PHYSICAL FITNESS — DEFINITION AND ASSESSMENT

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SYNOPSIS

Physical fitness can be defined as "the ability to carry out daily tasks with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and meet unforseen emergencies."

Present day concepts indicate the need to further differentiate between health and performance related fitness. Health-related fitness requires minimum desirable levels of cardiorespiratory fitness, body composition, joint flexibility and muscular strength, as they help reduce the incidence and severity of degenerative type diseases. Performance-related fitness often requires reasonable levels of health-related fitness, together with desirable levels of agility, speed, muscular endurance and power. This enables individuals to perform better in physical activities related to their occupation or recreation.

Clinical, laboratory and field assessments of fitness are outlined. Results of some studies on the fitness of people in Singapore and the proposed National Physical Fitness Award Scheme are presented and discussed briefly.

INTRODUCTION

Physical fitness has been defined in many ways, one of which is "the ability to carry out daily tasks with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforseen emergencies" (1). This definition has been, and still is, well-accepted by most authorities involved with physical fitness, including those in the fields of medicine (particularly sports medicine), exercise physiology and physical education. This definition implies that physical fitness is more than merely "being well" or "not being sick". Present day concepts of physical fitness has indicated the need to further differentiate between health-related and performance-related physical fitness (2).

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Health-related fitness requires a minimum level of desirable cardiorespiratory fitness, body composition, joint flexibility and muscular strength. This is because these basic components of fitness are able to assist in reducing the incidence and severity of diseases and conditions like coronary heart disease, obesity and various musculo-skeletal disorders. These afflictions have also been referred to as "hypokinetic diseases" (3) because they are often associated with sedentary individuals with low levels of energy expenditure. Attainment of reasonable levels of health-related fitness should therefore be the primary concern and objective of all individuals, regardless of their age, sex, race, occupation or socio-economic status.

Performance-related fitness often requires a reasonably high level of health-related fitness, together with minimum desirable levels of the additional four basic fitness components of muscular endurance, muscular power, agility and speed. This enables individuals to perform better in physical activities related to their occupation, vocation or recreation. Examples of such individuals are manual labourers, police and armed forces personnel, and recreational or competitive athletes. Therefore total desirable fitness requires reasonably good levels of fitness in all these eight basic components of health-related and performance-related fitness.

CARDIORESPIRATORY FITNESS

Cardiorespiratory fitness can be defined as the ability of the cardiorespiratory system to respond adequately and safely to the blood, oxygen and other nutritional requirements of the body's organs and tissues, particularly the working muscles during physical activity. A desirable level of cardiorespiratory fitness is generally considered to be the most important component of health-related fitness. This is because most authorities in cardiology, pulmonology, sports medicine, rehabilitation medicine and cardiorespiratory physiology are presently convinced that judicious physical activity which is sufficient to maintain or improve desirable levels of cardiorespiratory fitness, is an important factor in reducing the incidence and severity of cardiorespiratory diseases, particularly coronary heart disease.

A desirable level of cardiorespiratory fitness also provides beneficial effects to an individual's physical working capacity or physical performance. The improved blood, oxygen and nutritional supply to the working muscles enables the individual to work or exercise at a higher intensity or for a longer period or both. The reduction in muscular fatigue and improvement in physical performance makes cardiorespiratory fitness a very important basic component in performance-related fitness also. This is particularly so for those occupations, vocations or recreational activities which require reasonably high levels of cardiorespiratory fitness.

Cardiorespiratory fitness can further be broadly subdivided into aerobic ("with oxygen") or anaerobic ("without oxygen") fitness. Aerobic or cardiorespiratory endurance fitness is characterised by the ability of the cardiorespiratory system to adjust submaximally to the increased metabolic demands of repeated bouts of moderate to severe (but submaximal) contractions of large muscle groups over relatively long periods of time, as in long distance running, cycling and swimming. Anaerobic fitness is characterised by severe submaximal or maximal contractions of muscle groups in an oxygen-deficit condition, with the rapid production and accumulation of anaerobic metabolites like lactic acid, resulting in muscular fatigue within a short period of several seconds to a few minutes, as in weight-lifting and sprint-running.

