Sport and Medicine

Peter N Sperryn

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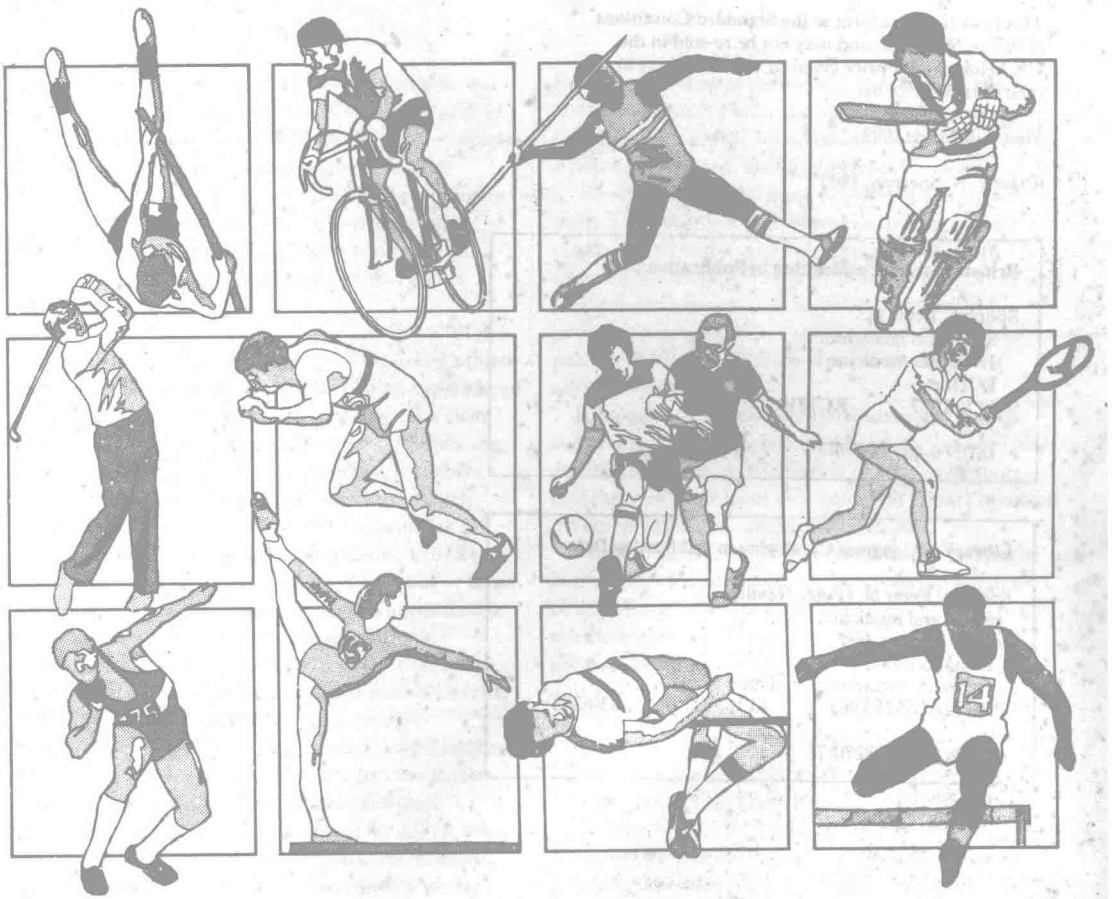
Peter N. Sperryn

MB BS, FRCP(Glasg), DPhysMed
Consultant in Physical Medicine, Hillingdon Hospital;
Honorary Secretary, British Association of Sport and Medicine;
Honorary Medical Adviser, British Amateur Athletic Board;
President, London Athletic Club



Butterworths
London Boston Durban Singapore Sydney Toronto Wellington

First published, 1983

British Library Cataloguing in Publication Data

Sperryn, Peter N.
Sport and medicine.
1. Sports medicine
I. Title
617'.1027 RC1210

ISBN 0-407-00270-7

Library of Congress Cataloging in Publication Data

Sperryn, Peter N. (Peter Neville)
Sport and medicine.

Includes index.
1. Sports medicine. I. Title
RC1210.S626 1983 617'.1027 83-6388

ISBN 0-407-00270-7

Photoset by Butterworths Litho Preparation Department
Printed and bound by Robert Hartnoll Ltd, Bodmin, Cornwall

Foreword 1

This is a very interesting and challenging book; it is also remarkably comprehensive. The significance of the title – *'Sport **and** Medicine'*, I would suggest, singles it out from the many previous books on 'sports medicine'. It is obviously intended for the intelligent layman (physiotherapist, coach, trainer, team manager, etc.) as much as for the doctor with a particular interest in sports medicine and sports injuries.

