children (Kahn & Freedman, 1959).

The growth curve for weight of boys follows the same general pattern as the curve for height and the greater weight of White than of Coloured boys and of Coloured than African may have the same nutritional basis as the differences in height. The arrest of weight gain in White and Coloured girls and the considerable increase in weight of African girls during adolescence may have a sociological basis. At this age girls wish to be attractive to boys; in the White and Coloured communities the more slender girl is considered more attractive whereas in the African community the more obese girl is favoured. Consequently White and Coloured adolescent girls tend to restrict their diet, whereas Africans are content to gain weight, which is

easily achieved on their low-protein, high-carbohydrate diet.

The improvement in pull-ups with age is presumably related to progressive increase in muscular strength and the poorer performance of African boys may be due to poorer muscular development, resulting from a less adequate diet. The modified pull-ups proved useless as a fitness test for South African girls since nearly all of them could achieve without effort the arbitrary maximum score of 40.

Sit-ups, a test of strength and flexibility, showed less obvious age trends, possibly because increasing strength is accompanied by diminishing flexibility. White boys, presumably the strongest group from their greater weight and superior performance at pull-ups, were the best at this test. In girls, whose strength does not increase much after puberty, reduced flexibility led to deterioration, especially in White and African girls. The Coloured girls, not apparently stronger than the White, retained more flexibility. An unsatisfactory feature of this test is the arbitrary maximum score of 100 for boys and 50 for girls. Many children can exceed this maximum; indeed 1 boy performed 468 sit-ups.

As shown by the shuttle run, speed and agility improve with age in boys and deteriorate in girls. The superiority

of White boys and of Coloured girls has no obvious explanation but the very poor performance of African girls may be related to obesity.

The increase of strength with age in boys and the greater strength of White boys explains the progressive improvement with age and the superiority of White boys at the standing broad jump. The absence of any age trend in girls at this test is not surprising but the superiority of Coloured girls is unexpected; from their slighter build one would expect them to be less strong than White girls but it seems that they can mobilise their strength more efficiently for a test of power (explosive strength).

At a test of speed (50-yard dash) White and Coloured boys showed the expected improvement with age, whereas African boys did not. Unlike Botha et al. (1945) I found African boys worse than others at this test, possibly because my subjects were urban, whereas many of his were rural. The deterioration of Coloured and African girls at this test after puberty follows the expected pattern (vide supra) but White girls, although not improving, did not deteriorate.

The better performance at the softball throw in older boys is associated with greater strength and probably better

neuro-muscular coordination. The greater strength of the White boys explains their superiority at this test. Since girls do not gain strength appreciably after puberty they show no consistent improvement. As in the other test of explosive strength (the standing broad jump) the Coloured girls were superior. The very poor performance of this test by White girls is unexplained.

Finally, in the test of endurance (600-yard run-walk) White and Coloured boys showed the expected improvement with age. African boys were much poorer than White or Coloured boys and, in most age-groups, than White or Coloured girls. This observation conflicts with that of Botha et al. (1945) who found African boys superior at the 600-yard run. Since I am assured by an eminent social anthropologist (Professor Monica Wilson) that there is no sociological reason why African boys of this age should not exert themselves (it is not considered undignified to run) I am at a loss to explain this observation. If it were due to dietary deficiency one would expect to notice signs of this, but such signs were absent. African girls, but not White or Coloured, showed the expected reduction in endurance after puberty (*vide supra*) and, like African boys, were much worse than the other racial groups. In

the girls' case the difference in body build (obesity in the Africans) may be at least a partial explanation.

Although the first investigation had shown some improvement at most of the tests from 15 to 17 years of age in boys, these were not sufficient to persuade me to ignore the recommendation of Gross and Casciani (1962) that senior high school boys may be regarded as a homogeneous group with respect to age for the AAHPER tests. The senior high school girls in my first series showed no significant age trend at any of the tests, which agrees with the observations of Gross and Casciani. Consequently in the second investigation of children I considered the White boys, Coloured boys, White girls, and Coloured girls as constituting 4 homogeneous groups. T-scores for boys and for girls were derived from the AAHPER scores of White and Coloured children to give rough standards of fitness for high school children in and near Cape Town. It is highly desirable that a more extensive survey be undertaken to establish standards for the country as a whole.

The second investigation confirmed the greater height and weight of White than of Coloured boys and the superiority of White boys at tests of strength, flexibility, speed, and endurance. In this investigation, limited to the

older age-groups, the Coloured boys were superior in agility (shuttle run) and there was practically no difference in power (broad jump and softball throw). In the general criterion of fitness White boys were superior to Coloured. The RFI, another measure of endurance, was higher for White boys, in whom it had a low but significant correlation with the AAHPER criteria. It appears that the extra weight of the White boys, probably due to muscle, gives them greater strength, speed, and endurance, but reduces their agility.

As in the previous investigation, White girls were much taller and heavier than Coloured girls and were better at tests of strength, flexibility, and endurance and worse at throwing the softball. Although the younger age-groups of Coloured girls in the previous investigation were better than White girls at the standing broad jump, the Coloured girls in the second investigation were not significantly better. Although the White girls in the earlier investigation showed greater speed (50-yard dash) the mean performance in the second was identical for the two groups. That there is less inter-racial difference in physical fitness in girls than in boys is shown by the lack of

significant difference between White and Coloured girls in the total criterion. The greater endurance of White girls is confirmed by a higher RFI.

The AAHPER tests which showed the highest correlation with the total criterion were the 50-yard dash, and the standing broad jump, which agrees with the findings of Baacke (1964) and my own observations on young adults (Chapters 6 & 8). All the correlations between the criterion and its individual constituents were reasonably good. The RFI had a low (though significant) correlation with the AAHPER criterion; it correlated better, as might be expected, with another endurance test (600-yard run-walk) and the lowest correlation was with a test of arm strength (pull-ups); these findings are similar to my results with young adults.

Summary

The influence of age and of race on physical fitness was studied in a series of 5,962 South African children who performed the original AAHPER battery of tests. Boys showed the anticipated gains in height and weight with increasing age and girls showed the anticipated gain in height with advancing age and in weight up to puberty. From the age of 14 years African girls increased markedly in

weight, which may be attributable to sociological and dietary factors. In each age-group and each sex, White children were the tallest. There was no consistent difference in height between Coloured and African children. At all ages White boys were heavier than Coloured and at most ages heavier than African, there being no consistent difference in weight between Coloured and African boys. White girls were the heaviest at every age but, in the older age-groups African girls were heavier than Coloured.

Boys showed progressive improvement with age at most of the AAHPER tests. At most of the tests White boys were superior to Coloured and Coloured were superior to African but the difference between White and Coloured was small at pull-ups and at the 600-yard run-walk. At the shuttle run and softball throw the differences between Coloured and African boys were significant only in some age-groups.

The modified pull-ups for girls proved an unsatisfactory test of fitness. Girls showed no consistent age-trend in the AAHPER tests. The differences between White, Coloured, and African girls at the several tests were less marked than the corresponding differences in boys, the White being superior at some tests and the Coloured at others. The African girls were the poorest at most tests, with the

exception of the softball throw, at which White girls were the worst.

In a second series of 393 White and Coloured children in a more limited age-range (15-17 years) inter-racial differences in physical fitness were studied with a modified AAHPER test battery, a composite criterion of fitness based on T-scores for the 7 tests, and the RFI derived from the Harvard step test. White boys and girls were taller and heavier than Coloured. White boys were superior to Coloured at most of the AAHPER tests, on the total criterion, and at the modified Harvard step test. Although White girls were superior to Coloured at 4 of the 7 AAHPER tests and at the modified Harvard step test there was no significant difference in the composite AAHPER criterion.

In the second series as a whole there was a highly significant correlation between AAHPER criterion and each of its constituent tests and between RFI and AAHPER criterion and each of the AAHPER tests.

Chapter 12

Comparison of the physical fitness of high school children in South Africa, Great Britain, and the United States of America

Few reports of international comparisons of physical fitness of children have been published. With the Kraus-Weber tests of flexibility, Kraus and Hirschland (1953, 1954) found much higher standards in Austrian, Italian, and Swiss children than in children in the U.S.A.; whereas 80% of American children failed to complete one or more of the tests the failure rate for each of the European countries was less than 10%. Smit (1961), comparing the performance of South African children with these results, found that both White and Bantu children in South Africa were superior to American but inferior to European children.

Measuring work capacity with a bicycle ergometer, Adams et al. (1961a) found little difference between Swedish and Californian children.

With a comprehensive test battery, Rodahl et al. (1961) found no marked difference in physical performance between American and German children but Swedish children were

superior to both. Campbell and Pohndorf (1961) applied the AAHPER test battery to more than 10,000 boys and girls aged 10-17 years in Great Britain and Cyprus and to about 8,500 boys and girls in the same age-range in the United States of America. They found that the performance of British and American boys and British girls improved with age, whereas American girls showed little improvement or regressed. British boys were superior to American at all tests except the softball throw and British girls were superior to American at all the tests. In some of the younger age-groups British girls were superior to American boys at 4 of the 7 tests. In 1961 I discussed these findings with Campbell and obtained his permission to use his results for comparison with the results of tests on South African children.

Subjects and methods

The subjects of this investigation were the 5,962 South African high school children, whose physical characteristics and athletic fitness have already been analysed on an inter-racial basis in Chapter 11. Since the American and British surveys, with which these were to be compared, were not racially differentiated, the South African children were taken as a homogeneous group for this comparison,

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INTERNATIONAL
COMPARISON

BOYS

S.A. 

U.K. 

U.S.A. 

GIRLS

S.A. 

U.K. 

U.S.A. 

Fig. 19

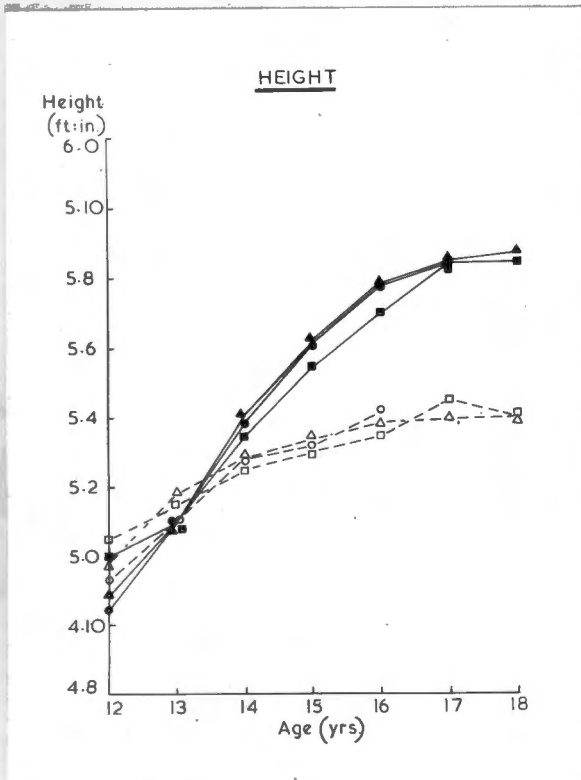


Fig. 20

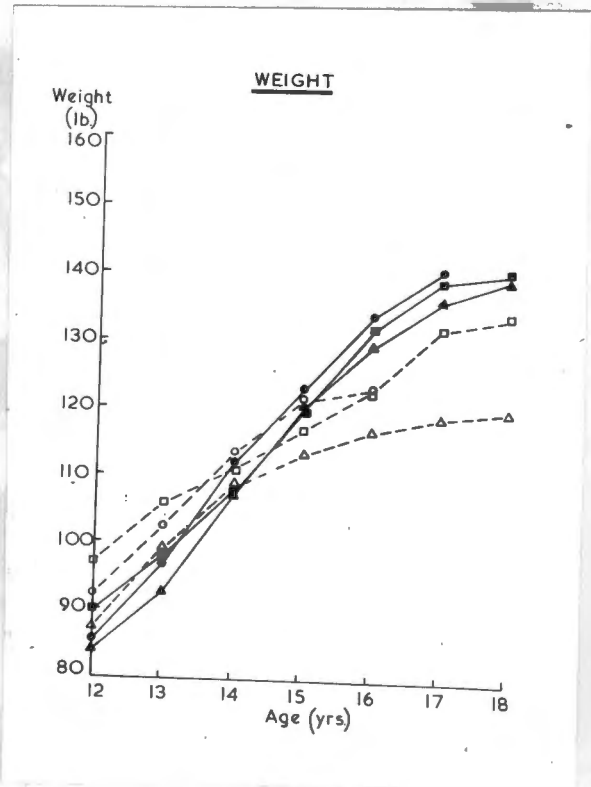


Fig. 21

although in fact there are significant inter-racial differences on many of the tests (Chapter 11) and the proportion of Coloured pupils is probably higher in the South African series than in the others. Since there were not enough children below the age of 12 years in the South African high schools for satisfactory statistical analysis, no comparison with the younger age groups (10 and 11) reported by Campbell and Pohndorf was possible. At the other end of the scale there were not enough American children or British boys above 17 or British girls above 16 in Campbell and Pohndorf's series for comparison.