Aerobic fitness assessment can be made with varying degrees of accuracy and reliability, in a clinical or human performance laboratory with the aid of special equipment or on the field with minimal equipment. Laboratory assessments may be submaximal or maximal graded exercise stress tests on the treadmill, bicycle, step, rowing or swim-flume ergometer. Indirect assessment of aerobic fitness usually requires heart rate, electrocardiogram monitoring and recording equipment, and tables or nomograms to predict or estimate the subject's maximum oxygen consumption rate (or max. $\dot{V}o2$). An initial laboratory study completed in 1977, on the aerobic fitness of 483 physically active and inactive adult male and females in Singapore, indicated a reasonably favourable max. $\dot{V}o2$ status of the subjects studied (4). This was also true when their aerobic fitness was compared with similar population groups in other countries, including some developed countries. Further follow-up studies since then have not indicated a significant change in the aerobic fitness status of people in Singapore (5).

Direct assessment of aerobic fitness requires additional equipment like respiratory gas analysers to measure the oxygen (O_2) and carbon dioxide (CO_2) concentrations in the subject's expired air, and a spirometer to measure maximal expiratory minute volume (max $\dot{V}E$), which is the product of the maximal tidal volume (max VT) and maximal respiratory rate (max FR). From these data, the max $\dot{V}o2$ can be directly determined in litres O_2/min (or ml. O_2/kg BW/min, when divided by the subject's gross body weight).

Probably the most commonly used protocol by cardiologists to indirectly assess aerobic fitness in low-fit subjects, like cardiac patients, is the Bruce treadmill test (6). However, this procedure may not be the most appropriate, in terms of accuracy and reliability, for moderate to high-fit subjects, for the following reason. The treadmill elevation of 16% grade and more from stage IV onwards ($\dot{V}o_2$ greater than 34 ml. O_2/kg BW/min) often causes severe local muscular fatigue in the subject's calf plantarflexors and ankle dorsiflexors, resulting in premature cessation of the maximal stress test, before true max. $\dot{V}o_2$ is attained. Particularly for such moderate to high-fit subjects, it has been suggested (7) that for true max. $\dot{V}o_2$ assessment, the following criteria should be satisfied:

1. Direct measurements must be made of the subject's expired O_2, CO_2, max. $\dot{V}E$, and max. $\dot{V}o_2$ determined from these data.
2. An all-out run of about 3-10 minutes be made at a minimum speed of 8 kph (5 mph), on a large tread-

mill, which is elevated at between 5.25-10.5% grade (3°-6°), at the time of total exhaustion.

Direct max. $\dot{V}o_2$ studies in our centre's human performance laboratory on more than 100 subjects (eg. national athletes, moderate and high-fit members of the public) have confirmed the validity of these criteria (5). Presently, our max. $\dot{V}o_2$ assessment protocol includes a preceding Åstrand submaximal bicycle ergometry test to predict max. $\dot{V}o_2$ (7), followed by a choice of treadmill speed and elevation from Bergh's table (see table 1), which satisfy the above criteria and is agreeable to the subject.

Table 1: **Estimated Energy Requirements ($\dot{V}o_2$ in ml. O_2/kg BW/min) with Reference To Treadmill Speed and Elevation (8)**

Elevation in Degrees (% grade) \ Speed in kph (mph)	8 (5.3)	9 (5.6)	10 (6.3)	11 (6.9)	12 (7.5)	13 (8.1)	14 (8.8)	15 (9.4)
3° (5.25%)	38	43	47	51	56	60	64	69
4° (7.00%)	40	45	50	54	59	64	68	72
5° (8.75%)	42	48	53	57	62	67	72	77
6° (10.50%)	45	51	56	61	66	71	76	82