The author is more than qualified to deal with this complex and extensive field. An accomplished athlete himself, he is also a mature doctor and an experienced administrator. Sports medicine is not really a clear cut specialty: it comprises applied multidisciplinary general practice with a modicum of surgery where required. However, dealing with what are largely minor ailments and complaints requires more than straightforward common sense combined with a sound basis of medical knowledge. There has to be an understanding of body function and an appreciation of the fact that anyone indulging in sport and recreation needs their medical 'troubles' diagnosed, treated and cured as expeditiously as possible so that they may continue those activities – be they entertaining, beneficial or competitive – with minimal interruption. It is a great pity that when the British Government set up the Sports Council which generated the excellent slogan 'Sport for All', it was not appreciated that this would also involve 'more sport injuries for all'. Sadly, in this country we lag a very long way behind our colleagues in Europe and America. I hope that this excellent book will help to further a rapid improvement in this state of affairs. It contains a mass of information presented in a clear, simple and practical style, assisted where necessary by straightforward, intelligible line drawings.

The first part of the book provides a simple but in-depth exposition of the function of the various organs of the body, and links this physiology to ailments associated with participation in sport as well as the medicaments used to deal with them. This precedes a description of sports injuries of various parts of the body and their treatment, including surgery.

Interspersed are excellent little articles on such continuing controversial subjects as age, alcohol, diet, doping, footwear, participation of women in sport – and the very important psychological factors involved in recreational and athletic competitions.

There is something for everyone who is interested in this field. I would suggest that it should not at first be read from cover to cover; the index will assist selective reading. I have no doubt it will prove of great value to all concerned with sport *and* medicine and I wish it well.

The Rt. Hon. The Lord Porritt, GCMG, GCVO, CBE, MCh, FRCS
Formerly President, Royal College of Surgeons of England; President, British Medical Association; President, Medical Commission of the IOC; President, British Association of Sport and Medicine

Foreword 2

I strongly suspect that Peter Sperryn chose with great care the title of his latest book *Sport and Medicine*, the strong implication being that there are two separate broad general disciplines that are interrelated, the book being about that relationship. Of course, it is acknowledged that there are several other more specific disciplines involved, ranging through sound clinical diagnostic medicine, exercise physiology, biomechanics, coaching, psychology and education. The only assumption made, which few will deny, is that nowadays medical support is essential for the realization of the athlete's natural capacity for optimum performance.

I am certain that it is my own hypersensitivity, stemming from a deprived background, which makes me rejoice that the title is not *Sports Medicine*. A subtle difference perhaps, but under its banner, I often sense a glamour and mystique behind which many things are both promoted and justified, bringing with them a new breed of scientists who feel that through sport many of their own barriers may be quickly crossed or conquered. My own involvement in sport as an athlete, teacher, coach and mere observer for more than 30 years, convinces me that in the relationship between sport and medicine, sport has always made the more generous contribution in the past.

Of course, as coaches, we adopted and adapted Newton's laws and have been eternally grateful for A. V. Hill's work on acceleration in the 1920s, which seemed to be uniquely related to the needs of sport. It is little, however, compared with the generations of athletes who have given blood, sweat, urine, muscle biopsies and personality inventories, have often been immersed in tanks, and photographed naked in three dimensions at altitude. So often we were motivated to help by the assumption, if not the fact, that in other countries such as Cuba, East Germany and the Soviet Union, this was how their athletes were selected, trained, monitored and even manipulated in the pursuit of excellence. Without real knowledge we cannot make comparisons, cast aspersions or have any real confidence in our own teachings.

If I have been hypercritical of our medical colleagues, let me redress the balance by expressing my growing concern over recent observations within sport. Although generally there can be no doubt that standards of performance relate specifically to both the quality and quantity of training, the ground rules have now changed. We cannot assume that the old adage 'no amount of exercise will damage a healthy body' still applies. Many of our most serious medical problems occur directly through stress and overuse. There may well be biomechanical factors involved but bad techniques and imbalanced training programmes are more commonly the perpetrators. Too much, too soon; the nonsense of running through pain barriers; unsupervised weight training – we have all been guilty and often responsible for converting minor problems into major injuries. Osteochondritis and Achilles tendinitis are the bane of athletics, yet their specific cause is unknown and we have never monitored our training programmes to find related factors.