The South African boys and girls performed the same tests under the same conditions as the British and American children. As in the U.K. and the U.S.A. the investigation took a whole scholastic year so any seasonal influence on the results should be minimal.

Results

The heights and weights of the national groups are shown in Figs. 20 and 21. The figures for British children (unpublished) were kindly provided by Campbell and Pohndorf. As in my series the age is taken as the age in years at the last birthday. The figures for American children (medians, not means, in this case) are reported from a

A.A.H.P.E.R. INTERNATIONAL COMPARISON

PULL-UP (BOYS) AND MODIFIED PULL-UP (GIRLS)

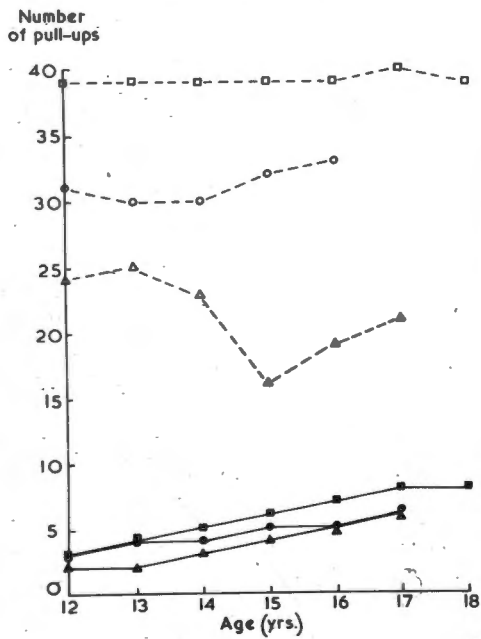


Fig. 22

SIT-UP

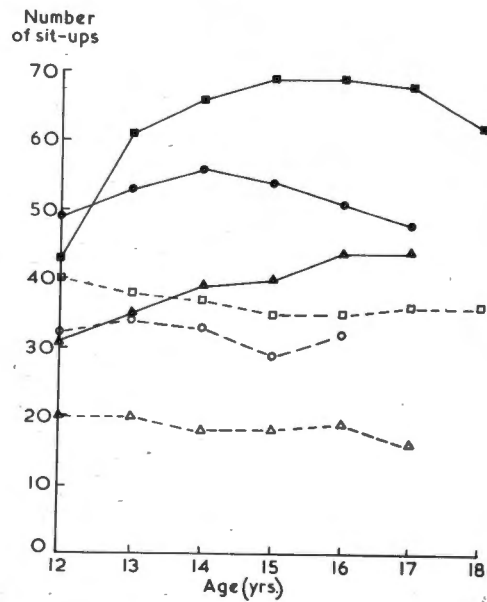


Fig. 23

study in Iowa City (Vaughan, 1964).

Since full statistical data are available only for the British and South African material the significance of the differences in each age group can be computed only for them (Tables A14, A15) but the American figures for height and weight are very close to the British except for the lesser weight of American girls. As might be expected when dealing with such large numbers of subjects most of the differences between South African and British results shown on the figures are highly significant. South African boys and girls in the younger age groups were significantly taller and heavier than British; thereafter the British boys were taller and heavier up to the age of 16 but girls showed no significant difference in height or weight.

Except in the youngest age-groups of boys, South African children were superior to British at pull-ups and modified pull-ups (Fig. 22; Table A16). It can be assumed from the figure that they were also superior to the Americans, but full statistical information was not available for the American series.

Except in the youngest age-group of boys, in which the British were superior, and the oldest age-group of girls where the difference was not significant, South African

A.A.H.P.E.R. INTERNATIONAL COMPARISON

SHUTTLE RUN

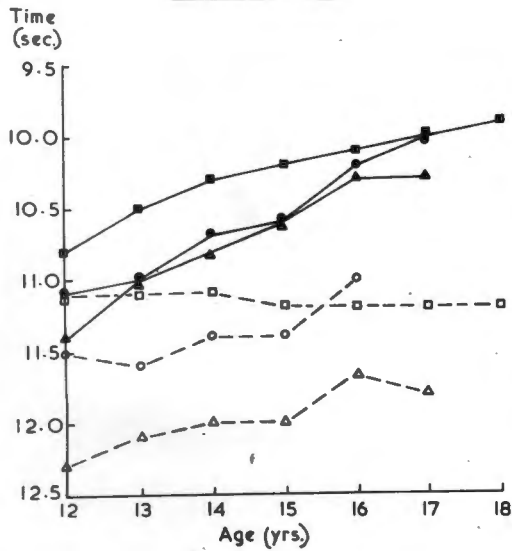


Fig. 24

STANDING BROAD JUMP

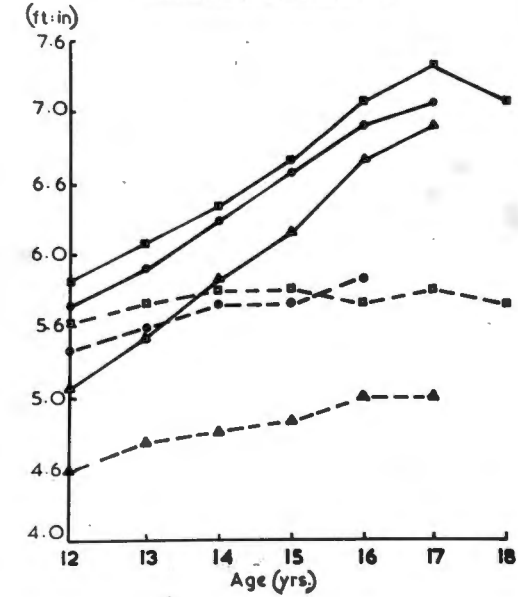


Fig. 25

SOFTBALL THROW

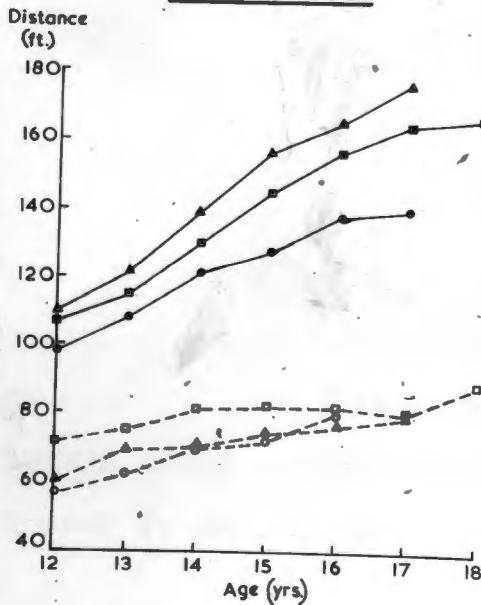


Fig. 26

50-YARD DASH

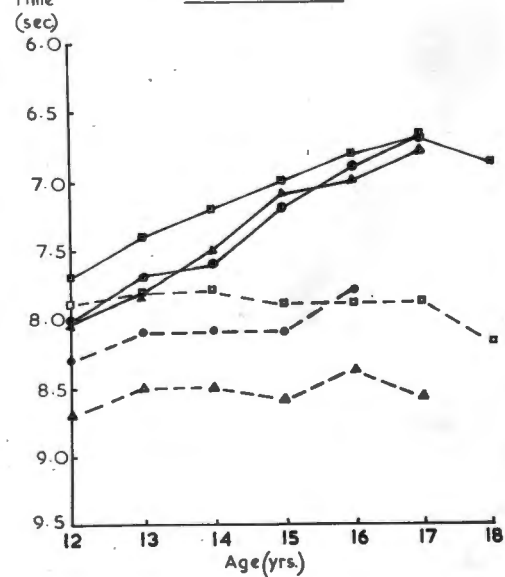


Fig. 27

children were superior to British (and hence to American) children at sit-ups (Fig. 23; Table A17).

At the shuttle run (Fig. 24; Table A18) South African children were superior to British (and presumably to American) children up to the age of 15. At 16 years of age British girls were superior to South African at this test.

At the standing broad jump (Fig. 25; Table A19) South African boys were superior to British (and American) boys at most ages but South African girls were significantly better than British only in the first 2 age-groups. American girls did very badly at this test.

At the 50-yard dash (Fig. 26; Table A20) South African children were superior to British up to the age of 15. At ages 14-17 it is impossible to determine from the available data whether South African boys were significantly better at this test than American boys but the performance of American girls was very poor.

In each age-group American boys had the best mean performance at the softball throw (Fig. 27) but the statistical significance of this cannot be determined with the available data. South African boys were significantly better than British at this test (Table A21). Up to the

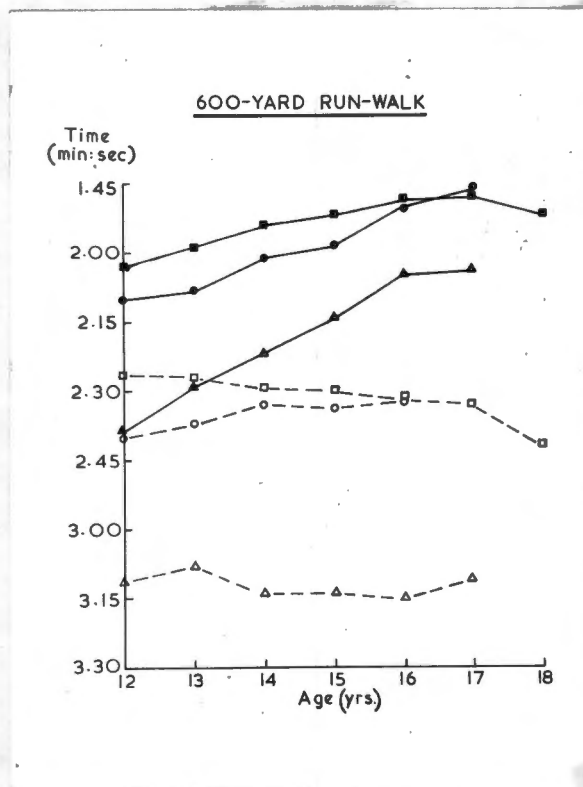


Fig. 28

age of 15 years South African girls were significantly better than British girls but, from the available data, the significance of their superiority over the Americans cannot be assessed.

Up to the age of 15 years South African boys and girls were significantly better than British at the 600-yard run-walk (Fig. 28; Table A22). The performance of American boys and girls at this test was very poor.

Discussion

In general there is less difference in heights and weights between the 3 national groups than in their performance of the AAHPER tests. The superiority in height and weight of South African children in the younger age-groups only may be due to the absence of African boys from the 12-year-old and of African girls from the 12-year-old and 13-year-old groups.

At most ages White South African boys and girls are taller and heavier than British or American (Cluver et al., 1946) but the inclusion of Coloured and African children in my series brings the figures below the British at most ages. In contrast to Cluver's finding that American children are heavier for a given height than White South

Africans I found, in my multi-racial series, little international difference in the height of girls but the American girls were considerably lighter than the others. I cannot explain why the English girls were heavier than the American but the greater weight of South African girls in the older age-groups may be due in part to the inclusion of Africans in my series.

The superiority of South African boys at pull-ups is unexpected as one would expect the heavier British and American boys to be stronger. If their extra weight were due to muscle one would expect their performance to be better than the South African, if due to fat one would expect it to be worse. An international comparison of body composition in relation to tests such as these would be very helpful in explaining the results. The poor performance of British and American girls at modified pull-ups is surprising since all races in South Africa performed the test so well that it proved useless for distinguishing degrees of fitness (Chapter 11).

In the tests of trunk strength and flexibility, agility, and power (sit-ups, shuttle run, and standing broad jump) the general pattern was of superiority of South African over British children and of British over American. At

the speed test (50-yard dash) the South Africans were again the best but there was little difference between British and American boys.

The superiority of American boys at the softball throw probably depends more on motor skill than on power, since American boys practise throwing a softball or baseball from an early age whereas these games are rarely played in Great Britain or South Africa. American girls do not reflect the superiority of American boys at this test, possibly because they are less active at games than South African or British girls.

The endurance test (600-yard run-walk) shows the greatest difference between South African and British children and American children. The name of this American test, 'run-walk', implying that many will be unable to run 600 yards, indicates the standard of endurance expected of American children, and the results confirm this supposition.

Two important questions arise from these observations. Why do South African children, who are considerably fitter than British in most of the younger age-groups, lose their lead in 3 of the tests at the age of 17 in boys and in 5 of the tests at the age of 16 in girls? And why are American boys and girls so much worse than the others at most of the tests?