Field tests for assessing aerobic fitness which correlate well with laboratory studies, have been developed over the past few decades. Presently, the field tests which have probably gained most acceptance for their relative accuracy, reliability and ease of administration, are Cooper's 12-minute and 2.4 km (1.5 mile) run-walk tests (9, 10). In the 12-minute run-walk test, the maximum distance covered during this period is compared against a table which indicates the subject's predicted max. $\dot{V}o_2$ according to age and sex (9, 10). In the 2.4 km run-walk test, the minimum time taken to complete this distance is compared against a similar table (9, 10). The National Aerobic Fitness Award (NAFA) Scheme, established by the Singapore Sports Council in 1976, is a 2.4 km run-walk test with the bronze, silver and gold award standards (see table 2 below) equivalent to Cooper's good, excellent and superior categories of aerobic fitness, respectively (10). The success of this scheme and the validity of the standards adopted for Singapore has been noted to be sufficiently good, particularly males in the under-30 year age group (11).

Laboratory and field tests, to assess anaerobic fitness, which are relatively accurate, reliable and easy to administer or conduct, have not been well-accepted or widely utilised. The following are some of the more commonly used assessment procedures:

1. Blood lactic acid level studies following standardised submaximal or maximal exercise (12).
2. Aerobic and anaerobic threshold determination, or both, through direct analysis of the subject's expired respiratory gases, during exercise on a treadmill or bicycle ergometer (13).
3. Margaria's test (14) which requires the subject to run up a steep flight of stairs as fast as possible. The anaerobic muscular power is then calculated from the subject's body weight, the height traversed and the time taken.

Table 2: **Singapore's National Aerobic Fitness Award Scheme Standards. (Time in min:sec to complete 2.4 km)**

Category \ Age Group (yrs)	Under 30	30 - 39	40 - 49	50 and above
Bronze:				
Males	10.16-12:00	11·01-13:00	11:31-14:00	12:01-14:30
Females	11:16-13:00	12:01-14:00	12:31-15:00	13·31-16:30
Silver:				
Males	8:45-10:15	9:30-11:00	10:00-11:30	10:30-12:00
Females	9.45-11:15	10.30-12:00	11:00-12:30	12:00-13:30
Gold:				
Males	< 8:45	< 9:30	< 10.00	< 10:30
Females	< 9 45	< 10:30	< 11.00	< 12.00

BODY COMPOSITION

Body composition can be defined as the relative percentages of fat and fat-free body mass (2). It is usually assessed and presented as percent body fat. Excess body fat, or obesity, means an unnecessary load to be carried whenever the individual has to move his body mass through any distance or height, or both. This requires unnecessary extra energy expenditure and requirements by such obese individuals, for any given amount of work to be done. This results in a significantly reduced efficiency in movement as the cardiorespiratory, musculo-skeletal and other body systems have to work harder unnecessarily. Such unnecessary stresses on these body systems, organs and tissues, which are already not in the fittest condition, increases the risk of developing cardiorespiratory, musculo-skeletal and other disorders. Obesity, is also known to be associated with high levels of circulating saturated fats in the blood, thereby increasing the incidence and severity of atherosclerosis, an important contributory risk factor to coronary heart disease. Obesity has also been associated with other conditions like diabetes mellitus, hypertension, degenerative arthritis particularly of weight-bearing joints like the knee joints, reduced cardiorespiratory fitness and reduced physical work capacity or performance.

Assessment of an individual's percent body fat may be through direct body density measurements like water-displacement or underwater weighing methods (15). However, the easier indirect method of skinfold measurements (16, 17, 18) which correlate well with direct measurements, has made this the method of choice in most studies except those carried out in the more sophisticated studies or better human performance laboratories. Table 3 below indicates the percent body fat ratings acceptable presently to most authorities, for the average adult male and female.