The mass of inexperienced joggers now joining our

club ranks pose an additional responsibility, for they are most vulnerable. Very often they jog seeking good health, but lose it when tempted into marathon mania. Specific fitness must not be 'sold' as the panacea for all ills, or confused with being healthy, despite the known relationships.

At last it seems that the message is getting through. Education, change, innovation, feedback and dissemination are now the commonsense practices which govern the relationship between sport and medicine. The coach must fully accept his role as the synthesizer or catalyst, choosing with care from the multitude of new ideas, science, innovation or research which comes his way. His own empirical knowledge is a vital part of the feedback of information. He frequently will have to make the ethical decisions, and make it clear that he accepts the responsibility.

The scientist has at last climbed from his lofty academic pedestal. There is a genuine desire to help and educate, as well as to look sympathetically at the jungle of panaceas, short-cuts, aids, props, etc. What is more, the help is all the more generous when one appreciates that, in Britain at least, it is freely given without reward and without institutional back-up.

The complex mosaic of human performance is a marvellously stimulating and fascinating field. It deserves the greatest care that all concerned are capable of. It is therefore a pleasure to welcome this most recent work of Peter Sperryn, whose writing not only conforms to my own personal and simplistic requirements, but also is actually the result of years of practical work in the field, of countless hours helping hosts of athletes from a wide range of sports, in an honest and earnest belief in the need for the dissemination of ideas and the minimum of bureaucracy and professional jealousy. Both Sport and Medicine can only be the richer for that.

Ronald J. Pickering, MEd, DPE
Former AAA National Coach; Fellow of the Physical Education Association; Fellow of the Institute of Leisure and Amenity Management

Preface

Sport in the 1970s brought greater demands on the champions and an explosive growth of public interest in mass participation. However, 'Sport for All' inevitably leads to 'Sports Injuries for All'. So we need 'Sports Medicine for All'.

Sadly, medicine has been slow to respond to the changing needs of society as it replaces its old afflictions with the new challenges of fitness and exercise. Twenty years after publication of the first major textbook on sports medicine in Great Britain, for instance, the National Health Service still discouraged provision of sports medical services; few medical and paramedical students received instructions in the subject; few sports organizations made substantial provision for their members.

Sports medicine is not a clear-cut medical specialty but is well defined as the medicine and science of exercise and sport – a wide interest, in which many different professions meet on the common ground of sporting endeavour.

Over my years in sport and medicine the gap between narrow specialist knowledge and its widespread dissemination seems to have widened. This book is written with the aim of bringing together in one volume the many strands of sports medicine in a clear, concise, factual and readable form. It is aimed at all sports enthusiasts interested in sports medicine and at those professional readers seeking to apply their medical knowledge to sport.

Considerations of space and economy dictate an emphasis on essential principles. I have tried to recruit relevant aspects of medicine and science to the immediate and practical aid of the doctor, therapist, physical educator and coach – and the player – puzzled by the problems of, and seeking answers to, the fascinating challenges of sports medicine. The index is designed to facilitate cross-reference to relevant subjects and thus keep the main text as concise as possible. I have not tried to include first aid or detailed traumatology, for which many good books exist.

Nobody can write such a book unaided. I thank my many colleagues around the world for their constant help and encouragement over the years of our continuing efforts to establish sports medicine in its proper place. My knowledge draws on the sum of theirs; my mistakes are my own. I am particularly indebted for detailed comments on chapters to Dr Carolyn Ritchie, PhD, Dr Denise Yeldham, BSc, MRCPsych and to Dr Craig Sharp, BVMS, PhD, MRCVS.

I thank Sheila Galbraith warmly for preparing the artwork from my thumb-nail sketches and my publishers for accepting so readily my suggestion of a second colour. My intention is to rely on simple line diagrams to highlight essentials and avoid confusion.

Most of all I thank Brian Banks, who responded to the challenge of such a text and initially commissioned me to produce this book. Since then he has relentlessly goaded me out of my sloth and shouldered all the heaviest burdens of subediting, labelling and planning. His constant encouragement and discipline have made a book come out of an idea.

Peter Sperryn

Contents

1 The case for exercise

There is much evidence that inactivity is related to physiological deterioration, illness and death. On the other hand, there is little evidence that specific levels of fitness or athletic participation give specific benefits in terms of longevity. Physical activity is beneficial to health in a general way and, while not necessarily guaranteeing the individual a longer life, can improve the quality of his daily life and delay deterioration in fitness due to age and inactivity.

