This chapter was published in:
Exercise Physiology in Special Populations - Advances in Sport and Exercise Science
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'Introduction: Increasing and maintaining physical activity in special populations', pp. 1 - 20,
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http://hdl.handle.net/1893/1133

Chapters

Chapter 1

Introduction

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This text on exercise physiology in special populations aims to cover a number of the prevalent health conditions that are either linked to an inactive lifestyle or whose effects can be ameliorated by increasing physical activity and physical fitness. Throughout the text the terms physical activity, exercise and fitness will be used. It is therefore important at this point to first define the assumed meanings of these three terms. Following this, the concepts of physical activity behaviour and the various measurement parameters used by exercise professionals or health care practitioners, as applied in each of the chapters of this text, to either monitor or prescribe exercise will be reviewed.

Physical activity is considered to be any muscular movement occurring above resting levels. It is an all-encompassing concept that includes any physical movements occurring within free daily living or planned leisure pursuits (exercise and sport). As will be mentioned throughout a number of chapters and in light of the Chief Medical Officer's (CMO) report for England and Wales (Department of Health, 2004), the prevalence of a number of illnesses or diseases is greater in those who expend less than 1500 kilocalories per week above their basal metabolic rate. The strength of the arguments highlighted within the CMO's report tend to suggest that declines in health, which are related to inactivity (hypokinesis) and obesity, are due more to the loss of physical activity in free daily living as compared to the debatable reduction in the populations' participation in organised exercise and sport (Cordain et al, 1998; Eaton and Eaton, 2003). One only has to look at the increased number of sports and fitness centres that have been built in the UK in the last decade to realize that there is certainly not a decline in those already engaged in organized sport and exercise. The reduction in energy expenditure within in normal daily life, especially in non-sporty/exercise participants, has greatly increased in the last two decades (CMO, 2004). This is a result of the increased attraction for sedentary leisure pursuits and decreases in the physicality of daily domestic-occupational tasks and transportation.

The discussion thus far focuses on the correlation between inactivity and the increased prevalence of chronic diseases. However, a number of chapters within this text relate to considerations for exercising individuals with conditions acquired either by poor nutrition or smoking, an accident or an unfortunate health event, including pulmonary disease, osteoporosis, Parkinson's disease, Multiple sclerosis, arthritis or spinal injury. These conditions can lead to declines in physical activity that contribute to an inactive lifestyle; thus putting them at risk of chronic diseases such as coronary heart disease and diabetes. In these cases, exercise can be used as a means of combating the future potential ills of inactivity as well as a therapeutic intervention in helping the client/client/patient, client or participant cope better in living with the imposed physiological and psycho-social challenges that lay ahead.

Exercise is typically planned and/or structured physical activity, which has an aim. The aim is usually to satisfy either a physical, psychological or social need; typically a mixture of all three. Exercise was traditionally used as a means of preparing soldiers for battle but in the last fifty years has become prominent in enhancing sporting performance, physical health and personal "body-image". Sports performance targets provide a natural motivation for maintaining exercise training. One's self-image, as promoted through the popular press, often relates to promoting shorter-term targets as looking good in a holiday swimsuit or for a large social event such as a wedding or important party. The motivation for regular and sustained participation in health promoting activity is sometimes less easy to measure than athletic performance as the true health outcomes may only be observed after years of participation. Enhancing social and enjoyment aspects of participation in health-based exercise becomes a very important aspect of sustaining any regime (Biddle and Mutrie, 2001). More frequent bouts ($\geq$ 3 times per week) of more intense activity provide a training threshold at which physiological fitness adaptations occur (i.e. enhanced cardio-respiratory fitness, improved blood lipid profile, glucose control and reduced insulin resistance) (ACSM, 1998).

Physical **Fitness** is a composite of seven components, which indicate the ability to perform a given task or physical activity. The benefits of improving fitness for health are two fold:

1. Being able to sustain an active life in order to functionally contribute to one's personal needs and/or roles within family, community and society and

2. That fitness is inversely linked with the incidence of morbidity of a variety of diseases and all cause mortality.

Whether exercising for health or sport performance, the seven components of fitness are the same (summarized below and in Figure 1.) and include:

1. Aerobic (cardio-respiratory) power, typically described as VO_2max. This is the maximal amount of oxygen the body can take in and utilize. It is influenced by three factors: the lungs' ability to oxygenate the blood, the cardiovascular systems' ability to deliver the oxygenated blood to the exercising muscles and the muscles' ability to extract and utilize the oxygen to produce energy for sustained contractions. Inactivity and/or disease impair one or a combination of these

three systems and hence reduce an individual's ability to function.