Table 3: Percent Body Fat Ratings for Average Adult Males and Females (19)

Ratings	Males	Females
Excellent	< 11%	< 16%
Good	11 - 15%	16 - 20%
Average	16 - 20%	21 - 25%
Fair	21 - 25%	26 - 30%
Obese	> 25%	> 30%

Even field assessments of percent body fat require a relatively expensive skinfold caliper. For this reason, the "pinch-test" has been suggested as a very approximate guideline eg. for routine screening, as to the percent body fat. If it is possible to pinch (with the thumb and index finger) more than 2.5 cm (1 inch) of skinfold from any part of the body (eg. waist, thigh or triceps areas), the individual probably has more percent body fat than desirable, and should therefore subject himself to further evaluation. A "pinch-test" of 1.25 - 2.5 cm (½ - 1 inch) usually indicates an acceptable level of percent body fat. A "pinch-test" of less than 1.25 cm (½ inch) indicates low percent body fat, which in the normal individual is often associated with a high level of performance-related fitness, particularly cardiorespiratory endurance fitness, eg. among successful competitive endurance athletes.

JOINT FLEXIBILITY

Joint flexibility can be defined as the degree in which a joint (or a series of joints - eg. the vertebral column) can move through its maximum possible normal range of motion (2). The determining factor in a joint's range of motion is the extensibility or stretch of connective tissues (eg. ligaments, capsules, skin) and musculo-tendinous structures, which act in or around the joint. Any restriction in the normal maximum extensibility of such structures contributes to a loss of desirable joint flexibility.

From a health standpoint, reduction of desirable joint flexibility often contributes to postural problems and increases the risks of developing musculo-tendinous and ligamentous injuries. A common adult problem presently is the loss of ability to touch the toes with the fingers, while keeping the knees fully extended. The causes of this are the loss of extensibility of the connective tissues and musculo-tendinous structures in the lower back and posterior aspects of the thigh (eg. hamstring muscles). This is mainly due to insufficient use of the normal full range of these joints, lack of specific stretching exercises and to some extent degenerative changes associated with increasing age (eg. osteoarthritis).

Clinical, laboratory and field assessments of flexibility in a joint or series of joints may be accomplished with the aid of goniometers, which can measure the actual angle between the longitudinal axes of bones at the centre of the joint. Although the flexibility in one or more joints, may be satisfactory, this does not imply that all joints in the individual's body are equally satisfactory. Therefore, flexibility assessments are usually specific only for the joint assessed. However, for practical purposes, routine screening or assessment of joint flexibility usually permits the inclusion of only one test of joint flexibility, of which the forward trunk flexibility test is the most favoured presently. This is because, bending the trunk forwards (eg. to pick up or carry objects at ground or low levels) is a common daily activity in the life of most individuals. Yet, as mentioned earlier, owing to decreasing utilisation of the full range of motion of the joints involved, the loss of desirable forward trunk flexibility, particularly among adults, is a major problem today. The sit-and-reach-the-toes test is rapidly replacing the previous stand-and-touch-the-toes test, as it has been suggested that a higher incidence of low back strains, sprains and other orthopaedic conditions, is associated with execution of the latter than the former test (20).

MUSCULAR STRENGTH

Muscular strength can be defined as the maximum tension a muscle or group of muscles can apply in a single contraction (1). The importance of strength in sports and performance-related fitness is fairly obvious to most people. Less obvious is the importance of desirable muscular strength to health-related fitness. Stronger muscles act and provide better protection to joints which they act on or cross, resulting in a reduced risk of musculo-tendinous and ligamentous injuries. The lower than desirable strength of the abdominal muscles in the majority of the population, is believed to be of critical importance in the aetiology of the low back pain experienced by about 80% of the population at some point in their lifetime (2). The logic is that weak abdominal muscles which are easily fatigued or injured, cannot support the spine in the proper alignment and allow the pelvis to tilt anteriorly, causing a hyperlordosis, thereby increasing the risks of developing low back pain.

Muscular strength assessment in the laboratory is often based on measurements of the maximum tension in a single contraction of each muscle or group of muscles. The use of spring or tension cable dynamometers, or weight-training equipment specially adapted for each muscle group, is normally required. As this is usually impractical when testing large numbers of individuals, muscular strength assessments on the field are usually based on field tests for muscular endurance, eg. pull-ups, sit-ups and squat thrusts.