Men and women of all ages can improve cardiac, respiratory and muscular functions by regular activity. Moderate levels of rhythmic exercise of the large muscle groups of the trunk and limbs produce the safest consistent improvement in oxygen uptake and cardiovascular function. The muscles become more efficient through chemical enzyme changes and increases in the capillary circulation. The optimum level of exercise is about three sessions weekly of 20 minutes each and sufficiently severe exercise should be taken to raise the pulse to between 140 and 160 beats per minute (beats/min). Harmful effects are unlikely, provided that exercise levels increase gradually from modest beginnings.

Psychological benefits develop hand in hand with increasing physical fitness and increased extroversion, self-confidence, self-awareness and well-being have all been demonstrated. Memory improvement has been shown in elderly subjects on an exercise programme. Training effects tend to be specific to the functions being trained and this event specificity, e.g. swimming/jogging/cycling, should be taken into account when activities are planned.

Childhood and adolescence

Children are spontaneously active and playful but become lazy and obese as they grow into conformity with the Western adult lifestyle. The instillation of positive attitudes to exercise and games in the young is more likely to create life-long commitments to enjoyable physical activity and this may be even more important for mentally or physically disabled or deprived children whose development lacks the stimulus of normal spontaneous play.

Pregnancy

Fit mothers have easier pregnancies and deliveries. Moderate exercise throughout pregnancy should be encouraged in the absence of specific medical contraindications. Smoking is associated with the birth of smaller-than-average babies.

Obesity

Forty per cent of the British adult population is obese to a degree which is associated with increased chances of cardiovascular disease, diabetes and complications from surgery. While dieting is generally boring for most people, exercise has a considerable anti-obesity effect because it speeds up the body's chemical activity in a way which allows it to burn off more fat than would be expected from the exercise itself.

Moderate exercise does not increase the appetite disproportionately so that regular exercise, despite some increase in appetite, does not lead to weight gain. Diabetic patients may find control easier if they take regular exercise.

Exercise and coronary heart disease

Physically active people have fewer fatal heart attacks than the lazy. It is thought that the heart is protected by long-term regular exercise, including regular amounts of fairly intensive work such as sport participation or garden digging. Exercise also improves other cardiac risk factors such as blood pressure, the level of circulating fats in the blood and the efficiency of the blood's clotting mechanisms.

Exercise and chronic disease

Most sick people show physical underachievement due to unfitness over and above the specific effects of their diseases. Regular exercise generates extra physical work capacity. This has been well shown in exercise programmes for heart-attack victims and is the basis for rehabilitation in locomotor and chronic respiratory disease. The aim in these circumstances is to improve the patient's quality of life by allowing daily functions to be performed with greater control and less fatigue.

Old age

Old people become unfit by letting their daily level of physical activity fall. Much of this age-related deterioration is readily corrected by simple exercise programmes. Muscle power, tendon strength and cardiorespiratory efficiency all improve considerably, even with simple walking programmes which are safe for most people. Much of the physical decline after the age of 60 can be delayed and partly prevented if substantial physical activity is maintained. Apart from the physical benefits, which also include reduction in joint stiffness and improved neuromuscular co-ordination, mental benefits such as increased concentration and memory and brightening of mood are all useful in the elderly. It is also possible that the increased heat production of the physically active body may play a part in the prevention of hypothermia, a common cause of death in the elderly.

Cardiac risk factors

The concept of risk factors is crucial to any discussion on exercise and health. Several factors have been clearly related to the incidence of cardiovascular disease. These include exercise, or lack of exercise, age, sex, family history, smoking, hypertension, hyperlipidaemia, diabetes and personality type. Each of these factors plays a part in the individual's tendency to suffer from heart disease. Different people have different degrees of liability to these diseases according to their individual constitution and habits.

All risk factors interrelate so that, for instance, the risks of smoking are added to those of high blood pressure or diabetes but are not simply corrected by an appropriate dose of hard exercise. This explains the difficulty in assessing the precise benefits of exercise of any sort in communities and even more so in individuals. It is simply impossible to relate a given amount of sport or exercise to a clear risk of heart attack or extra number of years to be lived. This may be surprising, particularly when surveys have suggested that the risks of smoking may be expressed as 5 minutes' loss of life per cigarette smoked. A 5 minute risk per cigarette is, however, an overall average figure which may be drastically modified in any individual by his other risk factors. Briefly, cardiac risk factors operate as follows.