I believe that the greater fitness of the younger South African children may be due to the greater participation in outdoor sports which is appropriate to the South African but more difficult to achieve with the British climate. Also South Africa does not suffer from television. The falling off in the older age groups, leading to the inferior fitness of South African men and women in young adult life (Chapter 10), may be due to the greater amount of time spent by the older South African adolescents basking in the sun, whereas more physical activity is required in Great Britain to maintain the body temperature. The older South African children are probably conveyed more often by motor transport than the British, who indulge more in walking or cycling, but most high school children of both countries are active at outdoor sports.

From my personal observation of the American way of life there seem to me to be two factors which, more than any others, militate against physical fitness in the children. The first of these is the school bus. If a child lives more than a very short distance from school he is driven each day from his home to school and from school to his home, instead of walking or cycling to and from school as is common practice in South Africa and Great Britain. The

American child need never walk further than from the garden gate to the television set. The other deleterious factor is the American attitude to sport. A high school or college has a football team, a baseball team, a basketball team, and perhaps one or two other teams, with a few reserves for each. The other children are expected to remain on the side-lines and give vocal encouragement to the team, instead of themselves playing in 2nd, 3rd, 4th, or other teams. According to Kiphuth (1956) only the 10-15% of American children actively engaged in competitive sport attain a reasonable standard of physical fitness.

Encouraged by the President's Council on Youth Fitness (President's Council, 1961) many American schools have intensified their physical education programmes during the last few years. The Education Department of the State of New York reports that the performance of the AAHPER tests both by boys and by girls in 1962 was much better than the national standards established for the U.S.A. in 1957 (University, 1963). It would be interesting to ascertain whether any such secular change in the physical fitness of high school children is taking place in South Africa or in

Great Britain, where there has been no comparable drive for improved standards.

Summary

The heights and weights of 5,962 South African boys and girls aged 12-18 years were compared with the heights and weights of British and American boys and girls in the same age-groups reported by other observers. There was little difference between the national groups except that American girls, in the older age-groups, were lighter than South African or British girls.

The performance of the AAHPER test battery by South African boys and girls was compared, in each age-group, with the scores at the same tests by British and American boys and girls reported by Campbell and Pohndorf. In general the South African children were the fittest and the British were fitter than the Americans but the South Africans lost their lead in the older age-groups. American boys were the best at throwing a softball. Reasons for the observed order of fitness are suggested.

GENERAL CONCLUSIONS

AND

ACKNOWLEDGMENTS

GENERAL CONCLUSIONS

Physical fitness is a positive concept, signifying more than merely absence of disease or deformity. It implies the capacity to perform a variety of physical tasks efficiently for prolonged periods without distress. The maintenance of a satisfactory degree of physical fitness demands regular physical exercise and avoidance of obesity. Physical fitness is important to the state as well as to the individual.

It is often convenient to consider 3 categories of physical fitness, viz.: static or medical fitness, dynamic or functional fitness, and motor skills fitness. There are however a number of measurable physiological factors involved in the performance of physical tasks, viz.: speed, strength, power, flexibility, agility, balance, coordination, and endurance. Endurance corresponds approximately to dynamic fitness.

Most tests of dynamic fitness are based on the physiological responses, particularly of the circulatory and respiratory systems, to strenuous exercise. A good example is the Harvard step test which, with appropriate modifications, may be applied to men, women, boys, and

girls. Other aspects of fitness are usually assessed by batteries of athletic tests, of which a good example is the AAHPER test battery.

The physical fitness of young men, as estimated by the Harvard step test and by the AAHPER test battery, is not related to their height or weight but dynamic fitness is reduced in the more obese subjects. Male physical education students are fitter than other male students but there is no consistent difference in fitness between White and Coloured although the former are taller and heavier. Assessing relative ectomorphy, mesomorphy, and endomorphy on the basis of reciprocal ponderal index and body fat, mesomorphic men are the fittest and endomorphic the least fit. Active training for rowing or rugby leads to a marked improvement in dynamic fitness.

In women as in men there is no consistent relationship between physical fitness and either height or weight but the more obese subjects are less fit. Female physical education students are fitter than other female students. White women students are taller and heavier but not fitter than Coloured. Physical fitness in women is not related to relative ectomorphy, mesomorphy, or endomorphy, and dynamic fitness is not affected by menstruation.

Intensive physical training raises the dynamic fitness of young women and less intensive, but regular, training prevents the deterioration which tends to occur without it.

Boys gain height and weight and their athletic performance improves from 12 to 18 years of age. Girls continue to gain height but gain little weight after about 15 years of age except African girls, who show a marked weight gain in this period. At most fitness tests the girls' performance fails to improve, or even deteriorates, in the older age-groups.

White boys are taller and heavier than Coloured and African boys. White boys are superior to Coloured, who are superior to African in most aspects of physical fitness, the greatest difference being in endurance. White girls are taller and heavier than Coloured and, in the younger age-groups, than African girls. There is little difference in the performance of fitness tests by White and by Coloured girls but both are superior to Africans.

Both in adults and in children there is little or no correlation between measures of physical fitness and either height or weight but in adults the obese subjects are less fit. In most of the groups studied there is

significant correlation between the composite criterion of fitness based on the AAHPER tests and the fitness index based on the Harvard step test. The best correlations between the AAHPER criterion and its several constituent tests are with the 50-yard dash and the standing broad jump. The best correlation between the fitness index and the AAHPER tests is with the 600-yard run-walk and the poorest is with pull-ups.

Comparing the physical fitness of high school children and of university and college students in South Africa, Great Britain, and the United States of America, the South African boys and girls are superior to the British in the younger age-groups at most of the AAHPER tests but lose their lead by about the age of 17 in boys and 16 in girls. American children are the worst at every test except throwing a ball. These differences may be due to sociological differences in the different cultures, particularly in the degree of physical activity of the children. The dynamic fitness of young adults of these national groups shows the same pattern as the athletic fitness of the older children. In general the British men and women are the fittest and the Americans the least fit. In the case of physical education students the standard of fitness

attained is related to the intensity of training rather than to the time devoted to it. In the case of other students dynamic fitness may be related to their extra-curricular physical activity.

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APPENDIX A

TABLES A1 - A22

Table A1. T-scores for AAHPER tests on young men

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B.Jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
0	0		10.8			105	
1		20		72		106	121
2					7.8	108	
3						109	120
4			10.7	73		111	
5		21				112	119
6	1			74	7.7	114	
7			10.6			115	118
8				75		117	
9		22				118	
10					7.6	120	117
11			10.5	76		121	
12						123	116
13	2	23		77	7.5	124	
14						125	115
15			10.4			127	
16				78		128	114
17		24			7.4	130	
18			10.3	79		131	113
19	3					133	
20		25		80		134	112
21					7.3	136	
22			10.2			137	
23				81		139	111
24		26			7.2	140	
25	4			82		142	110

Table A1 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min.)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
26			10.1			143	
27						145	109
28		27		83	7.1	146	
29			10.0			147	108
30				84		149	
31	5					150	107
32		28		85	7.0	152	
33			9.9			153	
34						155	106
35				86		156	
36		29			6.9	158	105
37			9.8	87		159	
38	6					161	104
39				88	6.8	162	
40		30				164	103
41			9.7			165	
42				89		167	102
43					6.7	168	
44	7	31	9.6	90		170	
45						171	101
46						172	
47				91	6.6	174	100
48		32	9.5			175	
49				92		177	99
50	8				6.5	179	
51		33		93		180	98
52			9.4			181	
53						183	97
54				94	6.4	184	
55		34	9.3			186	96

Table A1 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
56	9			95		187	
57						189	
58						190	
59		35	9.2	96	6.3	192	95
60						193	94
61							
62	10	36	9.1	98		196	93
63						197	
64						199	
65					6.1	200	92
66							
67							
68	11	37	9.0	99		202	91
69						203	
70						205	
71		38		100	6.0	206	90
72						208	
73						209	
74	12	39	8.9	101		211	89
75						212	
76						214	
77			8.8	102	5.9	215	88
78							
79							
80	13	40		103	5.8	217	86
81						218	
82						219	
83		41	8.7	104		221	85
84						222	
85						224	
86			8.6	105	5.7	225	84
87						227	
88						228	
89	13		8.5	106	5.6	230	83
90							
91							

Table A1 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
86		42				231	82
87				108	5.5	233	
88	14					234	81
89			8.4			236	
90		43		109		237	80
91					5.4	239	
92				110		240	
93			8.3			242	79
94	15	44		111		243	
95					5.3	244	78
96			8.2			246	
97				112		247	77
98		45				249	
99				113	5.2	250	76
100	16		8.1			252	

Table A2. T-scores for AAHPER tests on young women

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
0			12.6		10.4	15	232
1				44		16	231
2		6			10.3	17	229
3			12.5	45		20	228
4					10.2	21	227
5		7	12.4	46		22	226
6				47	10.1	23	224
7						25	223
8			12.3	48		27	220
9		8			10.0	28	218
10			12.2	49		30	217
11					9.9	31	216
12	0	9		50		33	215
13	1		12.1	51	9.8	34	214
14						36	211
15	2	10	12.0	52	9.7	37	210
16	3					39	208
17			11.9	53	9.6	40	207
18	4	11				41	206
19	5			54		43	204
20	6		11.8		9.5	44	203
21		12		55		46	202
22	7		11.7	56	9.4	47	199
23	8					49	198
24		13		57	9.3	50	197
25	9		11.6			52	195

Table A2 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
26	10			58	9.2	53	194
27		14	11.5			54	192
28	11			59		56	191
29	12			60	9.1	57	190
30			11.4			59	188
31	13	15		61	9.0	60	186
32	14		11.3			62	185
33				62	8.9	63	184
34	15	16				65	182
35	16		11.2	63	8.8	66	180
36				64		68	178
37	17	17	11.1			69	177
38	18			65	8.7	70	176
39						72	175
40	19	18	11.0	66	8.6	73	174
41	20					75	172
42	21		10.9	67	8.5	76	170
43						78	169
44	22	19	10.8	68	8.4	79	167
45	23			69		81	166
46					8.3	82	164
47	24	20	10.7	70		83	163
48	25				8.2	85	161
49			10.6	71		86	160
50	26	21				88	158
51	27			72	8.1	89	157
52			10.5	73		91	155
53	28	22			8.0	92	154
54	29		10.4	74		93	152
55					7.9	95	151

Table A2 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
56	30	23	10.3	75		97	149
57	31				7.8	98	148
58				76		99	147
59	32		10.2	77		101	145
60	33	24			7.7	102	143
61	34		10.1	78		103	142
62					7.6	105	140
63	35	25		79		107	139
64	36		10.0		7.5	108	138
65				80		110	136
66	37	26	9.9	81	7.4	111	134
67	38					112	133
68				82		114	132
69	39	27	9.8		7.3	115	130
70	40			83		116	129
71			9.7		7.2	118	127
72	41	28		84		120	126
73	42				7.1	121	124
74			9.6	85		123	123
75	43			86	7.0	124	121
76	44	29	9.5			126	120
77				87	6.9	127	119
78	45		9.4			128	118
79	46	30		88		130	115
80	47				6.8	131	114
81			9.3	89		133	112
82	48	31		90	6.7	134	111
83	49		9.2			136	109
84				91	6.6	137	108
85	50	32				139	106

Table A2 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
86	51		9.1	92	6.5	140	105
87						141	103
88	52	33	9.0	93		143	102
89	53				6.4	144	100
90				94		146	99
91	54		8.9	95	6.3	147	97
92	55	34				149	96
93			8.8	96	6.2	150	95
94	56					152	93
95	57	35	8.7	97	6.1	153	92
96						155	90
97	58		8.6	98	6.0	156	89
98	59	36		99		157	87
99						159	86
100	60		8.5	100	5.9	160	84

Table A3. T-scores for AAHPER tests on boys aged 15-17 years

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
0		12		60	8.0	66	142
1			12.3	61		68	
2						70	141
3		13		62		72	140
4			12.2		7.9	74	139
5		14		63		76	
6			12.1			78	138
7		15		64		79	137
8			12.0		7.8	81	
9				65		83	136
10		16	11.9			85	135
11				66		87	134
12		17	11.8		7.7	89	
13				67		90	133
14		18				92	132
15			11.7	68		94	131
16	0	19			7.6	96	
17			11.6	69		98	130
18						100	129
19		20	11.5	70		102	128
20					7.5	103	
21	1	21	11.4	71		105	127
22						107	126
23		22		72		109	
24			11.3		7.4	111	125
25	2			73		113	124