MUSCULAR ENDURANCE

Muscular endurance can be defined as the ability of a muscle or group of muscles to contract submaximally and fairly continuously or repeatedly over a period of time while working against a moderate but submaximal load. Desirable levels of muscular endurance are usually more important in performance-related fitness than in health-related fitness. However, significant improvements of muscular endurance in the more important muscle groups (eg. upper limb muscles, anterior abdominal muscles) would help reduce the risks of musculo-tendinous strains when an individual has to work against a moderate load for a period of time (eg. carrying a suitcase or a child).

Laboratory assessments of muscular endurance usually require the muscle or group of muscles to sustain a contraction or repeatedly contract against a known submaximal (eg. 50-90% of maximum) load. The duration sustained or number of repeated contractions possible, before local muscular fatigue develops, is thereafter used as an indicator of muscular endurance fitness of that muscle or group of muscles.

More familiar and commonly used assessments of muscular endurance are those tests which are also used as field tests. These include pull-ups (chin-ups), push-ups and flexed-arm hang (usually for females only) for the upper limb muscles; sit-ups for the anterior abdominal muscles; half-squats or knee-bends for lower limb muscles; and squat thrusts (burpees) for overall muscular endurance. The submaximal resistance in these tests are parts of or the whole of the individual's body weight. Scoring and assessment of muscular endurance fitness are usually based on the number of correctly executed repetitions in a specified period of time, which is usually 30 seconds for pull-ups and one minute for all the other tests mentioned (except for the flexed-arm hang test, in which the time in seconds the individual is able to maintain the required position, is used as the scoring and assessment factor).

On a health-related aspect, it is important to realise that the straight-leg sit-up appeared to be the most "hazardous" of six variations of sit-ups studied (21). The potential dangers include forward displacement of the fifth lumbar vertebra on the sacrum, increased intervertebral disc compression and undue stress on the ilio-psoas hip flexor muscles, which are the main muscles utilised during straight-leg sit-ups. It is for these reasons that the flexed-leg or bent-knee sit-ups, which utilise mainly the anterior abdominal muscles and do not appear to be similarly hazardous, has replaced the straight-leg sit-up presently.

MUSCULAR POWER

Muscular power can be defined as the ability of a muscle or group of muscles to release the maximum force in the shortest period of time (1). Muscular power is usually more important in performance-related fitness, particularly among competitive jumpers and throwers, than health-related fitness.

Laboratory assessment of muscular power include the use of highly sophisticated and expensive equipment like the Cybex II machine, Margaria's stair-climbing and Sargent's vertical jump tests. Among the field tests for muscular power assessment, the standing broad (long) jump and vertical jump tests, are probably the most popular.

AGILITY

Agility can be defined as the ability of parts of or the whole body to rapidly change positions or directions, or both, in a predetermined or precise manner (1). Agility is usually much more important in performance-related fitness, particularly among athletes like gymnasts, than in health-related fitness. A reasonable level of agility not only improves the standard of performance of competitive athletes, but also allows the recreational athlete to enjoy his chosen sport better and with less risks of injuries.

Laboratory and field assessments of agility are usually through tests in which the individual is expected to rapidly complete a predetermined pattern of movement for parts of or the whole of his body. Examples of the more commonly-used agility tests include the 4 x 10 m. shuttle-run, 10-second quadrant jump and 10-second squat thrust tests. The element of speed and muscular coordination involved is usually fairly significant in such tests of agility.

SPEED

Speed can be defined as the rapidity in which successive, and often repetitive, movements of parts of or the whole body can be performed, but not necessarily with significant changes in directions or positions (1). Like agility, speed is usually much more important in performance-related fitness, particularly among athletes like sprinters, than health-related fitness.

Laboratory and field assessments of speed usually consist of tests of short duration or distance, and which require rapid successive and repetitive movements. Examples of the more commonly used tests for speed include the 50-metre or 100-metre sprint, and the 4 x 10 m. shuttle run (which also assess agility and coordination).

THE PROPOSED NATIONAL PHYSICAL FITNESS AWARD (NAPFA) SCHEME FOR SINGAPORE

Although the development of such a scheme has been mooted by the Singapore Sports Council in late 1978, it was not till 1980 that definite attempts were made to develop and hopefully to implement the proposed scheme by 1981.