In general, the risk of vascular illness increases with age and affects males more than females. Premature cardiac deaths are usually related to extra

risk factors or structural abnormalities such as abnormal heart vessels. Family history dictates the general liability of the individual to various diseases, particularly those affecting the blood vessels; a strong family liability to hypertension, hyperlipidaemia and diabetes is often evident. In hyperlipidaemia, the circulating fats (cholesterol and lipids) in the blood exceed normal levels and this condition is related to premature formation of atheroma, or fatty plaques, in the blood vessel and heart linings which cause coronary thrombosis.

Hypertension, or raised blood pressure, increases the general risk of stroke and heart disease. Many large-scale surveys have suggested that long-term prophylactic treatment as a result of screening programmes may have some benefit. Unfortunately, this benefit is best shown in population studies and the detailed benefit to a given individual with high blood pressure is uncertain. The statistical benefit must be weighed against the great inconvenience of life-long daily medication. While exercise tends to lower blood pressure, this is neither dramatic nor therapeutically significant and it should be remembered that extreme exercise, or exercise associated with mental stress, will still cause a sharp temporary increase in blood pressure.

Risks of exercise

Death may occur during exercise. This sometimes happens simply because a very ill person happens to be exercising. On the other hand, the cause and effect relation may be more direct. It is difficult to interpret the published work on exercise related to death. This is partly because widely varying populations have been studied and widely differing results would therefore be expected.

For instance, military conscripts in one study showed 45 exercise-related deaths in a total of 660 000 man years of exposure to exercise programmes; 36 per cent of these deaths were due to cardiovascular causes. In contrast, a well-quoted study has shown the risk of exercise-related deaths for rugby referees to be as high as one per 3000 hours of exposure compared with one per 50 000 hours in the players themselves. This might be anticipated to some extent, bearing in mind that many rugby referees summate their risk factors of hypertension, obesity and smoking quite dramatically.

At the other end of the scale, experience of carefully supervised post-coronary rehabilitation programmes has been gained from North America in the 1970s. A summary of results from 25 different programmes involving over 8000 cases and over 80 centres showed 10 deaths, giving an overall risk of about one death per 30 000 hours of exposure to an exercise programme. The risk in the most experienced of all the North American coronary rehabilitation programmes was only one death per 216 000 hours of exposure. Thus it is evident that while there can be no dramatic individual promise related to an exercise programme, there is no disagreement about the general benefits to long-term health, and particularly well-being, in participants as a group and the risks associated with regular exercise are very small.

Two important factors should be remembered: first, exercise-related risks are to some extent dependent upon detection of obvious risk factors: and secondly, risks should be related to the overall hazards of life. For instance, the relative risks of death for various activities show four in 100 000 people to be at risk per year from playing football, compared with two in 100 000 from taking oral contraceptives, six in 100 000 from being run over, 20 in 100 000 from influenza and 500 in 100 000 from smoking over 20 cigarettes per day. Obviously, a sense of perspective is important!

Political aspects

The spread of 'Sport for All' shows that governments have gradually come to recognize that the state of a nation's health can be improved if a reasonably high level of physical activity can be achieved in the

population. Some countries have gone much further than others. For instance, in the German Democratic Republic, there is a constitutional commitment to physical activity throughout the population. In many other countries there has been a marked ambivalence at Government level about the strength of commitment to public fitness. The British Government's failure to bring about drastic reductions in smoking, because of largely financial considerations, should also be kept in perspective. For instance, figures quoted in 1979 showed that the British Government gained about £1000m in revenue from tobacco taxation, but spent only about £15m on its grant to the Sports Council whose motto is 'Sport for All' and just £1m on its anti-smoking campaign through the Health Education Council. This David faced the Goliath of a £100m promotional budget by the tobacco industry, including sports-related advertising. So strong is the influence of the smoking lobby and its selective advertising-based subsidy of certain sports activities, that the Sports Council was unable, even after two debates, to recommend a ban on tobacco advertising in sport. Ironically, the Government in the same year gave over £10m in capital grants for the development of cigarette factories in Durham and Northern Ireland.

Perhaps the 'political' factor should be added to the other cardiac risk factors outlined above.

2 Medical screening of fitness

Some of the dangers to health and life may be predictable by medical examination, others are unforeseeable. Between these two extremes the concept of risk factors, outlined in Chapter 1 with respect to heart disease, applies and the accuracy of risk prediction depends to some extent on the elaborateness (and hence expense) of assessment undertaken.