2. Aerobic (cardio-respiratory) endurance is the highest proportion of VO_2max at which an individual can sustain (> 20 mins) activity. It is closely allied to the lactate thresholds described in standard exercise physiology texts; the point at which muscular fatigue begins to be hastened. The elite endurance athlete can sustain activity typically at greater than 80% of his/her aerobic power, whereas the sedentary or diseased person may only be able to sustain activity at 40 to 50% of aerobic power. What this means is that the inactive or diseased person not only has a reduced capacity but they cannot utilize as much of whatever capacity they possess compared with the more active or fitter individual.

3. Metabolic function from a health perspective relates to the ability to control blood sugar levels better and from an exercise performance perspective the ability to deal with or buffer exercise related changes in muscle and blood pH. The latter demonstrates that the more active individual is also able to tolerate and deal with higher levels of metabolites and prolonging the time before muscular fatigue sets in.

4. Muscular strength (power) is the absolute amount of power that can be generated for one maximal voluntary contraction. It also needs to be considered that movement power is a product of both muscular strength and coordinated movement of a group of muscles. Strength is often represented by a one repetition maximum lift known as a "1-REP max". As described in the next fitness component, muscular endurance, maintaining or increasing strength is functionally advantageous to older individuals. There are also metabolic and cardiovascular benefits from increased muscular strength. The stronger and larger muscle has a greater number of blood vessels. Theoretically, on exertion, by possessing a greater number of blood vessels means a reduced rise in systolic blood pressure, compared to a smaller muscle, and a resultant reduced workload on the heart, and reduced sympathetic stimulation of the respiratory system. As discussed in a number of the chapters, reduced exertion related symptoms provide both real and perceived enhancements to movement in daily living.

5. Muscular endurance relates to the anaerobic power of an individual and the ability to sustain the highest level of muscular contractions for periods between 30 seconds and two minutes. The older individual, whose life consists of short

bouts of activity, is often limited more by a lack of strength and muscular endurance than by their aerobic fitness.

6. Flexibility is the range of motion through which a joint or group of joints can be moved. It is a function of the flexibility of the soft tissues in and around a joint (tendons, ligaments and cartilage) plus the ability of the muscle's neurological unit to relax. All movement requires a given amount of flexibility and regardless of the strength or endurance capabilities an individual has, flexibility can be a key limiting factor to function and performance.

7. Coordination/balance/proprioception is the ability of an individual to perform a sequence of movements and their awareness of joint positions within space. For sports that involve dynamic skill (typically ball sports) or the neurologically diseased (e.g. stroke, Parkinsons, Multiple Sclerosis, Head-injury), this becomes the limiting factor in functional performance movement, regardless of strength, endurance and flexibility.

Within each of the chapters to follow, the discussions will often focus on the dose of exercise necessary to bring about some health benefit from simple increases in daily physical activity or by a physiological fitness improvement to the above seven components of fitness (Figure

2). With some conditions, the enhancement of one or a number of these seven components will become the focus of the evidence that relates to either decreases in morbidity and mortality or increased quality of life for individuals with a given health condition. For example, the value of increased muscular strength and endurance and enhanced balance and coordination are primary outcome benefits for the older person (preventing falls) or an individual with osteoporosis.

Insert Figures 1 and 2 near here

The Behaviour of Increasing and Maintaining Health Related Physical Activity

As exampled within this text, for the individual studying sport and exercise science/medicine there is much focus on the technical biological or biomechanical measures that can be learned and researched. Yet this is of no value unless factors influencing an individual’s behaviour of being physically active within free-daily living and structured exercise are seriously addressed by the exercise professional or health care practitioner. If physical activity is not maintained, then any related physical or psychological health gains will eventually become redundant (Biddle and Mutrie, 2001). In other words the benefits of increased physical activity cannot be “banked” for the long term. For example, in the context of a structured exercise session (typically offered in a leisure, fitness or rehabilitation center) it is important to acknowledge the overall psychological (cognitive and behavioural) milieu surrounding physical activity participation. Long-term maintenance of a physically active life is greatly influenced by the psycho-social environment in which the non-athlete participant finds him or herself. Such a setting needs to ensure that the exercise is enjoyable, non-inhibiting, and one that promotes confidence and success. Most people do not engage in adequate amounts of physical activity to benefit health and approximately 50% of adults who begin an exercise programme dropout within six months. Therefore, encouraging people to initiate and sustain a physically active lifestyle is a difficult and challenging task for exercise professionals and health care practitioners.