Table A3 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
26		23	11.2			115	123
27				74		116	
28		24	11.1		7.3	118	122
29				75		120	121
30	3	25	11.0			122	120
31				76		124	
32			10.9		7.2	126	119
33		26		77		128	118
34						129	
35	4	27	10.8	78		131	117
36					7.1	133	116
37		28	10.7	79		135	115
38						137	
39			10.6	80		139	114
40	5	29			7.0	141	113
41			10.5	81		143	
42		30				145	112
43				82		146	111
44	6	31	10.4		6.9	148	110
45				83		150	
46			10.3			152	109
47		32		84		154	108
48			10.2		6.8	156	107
49	7	33		85		157	
50			10.1			159	106
51		34		86		161	105
52			10.0		6.7	163	104
53		35		87		165	
54	8					167	103
55			9.9	88		169	102

Table A3 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
56		36			6.6	170	101
57			9.8	89		172	
58	9	37		90		174	100
59			9.7			176	99
60		38		91	6.5	178	
61			9.6			180	98
62				92		182	97
63	10	39		93	6.4	183	96
64			9.5			185	
65		40				187	95
66			9.4	94		189	94
67		41				191	93
68	11		9.3	95	6.3	193	
69						195	92
70		42	9.2	96		196	91
71						198	
72	12	43	9.1	97	6.2	200	90
73						202	89
74		44		98		204	88
75			9.0			206	
76				99	6.1	208	87
77	13	45	8.9			209	86
78				100		211	85
79		46	8.8			213	
80				101	6.0	215	84
81		47	8.7			217	83
82	14			102		219	
83		48				221	82
84			8.6	103	5.9	222	81
85						224	80

Table A3 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
86	15	49	8.5	104	5.8	226	79
87		50	8.4	105		228	
88		51	8.3	106		230	
89		52	8.2	107		232	
90	16	53	8.1	108	5.7	234	77
91		54	8.0	109		236	
92		55	7.9	111		237	
93		56	7.8	112		239	
94	17	57	7.7	113	5.6	241	74
95		58	7.6	114		243	
96		59	7.5	115		245	
97		60	7.4	116		247	
98	18	61	7.3	117	5.5	249	71
99		62	7.2	118		250	
100		63	7.1	119		252	

Table A4. T-scores for AAHPER tests on girls aged 15-17 years

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
0						11	195
1		7	13.1		10.0	13	194
2				48		14	193
3			13.0			16	192
4				49	9.9	17	191
5		8				18	190
6			12.9	50	9.8	20	189
7						21	188
8			12.8	51		23	187
9		9			9.7	24	186
10				52		25	185
11			12.7		9.6	27	184
12						28	183
13		10	12.6	53		30	182
14					9.5	31	181
15				54		33	180
16		11	12.5		9.4	34	179
17				55		35	178
18			12.4			37	177
19				56	9.3	38	176
20		12	12.3			40	175
21					9.2	41	174
22	0			57		42	173
23	1		12.2		9.1	44	172
24	2	13		58		45	171
25	3		12.1			47	170

Table A4 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
26				59	9.0	48	169
27	4	14				49	168
28	5		12.0	60	8.9	51	167
29	6					52	166
30	7		11.9	61		54	165
31	8	15			8.8	55	164
32						57	163
33	9		11.8	62	8.7	58	162
34	10					59	161
35	11	16	11.7	63		61	160
36	12				8.6	62	159
37	13			64		64	158
38			11.6		8.5	65	157
39	14	17		65		66	156
40	15		11.5		8.4	68	155
41	16					69	154
42	17	18	11.4	66		71	153
43	18				8.3	72	152
44				67		73	151
45	19		11.3		8.2	75	150
46	20	19		68		76	149
47	21		11.2			78	148
48	22			69	8.1	79	147
49	23					80	146
50		20	11.1	70	8.0	82	145
51	24					83	144
52	25		11.0			85	143
53	26	21		71	7.9	86	142
54	27					88	141
55			10.9	72	7.8	89	140

Table A4 (cont.)

T-score	Raw Scores						
	Pull-up (no.)	Sit-up (1 min)	Shuttle (sec)	B. jump (ft)	50-yd. (sec)	Softball (ft)	600-yd. (sec)
86	53		9.6	86		133	108
87	54	30			6.5	134	107
88	55			87		135	106
89	56		9.5		6.4	137	105
90	57	31		88		138	104
91			9.4			140	103
92	58				6.3	141	102
93	59			89		143	101
94	60	32	9.3		6.2	144	100
95	61			90		145	99
96	62		9.2			147	98
97				91	6.1	148	97
98	63	33				150	96
99	64		9.1	92	6.0	151	95
100	65					152	94

Table A5. Inter-racial comparison of South African children: height

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	W>C (P<.001)	*	*
13	W>C (P<.001)	-	-
14	W>C (P<.001)	W>A (P<.001)	-
15	W>C (P<.001)	W>A (P<.001)	-
16	W>C (P<.001)	W>A (P<.001)	-
17	W>C (P<.001)	W>A (P<.001)	-
18	W>C (P<.001)	W>A (P<.001)	-
<u>Girls</u>			
12	W>C (P<.001)	*	*
13	W>C (P<.001)	*	*
14	W>C (P<.001)	W>A (P<.001)	-
15	W>C (P<.001)	W>A (P<.001)	-
16	W>C (P<.001)	W>A (P<.001)	A>C (P<.05)
17	W>C (P<.001)	W>A (P<.001)	-
18	W>C (P<.001)	W>A (P<.001)	-

In Tables A5-A13:

W = White

C = Coloured

A = African

- = no significant difference

* = data not available

**Table A6. Inter-racial comparison of
South African children: weight**

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	W>C (P<.001)	*	*
13	W>C (P<.001)	-	-
14	W>C (P<.001)	W>A (P<.001)	-
15	W>C (P<.001)	W>A (P<.001)	-
16	W>C (P<.001)	W>A (P<.001)	A>C (P<.05)
17	W>C (P<.001)	W>A (P<.001)	-
18	W>C (P<.001)	W>A (P<.001)	-
<u>Girls</u>			
12	W>C (P<.001)	*	*
13	W>C (P<.001)	-	-
14	W>C (P<.001)	W>A (P<.001)	-
15	W>C (P<.001)	-	A>C (P<.01)
16	W>C (P<.001)	-	A>C (P<.001)
17	W>C (P<.01)	-	A>C (P<.001)
18	W>C (P<.01)	-	A>C (P<.05)

Table A7. First inter-racial comparison of South African children: pull-ups (boys) and modified pull-ups (girls)

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	-	-	-
14	-	-	-
15	-	W>A (P<.05)	C>A (P<.05)
16	-	W>A (P<.05)	C>A (P<.05)
17	-	W>A (P<.001)	C>A (P<.01)
18	-	W>A (P<.01)	C>A (P<.001)
<u>Girls</u>			
12	-	*	*
13	-	*	*
14	-	-	-
15	-	-	-
16	-	-	-
17	-	-	-
18	-	-	-

Table A8. First inter-racial comparison of South African children: sit-ups

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	W>C (P<.01)	*	*
13	W>C (P<.001)	W>A (P<.001)	C>A (P<.05)
14	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
16	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
17	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
18	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
<u>Girls</u>			
12	W>C (P<.001)	*	*
13	W>C (P<.001)	*	*
14	W>C (P<.001)	-	-
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.05)
16	W>C (P<.001)	W>A (P<.001)	-
17	-	W>A (P<.001)	C>A (P<.01)
18	-	W>A (P<.001)	C>A (P<.01)

Table A9. First inter-racial comparison of South African children; shuttle run

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	W>C (P<.001)	-	-
14	W>C (P<.05)	W>A (P<.05)	-
15	W>C (P<.001)	W>A (P<.001)	-
16	-	-	-
17	W>C (P<.001)	W>A (P<.01)	-
18	W>C (P<.001)	W>A (P<.01)	-
<u>Girls</u>			
12	-	*	*
13	-	*	*
14	C>W (P<.01)	-	-
15	C>W (P<.01)	W>A (P<.001)	C>A (P<.001)
16	-	W>A (P<.001)	C>A (P<.001)
17	-	W>A (P<.01)	C>A (P<.01)
18	C>W (P<.05)	W>A (P<.05)	C>A (P<.001)

Table A10. First inter-racial comparison of South African children: standing broad jump

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	W>C (P<.001)	W>A (P<.05)	-
14	W>C (P<.001)	W>A (P<.001)	C>A (P<.05)
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.05)
16	W>C (P<.001)	W>A (P<.001)	C>A (P<.01)
17	W>C (P<.001)	W>A (P<.001)	C>A (P<.01)
18	W>C (P<.001)	W>A (P<.001)	-
<u>Girls</u>			
12	-	*	*
13	C>W (P<.05)	*	*
14	C>W (P<.05)	-	-
15	C>W (P<.001)	W>A (P<.001)	C>A (P<.001)
16	-	W>A (P<.001)	C>A (P<.001)
17	C>W (P<.05)	W>A (P<.001)	C>A (P<.001)
18	-	W>A (P<.01)	C>A (P<.001)

Table All. First inter-racial comparison of South African children; 50-yard dash

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	W>C (P<.001)	W>A (P<.01)	C>A (P<.05)
14	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.05)
16	-	W>A (P<.001)	-
17	-	W>A (P<.01)	-
18	W>C (P<.001)	W>A (P<.001)	C>A (P<.01)
<u>Girls</u>			
12	W>C (P<.05)	*	*
13	-	*	*
14	W>C (P<.01)	W>A (P<.001)	C>A (P<.01)
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
16	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
17	W>C (P<.001)	W>A (P<.001)	C>A (P<.01)
18	W>C (P<.01)	W>A (P<.001)	C>A (P<.05)

Table A12. First inter-racial comparison of South African children: softball throw for distance

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	W>C (P<.001)	W>A (P<.01)	-
14	W>C (P<.001)	W>A (P<.05)	-
15	W>C (P<.001)	W>A (P<.01)	-
16	W>C (P<.001)	W>A (P<.001)	-
17	W>C (P<.001)	W>A (P<.001)	-
18	W>C (P<.001)	W>A (P<.001)	-
<u>Girls</u>			
12	C>W (P<.001)	*	*
13	C>W (P<.001)	*	*
14	C>W (P<.001)	-	C>A (P<.05)
15	C>W (P<.001)	A>W (P<.05)	C>A (P<.05)
16	C>W (P<.001)	A>W (P<.001)	-
17	C>W (P<.001)	A>W (P<.001)	-
18	C>W (P<.001)	A>W (P<.01)	-

Table A13. First inter-racial comparison of South African children; 600-yard run-walk

Age (yrs)	White v. Coloured	White v. African	Coloured v. African
<u>Boys</u>			
12	-	*	*
13	W>C (P<.01)	W>A (P<.05)	C>A (P<.05)
14	-	W>A (P<.001)	C>A (P<.001)
15	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
16	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
17	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
18	W>C (P<.001)	W>A (P<.001)	C>A (P<.001)
<u>Girls</u>			
12	-	*	*
13	W>C (P<.05)	*	*
14	W>C (P<.05)	-	-
15	W>C (P<.05)	W>A (P<.001)	C>A (P<.001)
16	-	W>A (P<.001)	C>A (P<.001)
17	-	W>A (P<.001)	C>A (P<.001)
18	-	W>A (P<.001)	C>A (P<.001)

Table A14. International comparison of South African and British children: height

Age (years)	Boys	Girls
12	S>B (P<.001)	S>B (P<.01)
13	-	S>B (P<.001)
14	B>S (P<.05)	-
15	B>S (P<.001)	-
16	B>S (P<.001)	-
17	-	*

Table A15. International comparison of South African and British children: weight

Age (years)	Boys	Girls
12	S>B (P<.01)	S>B (P<.01)
13	-	S>B (P<.01)
14	B>S (P<.001)	-
15	B>S (P<.01)	-
16	B>S (P<.05)	-
17	-	*

In Tables A14-A22:

S = South African

B = British

- = no significant difference

* = data not available

Table A16. International comparison of South African and British children; pull-ups (boys) and modified pull-ups (girls)

Age (years)	Boys	Girls
12	-	S>B (P<.001)
13	-	S>B (P<.001)
14	S>B (P<.001)	S>B (P<.001)
15	S>B (P<.001)	S>B (P<.001)
16	S>B (P<.001)	S>B (P<.001)
17	S>B (P<.001)	*

Table A17. International comparison of South African and British children; sit-ups

Age (years)	Boys	Girls
12	B>S (P<.01)	S>B (P<.001)
13	S>B (P<.001)	S>B (P<.001)
14	S>B (P<.001)	S>B (P<.001)
15	S>B (P<.001)	S>B (P<.001)
16	S>B (P<.001)	-
17	S>B (P<.001)	*

Table A18. International comparison of South African and British children: shuttle run

Age (years)	Boys	Girls
12	S>B (P<.001)	S>B (P<.001)
13	S>B (P<.001)	S>B (P<.001)
14	S>B (P<.01)	S>B (P<.001)
15	S>B (P<.001)	S>B (P<.05)
16	-	B>S (P<.05)
17	-	*