Who is eligible for an exercise programme? Virtually everybody in the population would benefit by regular exercise. This includes many disabled persons who are living second-rate lives because of underactivity, often because of preventable social factors further reducing their degree of independence.

Do we need a medical examination before a training programme? This is a difficult question to answer. Probably, the main motivation is the question of medicolegal protection for those leading the exercise programme, coupled with the benefit of picking up the more obvious risk factors in potential patients. This slightly sidesteps the issue however. An ideal state of affairs would be for the entire population to have regular health screening programmes, coupled with a regular exercise commitment.

Absolute contraindications to exercise

Patients suffering from active cardiovascular and respiratory disease should not be actively exercised before completion of adequate medical treatment. Active infections, fever, gross anaemia and metabolic disorders such as thyroid, adrenal or kidney diseases preclude athletic exercise until cure is achieved because all these conditions may cause sudden death, usually through the final mechanism of cardiac failure.

Relative contraindications to exercise

Recent recovery from the above disease states, chronic disabilities from lesser degrees of these conditions, uncontrolled hypertension and musculoskeletal disease all call for expert medical assessment. One aspect calling for particular professional attention is the part which drugs may play in disease and exercise. Many drugs have primary or secondary effects which may alter the safety of, or capacity for, exercise and a temporary restriction of exercise may be necessary.

Medical examination for fitness programmes

A clinical history and physical examination are required. The most frequent extension of this simple protocol, similar to the short Life Assurance type of examination, is the electrocardiograph (ECG). Beyond that, more sophisticated testing involves

blood tests and other tests designed solely to check up on risk factors, e.g. circulating blood lipids.

Clinical history

This may be combined with a computerized *pro-forma* seeking details of the subject's previous medical symptoms, relevant family history and medication.

It is axiomatic that the proposed nature of the training programme must be carefully considered and related to the whole medical examination.

Physical examination

The routine clinical examination includes examination of the height, weight, degree of obesity, skin features, breasts, arm-pits, neck and groin for palpable lymph nodes indicating possible infection, and the superficial appearances of the hair and scalp, eyes, ears, nose and mouth, including teeth and gums, tonsils and throat. The blood pressure is measured and the heart and lungs are listened to for abnormal sounds.

While the range of normal heart sounds, as well as those relating to diseased valves, is well established, there may still be considerable difficulties in interpretation of findings. The most common single problem lies in the assessment of cardiac murmurs which are caused by high rates of blood flow through the valves lying between the chambers of the heart. This may be due to diseases like rheumatic fever which may, in some instances, call for care or even prohibition of exercise. Simple murmurs often reflect only the increased rate of blood flow in fit subjects however, and the presence of 'murmur' is not necessarily a sign of disease.

The pulse rate and rhythm are examined. Increasing fitness leads to slowing of the pulse and the normal sinus arrhythmia with its slight acceleration of pulse rate during inspiration may be mistaken for fibrillation by the inexperienced. A grossly irregular pulse calls for full medical assessment.

In cases of doubtful murmurs, it is often helpful to re-examine the heart carefully after exercise. This is useful to confirm that slight irregularities of heart sounds and pulse are normal if they become entirely regular during the test exercise.

The abdomen is palpated for the obvious landmarks of the liver and spleen margins as well as for any unexpected findings of disease or unusually palpable or anatomically abnormal kidneys. The inguinal area in the groin is examined for the presence of hernias, particularly if vigorous exercise involving straining or lifting is envisaged. This is combined with external examination of the genitalia.

The central nervous system examination is usually limited to assessments of the response of the eyes to light and of the reflexes elicited by tapping tendons at the elbow, wrist, knee and ankle with a small rubber-capped reflex hammer.

Further examination

Further examination is indicated if the clinical history or routine physical examination suggests any form of disease calling for more specific examination, such as tests of hearing, examination of the interior of the eyes with the ophthalmoscope, or internal pelvic examination indicated in certain alimentary or genitourinary conditions.

Sport-specific examination

Clearly, a fitness certificate does not let a blind man play cricket or a child with deformed feet run very far, although both subjects are in all other normal respects 'fit'. The purpose of a sports medical examination is, in the light of medical findings, to guide the subject towards suitable forms of exercise. The physician should not encourage either false hopes or apply the, regrettably, more usual medical response of absolute prohibition, without further thought.