Health professionals need to understand the key psychosocial factors influencing participation in physical activity and know how to address these factors in order to improve participation. In addition, understanding exercise issues specific to the client’s medical condition is required, such as the dose needed to produce benefits, contraindications to exercise and the appropriate exercise prescription. The aim is to develop an exercise prescription/activity plan that is tailored to the individual’s motivation, health status, lifestyle, activity and fitness levels, taking into account key psychosocial factors such as barriers to exercise and self-efficacy to ensure clients adopt and maintain an active lifestyle in the long-term.

A number of psychological and social factors have been shown to have a strong influence on participation in physical activity and exercise in both non-clinical and clinical populations (Trost et al, 2002; Woodward et al, 2001). These include self-efficacy, enjoyment of activity, social support, perceived benefits of activity and perceived barriers to activity. Therefore, targeting these factors can assist individuals with behaviour change. Furthermore, several theoretical models of behaviour change have been used to understand physical activity behaviour and interventions based on these models have successfully increased and maintained physical activity in the general population and client groups (Biddle and Mutrie, 2001; Khan et al, 2002). The following section describes key cognitive behavioural strategies that can be used to help clients adopt and sustain a physically active lifestyle. These strategies are guided by evidence-based models of behaviour change and target the key factors influencing participation in physical activity and exercise. The strategies can be applied to all client groups and include the stages of change, decisional balance, self-monitoring, goal setting, enhancing self-efficacy and relapse prevention training. Health care professionals can use these techniques in consultations with individual clients but could also incorporate them into small group-based exercise programmes.

Client-centred approach

Consultations about behaviour change are more effective if practitioners actively engage clients in the behaviour change process rather than persuading or telling them what to do (Rollnick et al, 2005). Therefore, clients should be encouraged to accept responsibility for the behaviour change, to elicit their own reasons for change and set their own goals for change. The practitioner's task is to guide the client through the process by helping them weigh up the value of change and ensure realistic goals are set (Rollnick et al, 2005; Loughlan and Mutrie, 1995). Core interpersonal skills required to achieve a client-centred approach include good verbal and non-verbal communication, active listening and expressing empathy (Rollnick et al, 2005; Loughlan and Mutrie, 1995). For further information on the client-centred approach see Rollnick et al, 2005, Loughlan and Mutrie, 1995.

Stages of Change

The Stages of Change are part of the Transtheoretical Model (TTM), which has been used to understand and modify a broad range of health behaviours including physical activity (Biddle and Mutrie, 2001). The TTM proposes that individuals attempting to change their physical activity behaviour progress through five stages. The stages differ according to an individual's motivation and behaviour, and have been labelled; Precontemplation (inactive and no intention to change), Contemplation (inactive, but intending to change in the next 6 months), Preparation (engaging in some activity, but not regularly), Action (regularly physically active, but only began in the past 6 months) and Maintenance (regularly active for more than six months). Individuals progress through these stages at varying rates and often relapse back to an earlier stage when attempting behaviour change (Marcus and Simkin 1994). The model proposes that strategies to encourage change should be matched to the individual's stage or motivation (described in Table 1). Interventions based on the TTM have been effective in promoting and maintaining physical activity in several populations including people with type-2 diabetes and coronary heart disease (CHD) (Kirk et al, 2004; Hughes et al, 2007; Marcus et al, 1998) Exercise practitioners can use the stages of change to assess an individual's motivation to become more active and then select appropriate stage-matched strategies to promote and maintain behaviour change. For further information on the TTM within the context of physical activity see Biddle & Mutrie 2001.

