Dynamic Physical Fitness and Body Composition

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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 daily tasks without limitations imposed by poor function of any of the systems of the body.

Gallagher and Brouha (1943) divided physical fitness into three categories: static fitness, dynamic fitness, and motor skills fitness. It is useful to be able to assess the standard of fitness in each category and to know how to maintain, and if necessary improve, each type of fitness.

Static (medical) 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 the others, and our concept of what constitutes health is quite arbitrary.

Dynamic (functional) fitness is the capacity for strenuous physical exercise. Assuming that the 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.

Motor skills fitness depends on the coordination of groups of muscles to perform purposive movements. This is achieved by the nervous system and improves with practice. The development of motor skill 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 neuro-muscular coordination.

Other investigators postulate various categories of physical fitness based on athletic tests. Apart from endurance, which is closely related to dynamic fitness, the main categories are strength, balance, agility, power, and flexibility (Cureton, 1947). Nicks and Fleishman (1962) subdivide the strength factor into explosive (power), dynamic, and static strength, and add speed and coordination. Many batteries of tests have been devised to assess the degree of fitness in each of these categories and from that to derive an estimate of general fitness.

HARVARD STEP TEST

The Harvard step test (Brouha, Graybiel, and Heath, 1943) is a simple test, yet fulfils the criteria for a satisfactory test of dynamic fitness. The subject works at a constant rate proportional to his body weight; large muscle groups are used so local fatigue is not as a rule the limiting factor, and the exercise requires no unusual skill. The results of the Harvard step test have a high correlation with measurements of maximum oxygen intake (Hettinger et al., 1961; Rodahl et al., 1961) currently the most fashionable expression of work capacity, but requiring complex and costly apparatus.

In the original test the subject steps onto and down from a bench or platform 20 inches high 30 times a minute for five minutes or until fatigue compels him to stop. Immediately after the exercise he sits down and his pulse rate is counted for the periods 1 to 1½, 2 to 2½, and 3 to 3½ minutes after the exercise. The fitness index (FI) is then derived from the duration of exercise in seconds (× 100) divided by the sum of the three pulse counts (× 2). Montoye (1953) showed that an almost identical FI is obtained if the first pulse count only (× 5.5) is used, as follows: FI = (duration of exercise (sec) × 100)/(5.5 × pulse count 1 to 1½ min after exercise).

On the results of the test, individuals may be classified in three categories. An FI below 50 is considered poor, 50 to 80 average, and above 80 good.

The Harvard step test was designed for adult men, but with suitable modification it may be used for women or children. Since I found that young women performing the test on a bench 17 inches high had similar FIs to a comparable group of young men stepping onto a 20-inch bench (Sloan, 1959), I have used a 17-inch step routinely for women. However, since 1959, most groups of women I have tested have achieved lower mean FIs than corresponding groups of men.

DYNAMIC FITNESS OF YOUNG MEN AND WOMEN

During the past 8 years I have applied the Harvard step test (or the modified test for women) to many groups of young adults in South Africa, the United States of America, and Great Britain (Keen and Sloan, 1958; Sloan and Keen, 1959; Sloan, 1959, 1961, 1963). Physical education (PE) students were compared with other medically fit students, non-athletic (NA) in the sense that they were not in regular training for any competitive sport.

The mean FI for each group is given in table 1. In Cape Town the non-athletes were medical students or student teachers: in Chapel Hill they were students of liberal arts; in England they were student teachers; and in Richmond they were students of medicine, dentistry, or physical therapy. In general the PE students had higher FI's than the others, and British men were more fit than South African, who in turn were more fit than American. There was no consistent difference in fitness between the national groups of women.

BODY COMPOSITION

Probably the best method available at present for the estimation of body composition is the underwater weighing technique for determining body density (Behnke, Feen, and Welham, 1942). Applying the time-honoured principle of Archimedes, the subject is weighed first in air and then completely submerged in water; from the loss of weight on immersion the specific gravity is calculated. Assuming that the body consists of two components (fat and lean body mass), each of known and constant specific gravity, if one finds the specific gravity of the body as a whole and makes allowance for air in the lungs and air passages, one can calculate the proportion by weight of fat in the body. The most popular formula is that of Keys and Brožek (1953):

$$\% \text{ fat} = 100\ (4.201/SG - 3.81)$$

Since the apparatus for underwater weighing is not portable and the technique is not practicable on every subject, other ways of predicting body composition have been sought. For many years obesity has been roughly assessed from the thickness of skinfolds pinched up at selected sites and measured by suitably constructed calipers. Formulae have been worked out for the prediction of specific gravity and hence of percentage body fat from skinfold measurements in young men (Brožek and Keys, 1951; Sloan, 1966) and in young women (Sloan, Burt and Blyth, 1962).

A more sophisticated technique for assessing the depth of subcutaneous fat is based on ultrasonic echoes (Hill and McColl, 1961; Whittingham, 1962). A generator produces pulses of ultrasonic waves at a frequency of 2.5 megacycles per sec, which are applied by a small probe through a thin layer of oil to the subject's skin. The probe has two crystals, one of which produces the ultrasound while the other detects the echoes reflected from interfaces between tissues of different composition. The echoes are then amplified and displayed on a cathode ray oscilloscope. The distance between the signal artifact on the oscilloscope screen and the first major peak (echo from muscle sheath) is a measure of the depth of subcutaneous fat. As with skinfold measurements, specific gravity may be predicted from ultrasonic measurements at selected sites. The most appropriate sites for this technique and the corresponding formulae have yet to be found.

BODY COMPOSITION OF YOUNG MEN AND WOMEN

In 1961 I estimated by underwater weighing the proportion of body fat in women students at the University of North Carolina (Sloan et al., 1962). Skin-fold and girth measurements were made on the same subjects and the best prediction of body fat was found to be from two skin-fold measurements (iliac crest and back of arm). This prediction had a high correlation ($r = 0.74$) with the estimation of body fat from specific gravity.