More specific examination is needed of those parts of the body most involved in particular sports. For instance, marksmen clearly need normal or properly

corrected visual acuity as part of their fitness, runners need healthy feet, and swimmers need to have their sore throats and ears put right before they are fit for their endeavours. It is the responsibility of sporting bodies to define the levels of fitness required for their particular sports and medical officers will bear these obvious criteria in mind whenever they examine potential sportsmen and sportswomen.

Tests

A normal part of routine clinical examinations is to test a small sample of urine with a chemically impregnated dipstick which indicates the presence of blood, protein or sugar. Positive findings may indicate that there is a need for further blood or urine tests and X-rays.

It is not normal to have X-rays as part of a routine medical examination of fitness. There may, however, be reasons why the individual should have an X-ray. These include relevant past or present illnesses or injuries. Routine chest X-rays are not now encouraged on a nationwide basis in the UK for the detection of tuberculosis as that disease has been gradually brought under reasonable control. As many conditions, including tuberculosis and some forms of cancer, may be easily detectable in their early stages with a chest X-ray, it is sound practice to include a chest X-ray in subjects of any age known to be in contact with tuberculosis or from the immigrant communities which are now the main source of tuberculosis in the UK.

Blood tests Blood tests are not normally required as part of a routine medical examination. Anaemia is so common in women of childbearing age, however, that a simple finger-prick haemoglobin test is desirable.

Further blood tests would be indicated only by abnormal findings of the medical history or examination.

The application of automated blood testing systems in recent years has allowed mass screening of small blood samples for many substances. The usual screening programme involves checking the levels of about a dozen substances in the blood but, unfortunately, these are mostly indicative of disease states and there are no positive blood tests indicating fitness. Unfortunately, the relevance of automated blood screening tests to the fit athlete or even the middle-aged would-be jogger is unclear. They are expensive and sometimes throw up unexpected results which are frankly inexplicable – as well as, occasionally, the presence of unsuspected disease.

More specific blood testing on a large scale for blood lipid levels may be desirable as a preventive measure, especially where there is a strong family history of cardiac disease and a major cardiac risk factor may thus be detected and treated. The main deterrents to such screening programmes are expense and lack of availability, although the theory is sound.

Electrocardiograph (ECG) The ECG measures electrical potential differences between different parts of the heart as viewed from different angles. It is, in effect, an electrical three-dimensional picture of the heart. It is entirely painless as it simply measures the body's natural electricity through electrodes placed on the four limbs and the front of the chest.

The place of the routine ECG in clinical examination is much debated. It is probably unnecessary in the overwhelming majority of examinations. While, theoretically, it should be most useful in detecting heart abnormalities, its value is limited mainly by the ignorance and inexperience of the tester. Very fit athletes often have bizarrely abnormal ECGs and, if these are misinterpreted as signs of disease, the resulting prohibitions are unfortunate!

On the other hand, simple electrocardiography by an experienced practitioner is invaluable in the assessment of irregular heart rhythms and in the early detection of cardiac abnormalities precipitated or exacerbated by exercise. It is most valuable when performed during one of the many exercise tests protocols.

Summary

The routine medical examination for fitness therefore consists of a simple clinical history and physical examination, together with dipstick analysis of the urine. All further procedures are dictated by clinical findings or by more elaborate demands or protocols adopted by the parties involved. The role of the ECG is debatable on the mass scale but highly important in training programmes associated with cardiac disability.

Fitness testing

There are two levels of exercise testing. First, simpler protocols are used in medical practice to get an overall idea of exercise capacity and fitness as well as to assess the cardiac response to exercise, particularly if there is doubt about cardiac disease as a limiting factor. Secondly, more sophisticated protocols are used for highly trained subjects and many of these are closely linked with current research methods in fitness testing.

While the problems of assessing the precise degrees of fitness of elite sportsmen have always been matters for debate and continuing research, the practical use of simple exercise tests brings them within reach of the club sportsman as well as the general practitioner. It is true that many elaborate tests can be suitably modified to serve the needs of the simplest rehabilitation patient or 'man in the street'.

There are four levels of exercise testing which can be considered – step tests, bicycle ergometry, treadmill studies and actual sport-specific protocols.

Step tests

There are numerous step-test protocols including the Harvard, Masters and Kasch and their various modifications. The principles are similar, the details vary.