Insert Table 1 Near Here

Decisional Balance

A significant relationship between the balance of the pros and cons of physical activity participation in clinical and non-clinical groups has been demonstrated (Trost et al, 2002; Woodward et al, 2001). Decisional balance, a component of the TTM, involves a comparison of the perceived pros (benefits) and cons (costs) of increasing activity (Biddle and Mutrie 2001). Through this process, clients are asked to consider the personal benefits of becoming more active. Examples include increased fitness, improved wellbeing, increased confidence and weight management. Health professionals may need to help clients understand the benefits of physical activity in relation to their medical condition (Biddle and Mutrie 2001). For example, a client with CHD may not be realise that participation in regular physical activity will improve his/her cardiac symptoms. The perceived cons (costs) of increasing activity should also be explored. Examples include having to make time for exercise and do not like walking in inclement weather. It is likely that some perceived costs will be related to the client's medical condition. The exercise practitioner should help the client find ways to overcome or cope with perceived cons, for example have an alternative indoor activity to do when it is raining. The aim of the decisional balance is to help individuals realise that the pros of becoming active outweigh the cons. This is an important strategy for individuals in the contemplation and preparation stages of change because the perceived costs of exercise are likely to outweigh or equal the perceived benefits (Marshall and Biddle, 2001).

Overcoming Barriers to Activity

A significant relationship between perceived barriers and involvement in exercise and physical activity has been demonstrated in several groups (Trost et al, 2002; Woodward et al, 2001). Therefore, identifying barriers to physical activity and devising ways to overcome these barriers is a useful strategy to increase activity (Biddle and Mutrie 2001). Some of the individual's barriers to activity will be similar to their perceived cons discussed previously. Common barriers to activity include time constraints, low fitness level, lack of energy and inclement weather. Possible solutions to these barriers are described in Box 1. It is likely that clinical groups will experience particular barriers to activity as a result of their medical condition and will need support from the exercise practitioner to overcome these barriers (Biddle and Mutrie 2001). For example, an individual with Type 2 diabetes may fear that exercise will cause hypoglycaemia, therefore education on how to avoid this situation during and after exercise will be required. Perceived barriers to exercise among individuals with osteoporosis include fear of falling and concern that exercising will increase the risk of fracture. These anxieties could be alleviated by providing guidance on exercises to avoid such an event. Many clients do not feel confident in their ability to engage in exercise, thus reassurance that the exercise prescription will be tailored to the individual's abilities and disease state, and utilising strategies to enhance confidence (described below in self-efficacy section) may address this barrier. The exercise practitioner should understand the specific barriers to exercise among the client group with whom he/she is working and be able to provide advice and reassurance to address these barriers and alleviate concerns.

Box 1: Strategies to Overcome Barriers

Lack of time: incorporate activity into daily living (e.g. walk part of the journey to work, walk at lunchtime) instead of having to take 'time out' of daily life to participate in structured exercise sessions.

Low fitness: tailor the exercise prescription to the individual's physical ability and fitness level and very gradually increase the frequency, duration and/or intensity.

Lack of energy: engage in moderate activities or accumulate activity in short bouts (e.g. 10 minutes), which requires less effort than exercising vigorously or continuously.

Social Support

Social support has a major influence on participation in physical activity and exercise in clinical and non-clinical settings (Trost et al, 2002; Woodward et al, 2001). Sources of support include friends, family members, neighbours, exercise leaders and other participants, co-workers and health professionals. Different types of social support may be required, such as having a 'buddy' to go walking with, receiving encouragement and praise for achieving an activity goal, obtaining information and advice from an exercise practitioner on appropriate types of activity and having someone to make it easier to be active (e.g. to look after the children so he or she can attend an exercise class). Joining an appropriate group exercise programme can provide a supportive environment for some individuals but choice of the programme is paramount; sometimes it can have the opposite effect on confidence and self-esteem.

Goal-Setting and Self-Monitoring

Throughout this text, there will be specific physiological doses, targets or thresholds that need to be achieved in relation to the frequency, intensity, duration and type of activities performed. It must be remember that each individual need to be psychological ready to cope with such targets, even if it is clear he/she is clearly physiologically capable. Initially the activity dose may thus need to be progressed from levels below the actual physiological target threshold, until such a time where the client clearly has the self-efficacy to do so and the various social barriers have been cleared to do so.