Table A19. International comparison of South African and British children: standing broad jump

Age (years)	Boys	Girls
12	-	S>B (P<.01)
13	S>B (P<.001)	S>B (P<.01)
14	S>B (P<.01)	-
15	S>B (P<.01)	-
16	-	-
17	S>B (P<.01)	*

Table A20. International comparison of South African and British children; 50-yard dash

Age (years)	Boys	Girls
12	S>B (P<.001)	S>B (P<.001)
13	S>B (P<.001)	S>B (P<.001)
14	S>B (P<.001)	S>B (P<.001)
15	S>B (P<.001)	S>B (P<.01)
16	-	-
17	-	*

Table A21. International comparison of South African and British children; softball throw for distance

Age (years)	Boys	Girls
12	S>B (P<.01)	S>B (P<.001)
13	S>B (P<.001)	S>B (P<.001)
14	S>B (P<.001)	S>B (P<.001)
15	S>B (P<.001)	S>B (P<.001)
16	S>B (P<.001)	-
17	S>B (P<.001)	*

Table A22. International comparison of South African and British children; 600-yard run-walk

Age (years)	Boys	Girls
12	S>B (P<.001)	S>B (P<.001)
13	S>B (P<.001)	S>B (P<.001)
14	S>B (P<.001)	S>B (P<.01)
15	S>B (P<.001)	S>B (P<.05)
16	-	-
17	-	*

APPENDIX B

PUBLICATIONS

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Observations on the Harvard Step Test

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ABSTRACT

KEEN, E. N. AND A. W. SLOAN. *Observations on the Harvard step test.* J. Appl. Physiol. 13(2): 241-243. 1958.—The Harvard step test was applied to two groups of healthy young men, one consisting of medical students and the other of physical education students. The fitness index, as calculated from the results of the test, was not significantly correlated with stature, weight, length of leg, or bi-iliac diameter, but inverse correlation with the resting pulse rate was highly significant. The physical education students, who were all undergoing routine physical training, had higher fitness indices and lower resting pulse rates than the medical students.

THE HARVARD step test, devised during World War II and used for the selection of combat officers, has since been extensively applied as a measure of physical efficiency. The test involves stepping onto and down from a platform 20 inches high, 30 times a minute for 5 minutes, or until the subject is unable to continue (1). The pulse rate is counted during the periods, 1-1½, 2-2½ and 3-3½ minutes after the exercise is completed. An arbitrary fitness index is then calculated, which is directly proportional to the duration of exercise and inversely to the sum of the post exercise pulse counts, as follows:

fitness index

$$= \frac{\text{duration of exercise in sec.} \times 100}{2 \times \text{sum of three } \frac{1}{2} \text{ min. pulse counts}}$$

An index of less than 55 is considered poor, 55-64 is low average, 65-79 is high average, 80-89 is good and over 90 is excellent (2).

So simple a test has naturally aroused much interest and has provoked lively discussion, much of which is directed to seeking factors other than physical efficiency which may influence the results. The form of the test has been criticized, as has the basis of calculation of the fitness index.

Our own interest was first directed to the possible influence of stature and leg length on

the ease with which subjects mount what is, after all, a step of considerable height. We found, when the test was introduced into a practical physiology course, that the tall, long-legged students seemed to have less difficulty than their shorter fellows. Theoretical propositions to justify such a belief are not difficult to construct. We investigated also the significance of other parameters, which have been claimed to influence the results of the test.

EXPERIMENTAL

Our subjects were 75 healthy young men, of whom 51 were medical students and 24 were students of physical education. Their ages ranged from 17 to 27 years.

We measured stature, weight, leg length (as measured by the height of the iliac crest above the ground), bi-iliac diameter and resting pulse, in addition to the post exercise pulse as described above. The resting pulse was calculated in beats per minute from the sum of three ½-minute counts taken with the subject seated before commencing the exercise.

The subject then stepped onto and down from a stool 20 inches high, 30 times a minute in time with a metronome for 5 minutes, or until he was exhausted. Rubber-soled plimsolls were worn and the subject was allowed to lead off with either foot and to change step if he wished to do so. The fitness index was calculated as described above.

RESULTS

Five medical students were excluded from the series because they were unable to keep proper time or because they paused during the test. Two students of physical education were excluded because they had performed the test barefoot. The figures for the remaining subjects are given in table 1.

By a strange coincidence the mean stature and leg length in the two groups were the same. Stature, weight, leg length and bi-iliac diameter showed no correlation with the results of the step test in either group or in the series as a whole. In contrast to these negative findings, the resting pulse rate showed a high correlation with the post exercise pulse rate and so inversely with the fitness index, except in the cases of those students who failed to complete the 5-minute exercise of the step test (table 2).

Twenty-two of the medical students in the series failed to complete the 5-minute exercise, whereas all the students of physical education completed this period. Even excluding those medical students who failed to complete the test, the physical education students still had much higher scores than the remaining medical students, the difference being highly significant (means 85.6, 73.5; $P < 0.001$). The physical education students had also a lower mean resting pulse rate than the medical students who completed the test (means 74.4, 84.7; $P < 0.01$) and a lower absolute pulse increase¹ (means 44.5, 51.7; $P < 0.02$). In contrast to this the ratio of absolute pulse increase to resting pulse was almost identical in the two groups (mean ratio 0.61 for physical education students and 0.62 for medical students).

DISCUSSION

Seltzer (3) in an investigation of aviation cadets and college students found no relation between absolute stature or leg length and the fitness index obtained by the step test.

¹ Resting pulse rates were calculated in beats/min. from three $\frac{1}{2}$ -min. readings at $\frac{1}{2}$ -min. intervals before the exercise. Post exercise pulse rates were similarly calculated in beats/min. from the readings taken 1- $\frac{1}{2}$, 2-2 $\frac{1}{2}$, and 3-3 $\frac{1}{2}$ min. after the exercise. Absolute pulse increase is the difference between post exercise and resting pulse rates.

TABLE 1. PHYSICAL CHARACTERISTICS

	Mean	S.D.	Range
<i>A. 46 Medical Students</i>			
Stature, cm	176.6	5.7	164-188
Weight, kg	68.3	8.3	53.4-86.2
Leg length, cm	107.4	4.3	97-120
Bi-iliac diam., cm	28.5	1.4	25.7-31.6
Resting pulse, (beats/min.)	83.5	12.1	61-117
Fitness index	62.0	15.7	24-81
<i>B. 22 Physical Ed. Students</i>			
Stature, cm	176.6	4.0	169-184
Weight, kg	75.1	8.0	63.6-94.0
Leg length, cm	107.4	2.9	103-116
Bi-iliac diam., cm	28.8	1.0	27.3-30.4
Resting pulse, (beats/min.)	74.4	9.3	62-96
Fitness index	85.6	10.2	70-106

TABLE 2. CORRELATION RATIOS OF FITNESS INDEX WITH RESTING PULSE

Group	No. of Subj.	Ratio	Significance P
Phys. ed. students	22	-0.59	<0.01
Med. students who compl. 5-min. exer.	24	-0.60	<0.01
Med. students who did not compl. 5- min. exer.	22	-0.20	Not signif. >0.3
All compl. 5-min. exer.	46	-0.65	<0.001
Whole group	68	-0.36	<0.01

Cullumbine (4) obtained similar results in an extensive survey of young Ceylonese subjects. However, Gallagher and Brouha (5) and Johnson *et al.* (6), in order to obtain comparable results in different groups of boys, found it necessary to use a lower step for the smaller boys; an arbitrary division was made at a surface area of 1.85 m², an 18-inch step being provided for boys smaller than this. The better performance of the larger boys may have been related to greater physical capacity for exercise, irrespective of stature, but the point does not seem to have been examined. Weld (2) routinely employed an 18-inch step for boys and for women. Cullumbine (7) used a 15-inch step for boys under 14 years of age and for all female subjects.

The results of the present study fail to justify any lowering of the step for shorter adult men. Body weight was another factor which, in our series, was not correlated with the fitness index; this contrasts with the finding

by Reedy and Saiger (8) that lighter men attained significantly higher scores than heavier men.

We failed to substantiate a correlation between bi-iliac diameter and fitness index established by Cullumbine (4) on what was, admittedly, a much larger series of observations.

Another point of dispute is the significance of the resting pulse rate in relation to physical fitness. Gallagher and Brouha (5) found that the resting pulse showed no correlation with the fitness index, whereas Cogswell *et al.* (9) and Cullumbine (10) showed that a low resting pulse is associated with a low post exercise pulse and a correspondingly high fitness index. Our findings support this latter view.

The close negative correlation between resting pulse rate and fitness index raises several questions. For instance, is the correlation sufficiently close for us to abandon the step test and rely merely on the resting pulse rate as an index of physical fitness? We believe with Cogswell *et al.* (9) that this is not so, but that both should be recorded, although they may indicate different aspects of physical fitness. For example, the physical education students had a significantly higher mean fitness index and a significantly lower mean resting pulse; this could be due to individuals with inherently slow pulse rates selecting physical education as a career, or to intensive training lowering the resting pulse. Cogswell *et al.* (9) found no progressive decrease in the resting pulse rate with training, although the fitness index rose steadily.

Cullumbine (11), on the other hand, believed that the resting pulse is influenced by specialized training. If we accept the view that resting pulse rate is related to fitness, then what can we deduce about two subjects who have the same fitness index but different rest-

ing pulses? Should we say that the one with the lower resting pulse will be capable of greater improvement with training than the other? Alternatively, if two subjects have similar resting pulse rates but different fitness indexes, is the one with the lower index in poorer training than the other? Further investigations are in progress in an attempt to answer these questions.

Finally, the value of the test as an indication of physical fitness for strenuous exertion is shown by the much better performance of the physical education students than the medical students. The physical education students were all undergoing systematic physical training and it is reasonable to assume that they were fitter than the medical students and that the difference in fitness of the two groups shown by the test was a real difference in capacity for strenuous physical exertion.

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THE HARVARD STEP TEST OF PHYSICAL FITNESS*

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ABSTRACT

The Harvard step test is a simple test of physical fitness for strenuous muscular exercise. It requires no special skill on the part of the subject and it may be applied, with appropriate modifications, to healthy children, adolescents, or adults of either sex. The "fitness index" calculated from this test is useful in the allocation of individuals to duties within their physical capacity and in the assessment of response to physical training. The fitness index is not related to height, weight, length of leg, or width of pelvis but subjects with a slow resting pulse tend to have a high fitness index.

ASSESSMENT OF PHYSICAL FITNESS

Men have always been interested in physical fitness. For more than 2,000 years athletes have sought in competitive sport to excel the performance of their fellows. At a lower level than this it is useful in various activities to have some means of assessing physical fitness for strenuous exertion.

Gallagher and Brouha^{1, 2} considered physical fitness in three categories, viz.,

- (1) Static or medical fitness
- (2) Functional or dynamic fitness
- (3) Motor skills fitness.

Static fitness is merely the absence of any disabling deformity or disease; it is assessed by routine medical examination. Dynamic fitness is the ability to perform strenuous physical work involving large muscle groups. Motor skills fitness is the ability to perform

particular coordinated movements, such as those involved in swimming or jumping.

In the selection of individuals for hard physical work a test of dynamic fitness is of particular value. Medically unfit individuals are excluded *ab initio* and those lacking a particular skill can usually be taught to acquire it; the limiting factor then becomes the capacity of the heart and lungs to maintain the body in a state of sustained muscular activity. A test of dynamic fitness should subject large muscle groups to stress in such a fashion that the subject's capacity for exercise is limited by circulatory and respiratory embarrassment rather than by fatigue of the muscles concerned. Ideally the test should be so severe that about one-third of the subjects fail to complete it³; a more moderate test may fail to distinguish the fit from the less fit.

THE HARVARD STEP TEST

The Harvard step test, developed in the Fatigue Laboratory of Harvard University, fulfils these criteria⁴. The subject works at a constant rate which is proportional to his body weight, large muscle groups are involved, and the exercise requires no unusual skill. Another advantage is the simplicity of the apparatus required, only a rigid stool, platform, or bench 20 inches high and a stop-watch.

*Presented at the Lourenco Marques Congress of the Association, July, 1958. (Accepted for publication 20 September, 1958).

Briefly the technique of the test is as follows. The subject steps up and down from a 20-inch platform 30 times a minute for 5 minutes or until fatigue compels him to desist. Immediately after the exercise he sits down, and his pulse rate is counted for the periods 1-1½, 2-½, and 3-3½ minutes after the exercise. The fitness index is then calculated as follows:

$$\text{Fitness index} = \frac{\text{Duration of exercise in seconds} \times 100}{2 \times \text{sum of the 3 pulse counts during recovery.}}$$

On the results of the test, individuals are arbitrarily classified into several categories:

Fitness index	< 55	—poor
" "	55-64	—low average
" "	65-79	—high average
" "	80-89	—good
" "	> 89	—excellent

Brouha *et al.*⁴ found that the average for Harvard students was 75; for athletes, irrespective of the form of athletics practised, the mean fitness index exceeded 90.