In 1964, the underwater weighing technique was applied to men students at the University of Cape Town (Sloan, 1966). On the same subjects the depth of subcutaneous fat at selected sites was measured with a skinfold caliper and by the ultrasonic technique. The best pre-

TABLE 1
Dynamic fitness of young adults. Mean fitness index on Harvard step test (men) and on modified Harvard step test (women). Physical education (PE) students and non-athletic (NA) students in South Africa (SA), United States of America (USA) and Great Britain (GB).

		Mean Fitness Index			
Date		Men		Women	
	Place	PE	NA	PE	NA
1957	Cape Town (SA)	86	62		
1958			56	77	58
1959				77	60
1960		85	65	67	40
1961	Chapel Hill, N.C. (USA)	66	68		41
	Greensboro, N.C. (USA)			57	
	Exeter (GB)	96	82		
	London (GB)			70	61
1964	Cape Town (SA)	84	80	74	59
1965	Richmond, Va. (USA)		63		51

diction was found to be from two skin-fold measurements (front of thigh and inferior angle of scapula; $r = 0.84$). The best prediction from ultrasonic measurements (front of thigh and iliac crest; $r = 0.81$) was slightly less accurate than the prediction from skin folds.

From skin-fold measurements I have estimated the body fat of women students in Cape Town and of men and women students at the Medical College of Virginia. The Cape Town women were student teachers and the Virginian women were students of physical therapy. In Virginia the ultrasonic technique was used as well as skin-fold measurements, but only the estimation from skin-fold measurements has as yet been worked out. Table 2 gives the mean proportion of body fat in each of the groups studied.

RELATION OF FITNESS TEST PERFORMANCE TO BODY COMPOSITION

Men and women students in Cape Town and men in Richmond showed a significant negative correlation between FI (Harvard or modified Harvard step test) and proportion of body fat; for women students in Richmond there was no significant correlation (table 2). In Cape Town there was no significant correlation between FI and either height or weight, except for a low negative correlation between FI and weight in women ($r = -0.250$). In Richmond there was no significant correlation between FI and height or between FI and weight in women, but a highly significant negative correlation between FI and weight in men ($r = -0.413$).

DISCUSSION

As a general rule the capacity for strenuous exertion depends on the degree of physical activity of the individual. Athletic men have higher FI's than non-athletic men (Brouha et al., 1944; Taddonio and Karpovich, 1951; Keen and Sloan, 1958) and athletic women than non-athletic women (Sloan, 1961; Skubic and Hodgkins, 1963). Systematic physical training raises the FI of athletic men (Seltzer and Brouha, 1943; Sloan and Keen, 1959; Cureton, 1963) and women (Hardy, Clarke and Brouha, 1943; Sloan, 1961). Presumably improvement in neuromuscular coordination reduces the load on the heart, and the trained heart, having a greater stroke volume, meets the demands upon it with a less prolonged increase in rate.

The higher mean FI of British than of South African and of South African than American men may be due to the different degrees of physical activity customary in the different communities. Although it would be unwise to generalise about national characteristics from the study of such small groups it seems to me that the British pattern of life involves considerably more physical exertion than the South African and the South African than the American. Furthermore the physical education training which I have observed in Great Britain and in South Africa is much more strenuous than in North Carolina, where the American PE students were tested. The least fit PE students were American women but there was no consistent international difference in fitness of non-athletic women.

TABLE 2
Percentage by weight of fat in the bodies of young men and women and correlation coefficient (r) between percentage fat and fitness index (FI) on Harvard step test (men) and on modified Harvard step test (women).

Date	Place	Mean % Fat		Correlation between % Fat and FI	
		Men	Women	Men	Women
1961	Chapel Hill, N.C. (USA)		20.1		
1964	Cape Town (SA)	9.6	20.3	-0.520	-0.345
1965	Richmond, Va. (USA)	9.9	17.1	-0.533	-0.084

The proportions of body fat in young men in Cape Town and in Richmond were lower than the 13.3% (White, 1961) and 16% (Behnke, 1961) found in American men and fall between the 8% (Le Bideau, 1959) and 10.7% (Macmillan et al., 1965) found in Europeans. The figures for young women in Chapel Hill and in Cape Town are lower than the 24.9% reported from Cornell University (Young et al., 1961) but similar to the 19.6% for young women in Stockholm (van Döbeln, 1956). The physical therapy students at Richmond seem to be the least obese group of young women so far investigated.

Most investigators have found little or no relationship between the results of fitness tests and the height or weight of the individuals concerned but there is some evidence that obesity impairs performance of most motor fitness tests (Best and Kuhl, 1955; Riendeau et al., 1957). My investigations so far support this view. Although the mean proportion of body fat in men students at Richmond was similar to that at Cape Town the range was wider in the Americans and the heavier (and fatter) subjects were less fit. In contrast to this the Richmond women, with less body fat than other groups of women, showed no influence of either fat or weight on dynamic fitness.

SUMMARY

Dynamic physical fitness may be satisfactorily estimated by the Harvard step test (modified for women) and this and other aspects of physical fitness are measured by appropriate test batteries.

The percentage by weight of fat in the body may be calculated from the specific gravity or from caliper measurements of skin folds or ultrasonic measurements of the thickness of the layer of subcutaneous fat at selected sites.

In general, physical education students are fitter than non-athletic students. British men students of physical education are fitter than American. International differences are less marked in non-athletic men and in women.

Performance of fitness tests is not as a rule influenced by the height or weight of the subjects but the more obese subjects have a poorer performance as do heavier subjects when the extra weight is due to obesity.

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