Goal setting and self-monitoring are frequently used in physical activity interventions to increase and maintain peoples' motivation for behaviour change. (Biddle and Mutrie, 2001). The acronym SMARTER (specific, measurable, acceptable, realistic, time-phased, enjoyable and recorded) can be used to ensure effective goals are set (Biddle and Mutrie 2001). Specific goals (e.g. brisk walk for 15 minutes on three days per week) are more effective than vague goals, such as 'to be more active'. Goals should be acceptable and realistic in order to enhance confidence and ensure success. Individuals should be encouraged to make small, progressive changes to their physical activity behaviour by setting short, intermediate and long-term goals (shown in Table 2). Participants should choose activities that they enjoy and they should receive a copy of their goals for future reference. Keeping a written record of physical activity patterns (i.e. self-monitoring) allows the individual to evaluate progress towards their goals. Individuals should set their own goals, however, the exercise practitioner should assist with goal setting to ensure they follow SMARTER principles (Rollnick et al, 2005; Loughlan and Mutrie, 1995). Goals should be tailored to the individual’s motivation, baseline levels of activity and fitness, lifestyle and health status and take into account other psychosocial factors such as barriers to activity and self-efficacy to ensure long-term adherence to exercise and physical activity.

Insert Table 2 Near Here

Enhancing Self-efficacy

Self-efficacy is an important component in a number of theoretical models including the TTM and has a very strong influence on the adoption and maintenance of physical activity in non-clinical and clinical settings (Trost et al, 2002; Woodward et al, 2001). Self-efficacy is defined as an individual's confidence in his or her ability to perform a specific behaviour (Bandura 1977) and can have different forms including a person’s confidence in their ability to participate in regular physical activity in certain situations (e.g. when they are tired after a hard day at work or when it’s raining). It can also relate to a person’s confidence in their ability to overcome typical barriers to exercise, to achieve an activity goal (e.g. walking continuously for 30 minutes daily) or to perform a specific activity (e.g. going to an aerobics class).

Self-efficacy can be enhanced by targeting the main sources of self-efficacy: mastery experiences, verbal persuasion, modelling and interpretation of physiological states (Biddle and Mutrie 2001). The experience of performing a task successfully (i.e. mastery experience) has a strong positive influence on self-efficacy. This can be achieved by dividing a challenging goal (e.g. walking continuously for 30 minutes daily) into manageable components (e.g. walking for 10 minutes daily) that individuals feel confident they can achieve, successfully mastering the smaller goal will increase their confidence in their ability to set and master more challenging goals. Verbal persuasion can build confidence through the provision of encouragement and praise from important others. For example, an exercise practitioner praising a client for achieving an activity goal. Clients observing other people of similar age, physical characteristics or abilities successfully engaging in physical activity (known as modelling) can increase self-efficacy. This could be achieved by grouping people of similar abilities together in an exercise class, encouraging a client to attend an exercise class to observe others or providing examples of how similar clients have successfully increased physical activity. Self-efficacy can also be enhanced by having a plan to overcome barriers to exercise. Novice exercisers often view the normal physiological responses to exercise (i.e. increased heart rate and breathing, perspiration and muscle soreness) with some anxiety or discomfort, which can adversely affect self-efficacy. Therefore, exercise practitioners should teach participants how to monitor and positively interpret the body's response to activity. High levels of self-efficacy are needed both to become regularly active ***and*** to maintain an active lifestyle in the long-term (Marshall and Biddle, 2001). Thus, an individual's self-efficacy for exercise and activity should be assessed and then developed using appropriate strategies.

Preventing Relapse

Relapse prevention training is an effective strategy to encourage individuals to maintain regular physical activity in the long-term (King et al, 1988; Biddle and Mutrie 2001). Relapse is a breakdown or set-back in a person's attempt to change a target behaviour. The relapse prevention model was first developed to understand relapse from addictive behaviours such as alcoholism and smoking (Marlatt and Gordon 1985), but has since been applied to exercise and physical activity. The model proposes that relapse may result from an individual's inability to cope with situations that pose a risk of return to the previous behaviour. Common high-risk situations relevant to exercise and physical activity include bad weather, an increase in work commitments, boredom, change in routine or illness. Therefore, developing a plan to cope with high-risk situations will help to avoid relapse. For example, increased work commitments could be overcome by rescheduling an activity session or engaging in a shorter bout of activity. In addition, teaching individuals that a lapse from exercising (e.g. missing a few days of planned activities) need not lead to a relapse (e.g. missing planned activity sessions for an extended period), which can help to improve adherence. If relapse is unavoidable, for example as a result of illness, then a gradual restart in activity is recommended. Overall, relapse prevention training involves helping individuals to identify high risk situations that may cause a lapse or a relapse helping them acquire strategies to cope with these high risk situations.