The main objective of this scheme is to further promote and assess the health-related and performance-related fitness among people in Singapore, particularly schoolchildren, active or reservist armed forces or police personnel, competitive athletes and physically active members of the public. It has been proposed that the scheme provide bronze, silver and gold awards to those who qualify in this six-item fitness test battery. This battery will have representative measures to assess all the basic components of health-related and performance-related fitness, with the notable exception of body composition. The non-inclusion of body composition (or percent body fat) assessment presently, is due to the major administrative problems expected should it be included in the test battery now. The problems include non-availability of the rather expensive, but necessary, precision skinfold calipers, difficulty in recruiting or training sufficient numbers of adequately-trained staff who will be needed to measure skinfolds reasonably accurately and reliably; and the lack of consensus presently as to the choice of method, formula or protocol to adopt for percent body fat assessment for people in Singapore. It is hoped that these problems can be satisfactorily resolved in the not too distant future, so that this important component of fitness can be included in the proposed NAPFA test battery. In the interim period, the "pinch-test" guideline, mentioned earlier, will be recommended for estimation of percent body fat.

The proposed test battery consists of:

1. Maximum number of flexed-leg or bent-knee sit-ups, with a twist, in one minute, as a measure of anterior abdominal muscular endurance and strength.
2. Best of three standing broad (long) jump distances, as a measure of lower limb extensor muscular power and strength.

3. Best of three sit-and-reach distances, as a measure of forward trunk flexibility, hip flexibility and hamstring muscle extensibility.
4. Minimum time, to nearest tenth of a second, to complete a 4 x 10-metre shuttle-run, also requiring in the process to correctly pick up and place down two small objects by hand, as a measure of general speed, agility and coordination.
5. Maximum number of overhand grasp (pronated) pull-ups (chin-ups) in thirty seconds (with modifications or an alternative flexed-arm hang test, for females only), as a measure of upper limb muscular endurance and strength.
6. Minimum time to run-walk 2.4 km over a firm and level surface, as a measure of cardiorespiratory endurance and lower limb muscular endurance.

Standards for males and females for each test item are being drawn up for different age-groups (eg. 15-24, 25-34, 35-44, 45-54 & 55+ years). Initially, these standards will be drawn from local NAPFA studies on selected groups which are believed to have reasonable levels of desirable fitness in all the basic components of fitness. For example male standards may be drawn from the following mean ± 1 standard deviation (S.D) results of the recently-completed study on 248 army recruits who successfully completed 10 weeks of basic military training, which included at least thrice-weekly physical fitness training programmes (22).

Table 4: Mean ± 1 SD Results of a Fitness Study on 248 Male Army Recruits (Giam, et. al., 1980)

	Test Item	Mean ± 1 S.D.
1.	One-minute flexed-leg sit-ups	34 ± 7
2.	Standing broad jump distance	225 ± 17 cm
3.	Sit-and-reach distance	54 ± 10 cm
4.	4 x 10-metre shuttle-run time	10.7 ± 0.4 sec
5.	30-second overhand-grasp pull-ups	7 ± 3
6.	2.4 km run-walk time	11.7 ± 1.3 min

SUMMARY AND CONCLUSIONS

The concept that physical fitness is more than just being free from ill-health is well-accepted by most authorities in physical fitness. However, the present day concept that there is a need to further differentiate between health-related fitness and performance-related fitness, and that desirable levels of both are essential to total fitness, needs to be better accepted.

The eight basic components of total fitness are cardiorespiratory fitness, body composition, joint flexibility, muscular strength, muscular endurance, muscular power, agility and speed. The first four are essential to health-related fitness. Laboratory assessments with special equipment for greater accuracy and reliability, and field assessments with minimal equipment for large numbers of people have been presented and discussed.

Results of some studies on the fitness of people in Singapore and the proposed National Physical Fitness Award (NAPFA) Scheme for Singapore have been presented and discussed briefly. The main objective of this NAPFA scheme is to further promote and assess the health-related and performance-related fitness of people in Singapore, particularly school-children, armed forces and police personnel, competitive athletes and active members of the public.

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