The height of the stool and rate of stepping are such that a fair proportion of normal subjects fail to complete the period of 5 minutes. A disadvantage of the test is that it depends on willingness as well as on fitness but, by appropriate exhortation, most subjects can be induced to continue the test for 5 minutes or until stopped by physical exhaustion.

The reason for counting the pulse rate during three periods after exercise is theoretical³. The curve of pulse rate for the first 10 minutes of recovery is found to fit an exponential equation and can be drawn when any three values are known. Gallagher *et al.*⁵ found that fitness indices calculated from 3 heart rates during the first 3½ minutes after exercise on a bicycle ergometer agreed closely with those for which the third reading was taken 1 or 2 minutes later. Hence there is no advantage in taking the final pulse reading any later than 3½ minutes after cessation of exercise; much time would be wasted if later readings were taken on many subjects.

The amount of work performed and the

arbitrary correlation of duration of exercise with post-exercise pulse rates in calculating the fitness index have been criticised⁶. Some authors employ a lower step^{7, 8}. Others prefer to allocate an arbitrary fitness index on the basis of time of exercise alone to those who fail to complete 5 minutes^{4, 9}. We see no reason to believe that the original method of calculating fitness index, though arbitrary, is less precise than the modifications proposed.

COMPARISON WITH OTHER TESTS

Some investigators have compared the results of the Harvard step test with those of other tests on the same groups of subjects and with other measurements of physiological capacity. Seltzer¹⁰ found good agreement between fitness indices calculated from the Harvard step test, the Harvard pack test, and a treadmill test. Cogswell *et al.*¹¹ obtained similar results with the step test, a treadmill, and a bicycle ergometer. Hodgson *et al.*¹² tested women students of physical education with the Harvard step test, with maximal stepping on to a 12-inch stool, and with running 50 yards and 200 yards; they found that the capacity to perform these tests bore little relation to the physiological responses involved, such as heart rate and rate of oxygen consumption. Cullumbine¹³, in an extensive survey of physical fitness in Ceylon, used the Harvard step test, the endurance step test, the exhaustion step test, a weight-lifting test and a speed test; he found that the ability to perform these tests was influenced by environment, race, and sex. Cullumbine and Williams¹⁴ found no correlation between the fitness index for moderate exertion (Harvard step test) and the endurance indices for severe exercise. Ryhming⁸ found good agreement between the post-exercise pulse rates with a less strenuous step test and with equivalent work performed on a bicycle ergometer.

Hodgson *et al.*¹² found that fitness index calculated from the Harvard step test showed little relation to rate of oxygen consumption, ventilation or resting heart rate. Cullumbine and Williams¹⁴ found no significant relation between the fitness index and vital capacity, breath-holding time, or expiratory force.

APPLICATIONS

During the Second World War the Harvard step test was used in the selection of combat officers⁴. Since the war the original test or some modification of it has been applied to athletes^{14, 15}, lumbermen¹⁶, soldiers^{6, 17}, aviation cadets¹⁰, students^{7, 8, 10, 12, 15, 18, 19}, boys^{5, 9, 20}, and girls²¹.

Cullumbine¹⁵ obtained significantly higher fitness indices for students who were track athletes, boxers, or weight lifters than for other students. Keen and Sloan¹⁹ found significantly higher fitness indices for students of physical education than for medical students. Reedy and Saiger¹⁷, testing military recruits, found that individuals above a certain body weight had a lower fitness index. Insull *et al.*⁶ showed rapid improvement in a group of soldiers when the step test was repeated three times a week.

For testing women or children a lower platform is usually employed. Hardy *et al.*¹⁸ used an 18-inch step for women, and Gallagher and Brouha²¹ used a 16-inch step for school girls; in both these investigations the duration of exercise was reduced to 4 minutes. Ryhming⁸ used a 33 cm. step for women and reduced the rate of stepping to 22.5 steps per minute. Cullumbine¹⁵ routinely employed a 15-inch step for boys under 14 and for all female subjects. For testing schoolboys, Gallagher and Brouha²⁰ and Johnson *et al.*⁹ used an 18-inch step for those whose surface area was less than 1.85 sq. metres and a 20-inch step for the larger boys.

RELATION TO ANTHROPOMETRIC MEASUREMENTS

Fortier¹⁶ found that a high shoulder/hip ratio was significantly related to a good step-test result. Cullumbine²² found that the fitness index was significantly related to the bi-iliac diameter and to the ratios, bi-iliac diameter/height and chest circumference/height. In our series¹⁹ we found no relationship between bi-iliac diameter and fitness index.

In our investigations of young adult men¹⁹ we found that neither height nor length of

leg nor weight was significantly related to the fitness index as determined by the Harvard step test. In such a group there seems to be no justification for varying the height of the step for subjects of different stature. The weight factor might have been significant in our series, as in that reported by Reedy and Saiger¹⁷, had some of our subjects been obese, but such was not the case.

RELATION TO PHYSICAL TRAINING

We found that a group of physical education students, though not differing significantly in anthropometric characteristics from a corresponding group of medical students, had a much higher mean fitness index than the medical students ($P < 0.001$). Like Cullumbine²³ we found a significant correlation in each group between a high fitness index and a low resting pulse. In other words a pulse which is slow at rest tends to remain slow after exercise.

Previous investigators have noted the high fitness index of athletes^{4, 15} and that the fitness index rises with training^{11, 24}. The slow resting pulse rate of trained athletes is also a matter of common knowledge^{25, 26, 27}. There is however no general agreement as to whether this slow pulse rate is inherent in those who undertake athletics or is the result of training. Cogswell *et al.*¹¹ found no progressive decrease in the resting pulse rate with training but Cullumbine²⁸ considered that specialized training and a careful regime were factors of major importance in their influence on the resting pulse rate.

At present we are studying the effect of training on the fitness index and the resting pulse rate of rugby players and of oarsmen.

CONCLUSION

In conclusion we recommend the Harvard step test as a simple and practical test of fitness for strenuous physical work. It has proved its value in the selection of individuals for such activity and it should prove its value also in the assessment of individual response to systematic physical training.

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Physical fitness of oarsmen and rugby players before and after training¹

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SLOAN, A. W. AND E. N. KEEN. *Physical fitness of oarsmen and rugby players before and after training.* J. Appl. Physiol. 14(4): 635-636. 1959.—Resting pulse rates and fitness indexes by the Harvard step test were ascertained in 100 healthy male University students. The subjects included members of the University rowing and rugby clubs, who were about to undergo systematic training, and a third group of students not engaged in any such activity. The observations were repeated on 58 of the students after a period of 2-4 months. The mean resting pulse rates of the three groups were not originally significantly different but after training the pulse rate was significantly lower in the athletic groups than in the controls. At the beginning of the training period the oarsmen and rugby players already had higher fitness indexes than the controls and thereafter they showed significant improvement with training. A significant negative correlation between resting pulse rate and fitness index was found only in the athletic groups.

IN A PREVIOUS INVESTIGATION of physical fitness (1) we found a highly significant inverse correlation between resting pulse rate and fitness index in students who were able to complete the full 5 minutes of exercise for the Harvard step test. The fittest group of students had the slowest mean resting pulse rate but we were unable to decide whether this slow pulse rate was a manifestation of inherent capacity for strenuous muscular work or was the result of physical training. In this paper we report the effect of physical training on both resting pulse and fitness index in oarsmen and rugby players.

EXPERIMENTAL PROCEDURE

Our subjects were 100 healthy young men, aged 17-24 years, in the following three categories:

Rowing club	35 subjects
Rugby club	45 subjects
Controls	20 subjects

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The controls were medical students who were not undergoing systematic training for any sport although some of them played games such as golf, tennis or squash racquets.

Resting pulse rates were counted and the Harvard step test was performed, as in our previous investigation (1). The subjects were tested first at the beginning of the academic year and the tests were repeated after 2-4 months, during which the members of the rowing and rugby clubs had been undergoing systematic training for their respective sports. Most of the members of the rowing club were new to the sport but most members of the rugby club had played during the previous season.

A considerable number of subjects dropped out of the investigation after the first test. Eight members of the rowing club gave up rowing before the second tests were due and three failed to return for a second test. Four members of the rugby club stopped training and 10 were incapacitated by illness or injury before the second tests were due; 13 failed to attend for the second tests, the dates of which unfortunately coincided with University examinations. Those rugby players who, for various reasons, did not perform a second test represent a fair cross section of the group on the basis of physical fitness and resting pulse at the first test. Only four of the controls failed to return, one of them as a result of injury.

RESULTS

Table 1 shows the resting pulse rate and fitness index in each of the three groups at the beginning of the investigation. Analysis of variance revealed no significant difference in resting pulse rate between the three groups but the rowing and rugby groups had significantly higher fitness indexes than the control group ($P < .001$). There was no significant difference in fitness index between rowing and rugby groups.

Table 2A shows the resting pulse rate in the members of each group who completed both tests. In every group the resting pulse rate was significantly slower at the end of the period of investigation than at the beginning but, at the end of the period of training, it was signifi-

TABLE 1. *Initial Resting Pulse Rates and Fitness Indexes*

Group; No. Subj.	Resting Pulse, Beats/Min.	Fitness Index
Rowing; 35	79.5±14.4 (46-106)	80.2±12.0 (40-106)
Rugby; 45	79.1±12.0 (62-109)	75.0±13.5 (42-103)
Control; 20	84.8±10.1 (69-107)	56.0±19.9 (25-88)

Values are means ± S.D. Range in parenthesis.

cantly slower in the athletic groups than in the controls ($P < .001$).

Table 2B shows the fitness index in the members of each group who completed both tests. The rise in fitness index in rowing and rugby groups during the training period was highly significant, whereas no significant change occurred in the control group.

Comparing the changes in resting pulse rates and in fitness indexes in the three groups during the period of investigation we find that the fall in resting pulse rates in the rowing and rugby groups was not significantly greater than the smaller fall in the control group but the rise in fitness index in the rowing and rugby groups was significantly greater than that in the control group ($P < .01$). There was no significant difference in this respect between oarsmen and rugby players.

Each group was further analyzed to ascertain whether there was any correlation between low resting pulse rate and high fitness index, which depends on low pulse rates after exercise. In the oarsmen, this correlation was highly significant both before and after training. In the rugby players, the correlation just failed to reach significance before training but was significant after training. In the control group, neither at the beginning nor at the end of the period of investigation was there any significant correlation between resting pulse rate and fitness index.

DISCUSSION

There was no significant difference in physical fitness as shown by the Harvard step test between the oarsmen and the rugby players either at the beginning or at the end of the period of investigation but both these groups had consistently higher mean fitness indexes than the control group. It may be assumed that individuals proposing to take part in these active sports take steps to keep themselves physically fit, but it is interesting to note that their resting pulse rates were not significantly lower than those of the control group.

The significant fall in mean resting pulse rate of the controls at the second test requires some explanation. The subjects, with no previous experience of the test,

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TABLE 2. *Change in Resting Pulse and in Fitness Index*

Group; No. Subj.	Initial	Final	S.D. of Change	Range of Change	Signif. of Change
<i>A. Resting Pulse</i>					
Rowing; 24	78.8±13.8	71.5±9.2	±11.2	-28-+16	$P < .01$
Rugby; 18	77.6±12.3	66.8±8.4	±13.4	-43-+8	$P < .01$
Control; 16	86.2±10.4	80.4±10.2	±8.1	-20-+10	$P < .05$
<i>B. Fitness Index</i>					
Rowing; 24	81.1±12.6	91.8±11.4	±10.7	-9-+44	$P < .001$
Rugby; 18	81.3±13.1	92.6±11.8	±11.2	0-+46	$P < .001$
Control; 16	58.4±17.8	59.6±15.6	±9.0	-8-+25	N.S.

Values are Means ± S.D.

may have felt apprehensive before their first attempt. Again, a change in environmental temperature may have been involved; the tests were performed in an unheated room, most of the initial tests were made during the hot months of February and March and the final tests during the cooler month of June. Although the fall in resting pulse rate was not significantly greater in the athletic group the mean resting pulse rates of oarsmen and rugby players at the end of the investigation were significantly lower than that of the controls. This finding agrees with the observations of previous investigators (2-5) that systematic physical training lowers the resting pulse rate.

With training, the fitness indexes rose significantly in the athletic groups. Such a rise in fitness index with systematic physical training has already been reported by other investigators (6-10). That this change in our subjects was not due to other systematic factors is shown by the absence of any corresponding change in the control group.