It is vital that, whatever test is followed, the protocol is standardized because only if all subjects are given the same test can the results be comparable. In the basic test, the subject steps up and down from a standard-height step or bench at a predetermined rate, most simply governed by a stopwatch or metronome. For instance, one modification of the Harvard step test recommends 5 minutes of continuous stepping up to a height of 15¾ inches (40 cm) for men and 13 inches (33 cm) for women at the rate of 22½ steps/min, which corresponds to a metronome count of 90 beats/min. The subject faces the bench and leads with one leg ('up'), then steps up with the other leg ('two'), steps down with the leading leg ('three') and finishes the cycle by bringing down the second leg ('four'). Thus, the 'up–two–three–four' rhythm is repeated on the beat. Another modification (Gallagher) involves the same rhythm set at the faster rate of 30 cycles/min instead of 22½ for the shorter period of 4 rather than 5 minutes.

The pulse rates are then counted accurately at specified intervals after the cessation of exercise. In the simplest protocol, the pulse rate half a minute after exercise is taken as the determinant of fitness. In the more complex protocol (Gallagher), the pulse is measured at intervals of 1, 2 and 3 minutes after exercise and an index of fitness calculated from these three counts. The comparative fitness of the subject is then determined by reference to standard tables.

The would-be practitioner in this field has two choices. He can copy exactly one of the many existing protocols, including any exact bench heights specified, or he can modify the technique to suit his own circumstances. It is important that the shortcomings of these tests be remembered. Theoretically, all subjects should be put through the same workload. As this means an infinitely adjustable bench height for the different heights of subjects, this is obviously more complicated. Well-trained endurance athletes do unduly well in this test which is physiologically slanted towards aerobic capacity such as is necessary for moderate-intensity middle-distance running. For practical purposes, the taller endurance sportsman will tend to be flattered by his fitness

index; in contrast, the shorter, fatter power-event person will seem disproportionately unfit. Because of these disadvantages, more sophisticated physiological testing has been developed.

Bicycle ergometry

This consists of a modified bicycle with seat, pedals and variable-resistance drive wheel. The resistance of the drive wheel is adjusted to set a predetermined standard workload for the subject. He then has to sustain this workload either by faster pedalling against a smaller resistance or slower, harder pedal work against a bigger resistance. Thus, not only can overall workload be set, but the different aspects of stamina or power fitness can be considered.

In simple bicycle ergometry, the pulse rate can be plotted at the end of exercise and the fitness index compared with standard tables.

More sophisticated bicycle ergometry gives more information. The commonest extension is to combine this procedure with analysis of the gases breathed in from the atmosphere and exhaled from the lungs. In this test, the subject has his nose clamped and breathes in and out through a closed tubing system. This is easily managed with practice. The differences between the amounts of oxygen and of carbon dioxide breathed in and out are measured, the oxygen consumption is calculated and, by comparison with the workload at different rates, the maximum oxygen uptake ($\dot{V}O_{2_{max}}$) can be determined. This gives a comparison with other subjects as well as providing a measure of the individual's fitness compared with his own personal capacity, especially on repeated testing.

Treadmill tests

There are many types of treadmill available. The more expensive varieties have to be built into laboratory floors for stability; simpler ones are small and portable. They may operate only in the horizontal plane or they may be capable of being raised through various gradients, thus increasing the workload required of the subject.

The standard test protocols all follow assessment of standard measurements, e.g. pulse, at rest followed by continuous walking or running at progressively harder resistances. The subject starts by walking on the level. At least 3 minutes is usually allowed for each gradient so that physiological function can stabilize fully before the next increase in workload. At each stage, the treadmill gradient is raised one unit.

The advantage of this scheme is that the progressive increase in intensity of workload required is such that, despite its complexity, few tests last longer than about 20–25 min and the end point of the test coincides with the subject's maximum exercise capacity, thus giving the most useful information. Naturally, modified treadmill tests for medical purposes remain safely at the much lower submaximal levels which give relevant clinical information without needing to go to the length or severity of the tests required for trained athletes.

The practical difficulty is that, in order to gain maximum information from the treadmill tests, a considerable expense and degree of mechanization is required. It is difficult for inexperienced personnel to measure pulse and blood pressure accurately during locomotion, particularly when the rhythmic thumping of the running action or fast walking continues. The bicycle ergometer is much easier to use in this respect.

Sport-specific tests

For the moderately fit or unfit subject a test run of 1½ miles (2.4 km) gives a time which correlates well with aerobic capacity, or endurance fitness. This is one of the basic assessments associated with 'Aerobics', originally pioneered by Bruno Balke. The disadvantages of the actual test run are that it tends towards maximal exercise for the individual and therefore may introduce risk factors. Secondly, it requires a certain amount of training and fitness above the beginner's level and is therefore more