This text focuses entirely on managing the physiological and metabolic effects of exercise in a range of chronic diseases. However, participation in regular physical activity can also produce substantial psychological benefits in a range of clinical conditions (CMO 2004). These benefits include increased quality of life, improved mood, reduced anxiety and depression, and increased social opportunities. All of these factors impact on the above factors that affect the behaviour of participation in physical activity. These benefits are important because many people with the medical conditions described throughout this text have a concomittant impaired quality of life and psychological wellbeing. It is thought that the psychological effects of exercise may be just as important as the physiological effects among people with medical conditions (Biddle and Mutrie, 2001, Oldridge et al, 1988). Furthermore, it is the psychological effects of exercise that appear to motivate people to be physically active and continue participation in the long-term (Biddle and Mutrie, 2001).

Misperceptions about Physical Activity

A possible reason for low levels of physical activity in the population may be a misperception that health benefits can only be achieved by participation in continuous, high intensity exercise or sport (Biddle and Mutrie, 2001). Many people may not realise that performing moderate amounts of physical activity can improve health and instead believe that they must exercise at a hard level to gain benefit. These various health related thresholds will be discussed in each of the chapters throughout the text. These perceptions are partly caused by the traditional exercise guideline (ACSM 1990), which recommended engaging in at least 20 minutes of continuous, vigorous exercise on 3 days per week to improve fitness. However, most people failed to achieve these recommendations and common reasons given for not exercising included not being the sporty type, lack of time, too much effort required and dislike of vigorous exercise (Biddle and Mutrie, 2001). In addition, people are more likely to adopt and maintain moderate intensity activity compared to high intensity exercise (Trost et al, 2002). It is now known that lower levels of physical activity than the amount required to improve fitness, can produce substantial health benefits. New guidelines were published in 1995 which recommend accumulating 30 minutes of moderate physical activity on most days of the week to produce health benefits (Pate et al, 1995). This recommendation is more acceptable for sedentary individuals and clinical groups who are likely to have low fitness levels and functional limitations, and may be more appealing to those who dislike vigorous exercise. It should be noted, however, that this recommendation is intended to complement the 1990 traditional exercise guideline. It is much easier for sedentary individuals to incorporate small bouts of moderate activity into their daily routine rather than engaging in structured, planned programmes of vigorous exercise. However, individuals who are moderately active will gain additional health and fitness benefits by increasing the duration and/or intensity of their activities. The American Heart Association and the American College of Sports Medicine (Haskell et al., 2007) have published a joint up-date on the appropriate doses of physical activity that positively influence health.

Monitoring the exercise dose

In reading through each of the chapters the evidenced physiological health and fitness benefits will be a function of the total volume of physical activity performed. The components of the physical activity volume include the **frequency, intensity, duration and type of activity (FITT)** performed. This premise holds true for attaining improvement in each of the seven components of fitness (aerobic power, aerobic, endurance, muscular strength, muscular endurance, flexibility, metabolic control, or balance/coordination). The debates continue on the “optimal dose” required for health gain or fitness performance gain, where at one end of the spectrum is low intensity with frequent bouts throughout the day and week and at the other end shorter bouts of higher intensity activity performed as little as one to two times per week (Medicine & Science in Sports and Exercise, 2001; Swain, 2005; McFarlane et al, 2006).

Physical activity monitoring and guidance

Measuring physical activity reliably and validly is far more difficult than measuring fitness. Fitness can be measured in a very controlled testing situation. However, physical activity is a measure which needs to be assessed throughout the hours and days of typical weeks within an individual’s daily life. It is the amount of physical activity outside of the structured exercise session, where it is more difficult to estimate energy expenditure and yet it is here where most Calories are burnt in a person’s daily life; not in exercise classes, gyms or sports halls and playing fields (Eaton and Eaton, 2003; Cordain et al., 1998).