A negative correlation between resting pulse rate and fitness index was found only in our athletic groups. This agrees with our previous observation that such correlation occurs only in relatively fit individuals. Elbel *et al.* (11) found such a correlation in a group of medical students but the high fitness index of their subjects (mean = 84) suggests that they correspond to the members of our athletic groups rather than to a cross-section of our student community.

Whereas both a low resting pulse and a high fitness index may be indications of physical fitness we believe that the fitness index is a more reliable criterion because less subject to variation as a result of extraneous factors and more closely related to the capacity for strenuous exertion.

We are indebted to Mr. J. N. Darroch of the Department of Mathematics for help with the statistical analysis.

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A modified Harvard step test for women

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SLOAN, A. W. *A modified Harvard step test for women.* J. Appl. Physiol. 14(6): 985-986. 1959.—The fitness indexes of two groups of healthy young women performing the Harvard step test on steps of various heights were compared with the fitness indexes of a corresponding group of men performing the test on a step of the standard height (20 inches). The closest agreement with the results of the men was attained by women using a step 17 inches high. Not only did the mean fitness indexes correspond, but also the distribution of individuals in the several categories of physical fitness.

PHYSICAL FITNESS has three main aspects (1, 2). These are: static fitness (absence of disease), dynamic fitness (ability to perform strenuous work), and motor skills fitness. A popular test of dynamic fitness is the Harvard step test (3). In this test, which was designed for adult men, the subject steps on and off a platform 20 inches high, 30 times a minute for 5 minutes or until he is unable to continue. The pulse rate is then counted for three ½-minute periods, 1-1½, 2-2½ and 3-3½ minutes after completion of the exercise. The fitness index (F.I.) is calculated from the duration of exercise and the post-exercise pulse rates as follows:

$$F.I. = \frac{\text{duration of exercise in sec.} \times 100}{2 \times \text{sum of the three } \frac{1}{2}\text{-min. pulse counts}}$$

On the arbitrary standard adopted a fitness index of less than 55 is poor, 55-79 is average, 80-89 is good and 90 and over is excellent (4).

In order to ascertain which height of step for women would give results corresponding to those obtained on a 20-inch step by men, two groups of women were tested on different heights of step. Their fitness indexes were compared with those previously reported from a comparable group of men using a 20-inch step (5).

EXPERIMENTAL PROCEDURE

The subjects for the first investigation were 15 students of physiotherapy. All were healthy women in the age group of 17-21 years.

Each subject performed the test three times on dif-

ferent days, once on a 20-inch stool, once at 18 inches and once at 16 inches. The order of the tests was staggered so that the effect of practice would not favor performance at any particular height. The fitness indexes of the female physiotherapy students were compared with those of a group of 46 male medical students who performed the test on a 20-inch stool. Forty-two of the men were in the same age group as the female subjects and the oldest was 27.

Subsequently, 16 women medical students, aged 17-21 years, were subjected to the test at heights of 18 inches, 17 inches and 16 inches for comparison with the same group of men as before.

RESULTS

The fitness indexes of the groups of women and of the group of men with whom they are compared are summarized in table 1. The closest agreement in the first comparison was between women students at 18 inches and men at 20 inches, the mean for men falling between the mean for women at 18 inches and for women at 16 inches.

In view of these findings the tests of the second group

TABLE 1. *Fitness Indexes*

Subjects	Ht. of Step, in.	Mean F.I.	S.D. of F.I.
46 Men medical students	20	62.0	15.7
15 Women Physiotherapy students	20	45.6	22.2
	18	58.0	18.4
	16	68.9	18.7
16 Women medical students	18	54.9	16.4
	17	59.8	16.8
	16	69.8	13.8

TABLE 2. *Categories of Physical Fitness*

Subjects	Ht. of Step, in.	Poor <55	Average, 55-79	Good, >79
46 Men medical students	20	16	27	3
15 Women physiotherapy students	20	11	2	2
	18	7	6	2
	16	4	8	3*
16 Women medical students	18	8	7	1
	17	6	9	1
	16	2	10	4

* One subject came into 'excellent' category (F.I. 95).

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of women were performed at 18 inches, 17 inches and 16 inches. Although the *t* test showed no significant difference between the fitness indexes of any of these three groups and the fitness indexes of men on a 20-inch step, the closest agreement was found at 17 inches.

Each group was further analyzed to find the number of individuals whose fitness index fell into each of the main categories of physical fitness (table 2). The χ^2 -test was applied to the two-way contingency tables obtained by comparing men and women medical students in the three fitness index categories: poor, average and good. For women at 18 inches this gives $\chi^2 = 1.193$ with two degrees of freedom; for women at 17 inches the test gives $\chi^2 = 0.037$ with two degrees of freedom; for women at 16 inches it gives $\chi^2 = 2.860$ with one degree of freedom (because of the gross discrepancy in this case it was statistically necessary to group average and good categories together). Since the 98% point for χ^2 with two degrees of freedom is 0.040, there is no doubt of the excellence of the agreement between men tested on the 20-inch step and women on the 17-inch, in spite of the small numbers tested.

DISCUSSION

The Harvard step test has the merit of simplicity. It is sufficiently severe to distinguish those capable of sustained muscular effort from those who are not and sufficiently sensitive to demonstrate the improvement in dynamic fitness with systematic physical training (3, 4, 6-8). Since large muscle groups are used, the limiting

factor is usually cardiorespiratory embarrassment rather than local muscular fatigue. Within reasonable limits the fitness index does not depend on the weight, height, or length of leg of the subject (5, 9, 10).

Although the test was originally devised for men, it has been applied to women by a number of investigators, most of whom have arbitrarily lowered the height of the step to 18, 16, 15, or even 13 inches for female subjects (4, 6, 11-13). Some have also reduced the period of exercise (4, 6, 11) or the rate of stepping (13). Each such modification of the original test obviously necessitates a new set of values, however arbitrary, for interpretation of the results.

The results of the present investigation show that the Harvard step test is a useful test of capacity for strenuous exertion by women as well as by men. To obtain comparable results in women the height of the step must be reduced from the 20 inches commonly employed for male subjects. The 20-inch step has a particular disadvantage for women in that the limiting factor is often local fatigue of leg muscles; in these cases, the test is not a true measure of the capacity of the body as a whole for sustained muscular effort.

A suitable height of step for women performing the Harvard step test is 17 inches. With a step of this height the same arbitrary standards of performance may be applied with the same validity as for men on a 20-inch step.

The author expresses thanks to Professor M. J. Pollard for help with the statistical analysis.

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Effect of training on physical fitness of women students

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SLOAN, A. W. *Effect of training on physical fitness of women students.* J. Appl. Physiol. 16(1): 167-169. 1961.—To ascertain the effect of physical training on young women, four groups were subjected to a modified Harvard step test at the beginning of the academic year and again 4 and 9 months later. One group, specializing in physical education, had a very active program of gymnastics, dancing and games; two other groups had a much less active program; a fourth group had no physical training at all. In the series as a whole there was no correlation between fitness index and either height or weight and no evidence that menstruation influenced performance of the test. At the beginning of the investigation the physical education students had higher fitness indexes than the others and they improved with training. Lesser degrees of physical training caused no significant increase in fitness index but counteracted a tendency to deterioration observed in the group that had no physical training. Changes in the resting pulse were less consistent, and resting pulse rates showed little correlation with fitness indexes.

IN AN ATTEMPT to ascertain the effect of regular physical training on the physical fitness of young women, four groups undergoing different degrees of physical training were tested at the beginning of the school year and again 4 and 9 months later. The fitness index was estimated from a modified Harvard step test, and the pulse rate was counted at rest.

SUBJECTS

The subjects were 61 women student teachers, aged 17-20 years, at Cape Town Training College. All had been passed as fit at a routine medical examination.

Of these students 13 in their 3rd year of training were specializing in physical education; their weekly program included 2½ hours of gymnastics, 2 hours of dancing and at least 2 hours of games. A second group of 16 3rd-year students was specializing in infant-school teaching; they spent only 40 minutes a week at gymnastics, and

attendance at games was not obligatory. The remaining students were all in their 1st year of general training; of these, 19 did gymnastics for 40 minutes each week, and the other 13 did not. Attendance at games was obligatory for the 1st-year students doing gymnastics but not for the others.

EXPERIMENTAL PROCEDURE

The Harvard step test (1, 2) was employed to test the subjects' physical fitness for strenuous exertion. From this test, originally designed for men, a fitness index was derived that was directly proportional to the duration of performance of strenuous exercise up to a maximum period of 5 minutes and inversely proportional to the pulse rate thereafter. For this investigation of women the test was modified by reducing the height of the step from 20 to 18 inches. The subjects were dressed in light gymnastic costume and wore canvas tennis shoes. The height and weight of each subject were measured at the beginning of the investigation, and she was asked whether she was menstruating at the time of the test. The tests were performed in an unheated room, usually between 9 A.M. and 12.30 P.M. Environmental temperature in the mornings during the first set of tests varied between 19° and 24°C, except on one very hot day (29.5°C) when the first tests and resting pulse rates of physical education students were recorded. The second set of tests was carried out during the cool season at temperatures of 14.5°-16.5°C and the third set at temperatures of 18.5°-23.5°C.

In addition to the fitness index the resting pulse was counted, usually between 2 and 3 P.M. from ½ to 1½ hours after a light luncheon. To avoid the effect of excitement in anticipation of the test or the residual effect of exercise thereafter, the resting pulse was counted either several hours after the test or on a different day. The subjects were seated and relaxed for at least 5 minutes before the resting pulse was counted and the rate was calculated from three half-minute readings taken at half-minute intervals.

TABLE 1. *Fitness Indexes and Resting Pulse Rates*

Group	No. in Group	Fitness Index*			Resting Pulse Rate†		
		1st test	2nd test	3rd test	1st test	2nd test	3rd test
Physical education	13	61.2±15.5	73.0±11.7	76.8±4.7	88.7±9.5	73.8±7.7	80.6±10.0
Infant school	16	46.8±18.4	48.2±18.2	48.1±19.3	80.5±9.6	86.7±4.3	86.7±15.7
General course							
With gymnastics	19	51.1±17.9	53.8±18.4	52.3±18.5	79.6±8.7	86.8±12.4	78.9±8.6
Without gymnastics	13	41.1±18.3	37.9±17.8	36.6±12.7	89.4±11.0	87.7±9.2	82.3±8.6

* Mean ± S.D. † Mean rate per minute ± S.D.

RESULTS

No correlation was found between fitness index and height or weight except in the case of infant-school teachers, where the heavier subjects did less well. In this group there was a wider anatomical range of size and shape than in the other groups. There was practically no difference between the average performance of those who were menstruating at the time and those who were not, the mean fitness indexes being 49.8 and 50.0, respectively.

Table 1 shows the fitness indexes at the beginning of the investigation. The students who were about to specialize in physical education had a higher mean fitness index than the infant-school teachers ($P < 0.05$) or the 1st-year students who did not propose to do gymnastics ($P < 0.01$). There was no significant difference between the fitness indexes of the other groups.

All the physical education students repeated the test approximately 4 months and 9 months later. Three infant-school teachers and two general course students were absent from the 2nd and 3rd tests.

After approximately 4 months of the various courses the physical education students had higher fitness indexes than at the first set of tests ($P < 0.001$); this improvement was maintained without further significant change over the ensuing 5 months. Although no significant change in fitness index occurred in any other group, by the end of the first 4 months there was a significant difference in fitness index between the general course students who did gymnastics and those who did not ($P < 0.05$); this difference was maintained at the later tests.

Table 1 also summarizes the resting pulse rates at each stage of the investigation. At first the mean resting pulse rates of physical education students and of general course students who did not propose to do gymnastics were significantly higher than those of the other two groups ($P < 0.05$). The mean resting pulse rate of the physical education students fell during the first 4 months ($P < 0.001$) but rose again during the ensuing 5 months ($P < 0.05$). The infant-school and general course students who had one session of gymnastics each week showed a significant increase in resting pulse at the end of 4 months ($P < 0.01$), which was maintained by the infant-school but not by the general course students.

The 1st-year students not doing gymnastics showed a significant fall in pulse rate over 9 months ($P < 0.05$).

At the first set of tests there was no correlation between resting pulse rate and fitness index, which is related to pulse rate after exercise. After 4 months, although no individual group showed such correlation, in the whole series a slow resting pulse was associated with a high fitness index ($P < 0.05$). This correlation no longer held at the end of the period of investigation.

DISCUSSION

Systematic training for active sport has been found to increase physical fitness as estimated by exercise tolerance tests (3-6). After such training the resting pulse tends to be slow (7-10) and the pulse rate after exercise returns to the resting level more rapidly than in untrained subjects (11, 12).

The Harvard step test is a useful means of estimating the physical fitness of men or women for strenuous exertion. For women it has been found advisable to use a step 18 inches high (3, 13) instead of the 20-inch step originally recommended for men. Since the present investigation was started it has been shown that the closest agreement with the results of men performing the test on the standard 20-inch step is attained by women using a step 17 inches high (14) but, for the comparisons sought in this investigation, an 18-inch step was satisfactory.

The lack of correlation between fitness indexes and height or weight in this investigation agrees with previous observations on men (2). The absence of any ill effect of menstruation on the performance of strenuous physical work is not surprising in view of modern opinion on this topic. Menstruation does not impair athletic efficiency (15-17).

Furthermore, it is not surprising that the students who intend to make physical education their career should have higher fitness indexes than the others, even at the beginning of the academic year and on an exceptionally hot day. Presumably they keep fit during their vacation. The highly significant increase in fitness index of these students during the year is evidence of the efficacy of their strenuous program of physical training, since no such change occurs in any other group. Even the much

less strenuous gymnastic program of the general course seems to have some beneficial effect. The students in this course who did gymnastics were significantly fitter after 4 months than those who did not; the latter showed a steady though not significant fall in fitness index. This suggests that at least a certain minimum amount of regular physical training is advisable to counteract the tendency to physical deterioration associated with a very sedentary existence.

The physical education students had unexpectedly high pulse rates at the beginning of the investigation. Since these were recorded on the one very hot day (29.5°C), environmental temperature may have been a relevant factor. The pulse rates of these students were lower after a period of training but rose again while the training was still in progress. No comparable changes occurred in the other groups, and the 1st-year students doing no gymnastics showed a steady fall in resting pulse rate during the period of investigation. It may be that the effect of a little physical activity is to increase the resting pulse rate, presumably by increasing metabolism, whereas greater activity reduces it again as a result of

compensatory increase in cardiac efficiency. This hypothesis would explain all the observations except the final rise in pulse rate of the physical education students.

The lack of correlation between resting pulse and fitness index in the students of physical education is surprising. A number of investigators have reported such a correlation in young men (5, 12, 18-20). Keen and Sloan (2) found it only in athletic subjects. Damez and her colleagues (11) found that athletic schoolgirls had slower resting pulse rates and that their pulse rates returned more rapidly after exercise to the resting level than was the case in less athletic schoolgirls. If the resting pulse rate were closely related to the fitness index it would itself serve as an index of fitness for strenuous exertion but it is influenced by so many extraneous factors not connected with muscular activity that it is a much less reliable measure of physical fitness than is the Harvard step test.

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Physical Fitness of College Students in South Africa, United States of America, and England¹

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Abstract

The Harvard step test was performed by male students of physical education and male sophomores not specializing in physical education in Cape Province (South Africa), North Carolina, and England. A modified Harvard step test was performed by corresponding groups of women. Assessed by this test, the fittest male physical education students were the English, and the South Africans were fitter than the Americans. English female students of physical education were not significantly fitter than South Africans but were fitter than Americans. The fittest sophomores (men and women) were the English. There was no significant difference in performance between American and South African sophomores.

No correlation was found between fitness index and height, weight, or time devoted to organized physical training. Menstruation did not impair the performance of women students. The rapid method of calculating fitness index gave results almost identical with those obtained from the original, longer method.

IN COMPARING the athletic performance of different groups of men or women a major difficulty is the standardization of test conditions and the interpretation of results. This is the case particularly when different national groups are being tested each in their own country, and the only satisfactory solution is for the same investigator or team of investigators to visit and supervise the tests in each of the countries concerned. The author was fortunate in having the opportunity to test the physical fitness of college students in Cape Province (South Africa), North Carolina, and London and Exeter (England). The Harvard step test (1, 7) was selected as a good single procedure for assessing fitness for strenuous muscular activity; it has the merit of simplicity and the same observer, applying the same standards, can be responsible for all the tests.

Procedure

Male and female physical education (PE) students were tested in each of the localities. All were in the age-group 18-25 and had been passed as fit at routine medical examinations. The PE students, except for the English women, were in their third year at college but in their first year of specialized training as teachers of physical education; the English women were second-year students of physical education. No selection of PE students was exercised, all those available being tested. Male and female sophomores, not specializing in physical education, were also tested in each locality. These were healthy volunteers, aged 18-24; individuals in active training for competitive sport were excluded.

A menstrual history was obtained from each woman student to relate the date of performance of the test to the time in her menstrual cycle. The height and weight of each student was measured, wearing light gymnastic costume without shoes, and the test was performed in the same costume but wearing rubber-soled canvas shoes. The tests were performed during the cool season of the year in each place and between the hours of 8.30 A.M. and 1 P.M. Since the performance of an exhausting test depends on motivation as

¹ From the Department of Physiology, University of Cape Town. Thanks are due to staff and students of the following institutions for their enthusiastic cooperation: in South Africa, the University of Cape Town, Cape Town Training College, and Paarl Training College; in the U.S.A., the University of North Carolina, including the Woman's College at Greensboro; in England, Avery Hill Training College, London, and Saint Luke's College, Exeter.

well as on physical fitness, each group of students was told that the investigation was an international comparison of fitness and that their performance was a matter of national prestige. Each subject was actively encouraged to complete the test if he or she showed any sign of failing to do so.

Male students performed the standard Harvard step test, stepping on to a bench 20-in. high in time with a metronome 30 times a minute for 5 min. or until compelled by fatigue to desist. If a subject failed to stand erect or to keep up with the metronome for 15 sec. after exhortation to do so the exercise was stopped and the duration to the time of stopping recorded. Pulse rates were counted for three $\frac{1}{2}$ -min. intervals, 1-1 $\frac{1}{2}$, 2-2 $\frac{1}{2}$ and 3-3 $\frac{1}{2}$ min. after the exercise, and the fitness index (FI) calculated as usual (1, 7). Fitness indexes were calculated also by the rapid method from the first pulse count only (6, 13) to find the correlation between the results of this method (RFI) and the original standard technique used in this investigation.

Women performed the same test, but on a bench 17 in. high. This height was selected because, in a previous investigation (10) the performance of the test on a bench of this height by women corresponded very closely to that of men on the standard 20-in. bench.

The significance of differences between groups was estimated by the *t* test (2).

Results

Male PE students in North Carolina were taller and heavier than other PE students (Table 1). The tallest sophomores were South African men and women but they were not significantly taller than the Americans. There were no significant differences in weight between the groups of sophomore men or between any of the groups of women.

More time was allocated to physical training in the curriculum of male PE students at North Carolina than in that of any other group (Table 2). The highest allocation of physical training time for female PE students was in South Africa. Men and women sophomores in South Africa and men sophomores in England had no physical training period in the curriculum.

The mean fitness index (MFI) of English male PE students was higher than that of South Africans or Americans and the South African was higher than the American (Table 2). English female PE students had an MFI higher than American but not significantly higher than South African students. In the sophomore groups of men and women the English had the highest MFI. In South Africa both male and female PE students had a significantly higher MFI than the corresponding groups of sophomores ($P < 0.001$). In North Carolina the female PE students and in England the male PE students had a significantly higher MFI than the corresponding groups of sophomores ($P < 0.05$).

Neither in any individual group nor in the series as a whole was there significant correlation between FI and body weight. There was no significant difference between the MFI of women who performed the test during a menstrual period or within two days of the next menstrual period and other women.

In the whole series the correlation between the FI used in this investigation and the RFI was very high ($r = +0.996$).

Discussion

For the present investigation it was not possible to test a large and representative cross-section of the young people of each nation. Although each of the colleges where the tests were performed has a high reputation in its own community and can be considered a good representative of its national group, it would be unreasonable to interpret the findings in this paper as representing systematic differences in fitness between South Africans, Americans, and English. The results, however, are of interest, and possible explanations will be considered.

Any possible influence of environmental factors on the results was minimized by strict standardization of the test conditions. Since all the subjects were of European stock, no difference in racial aptitude for this form of exertion is likely to be involved.

TABLE 1.—HEIGHT AND WEIGHT (MEAN AND STANDARD DEVIATION)

Subjects	1. South Africa			2. North Carolina			3. England			Significant Differences		
	No. of sub-jects	Height (cm.)	Weight (kg.)	No. of sub-jects	Height (cm.)	Weight (kg.)	No. of sub-jects	Height (cm.)	Weight (kg.)	Height (cm.)	Weight (kg.)	Weight (kg.)
Physical Education (Men)	15	175±6.6	74.7±9.1	16	182±8.0	86.7±11.0	18	173±4.1	73.2±5.3	2>3(P<0.001) 2>1(P<0.01)	2>3(P<0.001) 2>1(P<0.01)	2>3(P<0.001) 2>1(P<0.01)
Sophomore (Men)	20	181±6.8	70.9±7.8	23	178±6.7	71.2±9.7	22	176±5.4	69.8±8.3	1>3(P<0.05)	Nil	Nil
Physical Education (Women)	14	166±6.8	61.9±10.5	15	164±5.1	57.1±6.4	21	165±6.3	60.0±6.5	Nil	Nil	Nil
Sophomore (Women)	28	166±6.4	61.4±8.5	22	164±6.5	55.8±12.0	22	162±5.9	56.4±6.2	1>3(P<0.05)	Nil	Nil

TABLE 2.—CURRICULAR PHYSICAL TRAINING AND FITNESS INDEXES (MEAN AND STANDARD DEVIATION)

Subjects	1. South Africa			2. North Carolina			3. England			Significant Differences	
	No. of sub-jects	P.T. (hours per week)	Fitness index	No. of sub-jects	P.T. (hours per week)	Fitness index	No. of sub-jects	P.T. (hours per week)	Fitness index	Fitness Indexes	Fitness Indexes
Physical Education (Men)	15	10.25	85.0±4.9	16	18.00	66.0±16.6	18	11.00	95.8±15.5	3>2(P<0.001) 3>1(P<0.01) 1>2(P<0.001)	3>2(P<0.001) 3>1(P<0.01) 1>2(P<0.001)
Sophomore (Men)	20	Nil	64.2±15.6	23	2.00	68.3±19.9	22	Nil	82.1±14.5	3>2(P<0.05) 3>1(P<0.01)	3>2(P<0.05) 3>1(P<0.01)
Physical Education (Women)	14	8.00	67.1±12.4	15	6.00	57.2±18.6	21	4.50	70.2±16.7	3>2(P<0.05)	3>2(P<0.05)
Sophomore (Women)	28	Nil	40.1±16.9	22	2.00	41.4±17.6	22	0.75	61.0±16.0	3>2(P<0.001) 3>1(P<0.001)	3>2(P<0.001) 3>1(P<0.001)

The significant differences in MFI of different groups might be due to differences of bodily habitus. Previous investigations in South Africa have shown no correlation between FI and either height or weight (7), but workers in the U.S.A. have found a significantly poorer performance in heavier young men (9). In the present investigation the male PE students in North Carolina were considerably heavier than their opposite numbers in the other countries and it may be that their low FI's are attributable to the extra work done in lifting the extra weight at each step up.

In North Carolina most male students were performing the Harvard step test for the first time, whereas in South Africa the male PE students and in England all the male students had performed it previously. All the female students were performing it for the first time. Previous investigations of men (12) and women (11) have shown no improvement in FI as a result of previous performance of the test, although systematic practice at it results in significant improvement (3, 5).

Male PE students in North Carolina, though devoting the most time of any group to physical training, had a lower MFI than other male PE students. The female PE students with the shortest allocation of time to physical training, the English, had the highest MFI. In the sophomore groups the English men and women had the highest MFI's but not the greatest allocation of time to physical training. The lack of correlation between the MFI of a group and the time allocated to their physical training is surprising in view of a previous investigation of female students in South Africa, in which the fitness index of each group was related to the amount of organized physical training in the curriculum (11). In the present investigation it may be that the training was more strenuous in one college than another or that one group of students was more active in extra-curricular physical recreation. Such factors, and also that of motivation, are difficult to assess.

The finding that neither menstruation nor the premenstrual period impaired performance of a severe physical test supports the modern view that healthy young women are capable of strenuous physical activity at these times (4, 11).

The very close agreement between the standard FI's calculated from three pulse counts and the RFI's calculated from one, supports the contention that the standard method may satisfactorily be replaced by the rapid method in future investigations (6, 8). When testing large numbers of subjects, much time is saved by adopting this procedure.

Summary

Groups of physical education and other students in South Africa, North Carolina, and England performed the Harvard step test. The English men and women had higher mean fitness indexes than corresponding groups of American or South Africans. All the differences were significant except that between female physical education students in England and in South Africa.

Fitness indexes were not related to height, weight, or time devoted to physical training. Menstruation did not impair women's performance of the test.

The rapid method of calculating fitness index is recommended for future investigations.

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