The two gold standards for measuring physical activity within free-daily living (not in a controlled laboratory) include doubly-labelled water and accelerometry. The use of the ***doubly-labelled water technique***, is where participants are given a known volume of water which contains “marker isotopes”. Over a period of days or weeks, samples of body water (from saliva, urine or blood plasma) are assessed for the elimination of these isotopes, which occurs through the body's metabolism. There is a direct correlation between the amount of carbon-dioxide produced and metabolic water produced and the amount of energy expended. The changes in the isotopes in the body-water over time are linked to oxygen usage and carbon dioxide production both of which are main biochemical components of energy metabolism (Schoeller and van Santen 1982). The use of ***accelerometers*** involves placement of monitors on different parts of the body that aggregate recorded total motion activity of these different body segments over hours, days and weeks (Chen and Bassett, 2005).

In addition to the high cost, the limitation of the doubly-labelled water technique or accelerometry is that they do not give a good indication of the physiological intensity involved in the physical activities being monitored. The use of heart rate monitoring has been added into measures of accelerometry devices in order to gain information on intensity and thus providing a better picture of the volume of activity being performed (Brage et al., 2006). It is important to determine whether the health gains from increases in activity levels include significant increases in fitness above and beyond the benefits of daily increases in caloric energy expenditure. Williams (2001) reported that when increased physical activity resulted in increased fitness, the health gains were significantly greater as compared to when daily energy expenditure was increased without gains in fitness. There were however definite health gains with increased daily physical activity even when improved fitness was not achieved.

Within health promotion and health based physical activity, the practical and inexpensive surrogate measures of doubly-labelled water and accelerometry include physical activity diaries, questionnaires and pedometers. If these are being used then the questionnaire protocol or the pedometer being used should have been validated against either doubly-labelled water, laboratory measures of energy expenditure and/or accelerometry. It is important to acknowledge that when evaluating the reliability and validity of the evidence, that one is aware of the benefits and drawbacks of the mode or device used to evaluate the volume of physical activity; much concern has been raised on the use of self-report questionnaires and diaries on their own (Shephard, 2003).

Relative versus absolute intensity doses of physical activity

Throughout this text, beneficial levels of physical activity and exercise will either be described in absolute terms (e.g. speed, resistance, metabolic equivalents, heart rate) or in relative terms (e.g. percentage of either maximal strength, maximal heart rate, maximal oxygen-uptake). The health promotion message in Europe, the UK and the USA, is for individuals to accumulate 30 minutes of moderate physical activity on most days of the week, with the option of allowing for this to be achieved in 10-minute bouts of activity (CMO, 2004). One of the issues with this is, what constitutes “moderate intensity” activity? For the less fit, sedentary, older or clinical populations, the recommended “absolute” walking pace of 3 miles per hour that qualifies for “moderate intensity” (Lee et al, 2001) could in fact qualify in “relative” terms as vigorous activity; it is possible for this intensity in such individuals to be greater than 70% of maximal aerobic capacity. It is therefore important when reading the literature to see how moderate has been defined; is it in relative (e.g. percentage of one’s maximum) or in absolute terms (e.g. a given walking speed, metabolic equivalent or more recently metabolic-equivalent-hours)?

Aerobic Exercise

Typically the intensity of aerobic exercise is described as a percentage of one’s maximal aerobic power (%VO_2max). In clinical or scientific settings a participant’s VO_2max will be measured using a maximal testing protocol that involves the collection of pulmonary gas exchange responses to the exercise being performed. In conjunction with this, will be measures of heart rate, ECG, blood pressure, blood lactate and ratings of perceived exertion (RPE) that can then be correlated with various proportions of an individual’s VO_2max. From the correlations between these measures a very accurate exercise prescription can be given. It is of importance to note that when testing clinical populations they may not meet the criteria for attaining a VO_2max (see guidelines from ACSM or the British Association of Sport & Exercise Sciences). They may have a clinical perturbation during the test or a co-morbidity that prevents them from attaining a true physiological maximum. In this instance test results reported in the evidence may often use the term VO_2peak. More recent evidence, especially when dealing with lower fitness populations, is the use of the *V*O_2 reserve method (exampled in Box 2.), which takes into account the difference between resting and maximal oxygen uptake.

Box 2. Example

> ***It is typical that an older or clinical-population individual will have a VO_2max of 20 ml.kg^{-1}.min^{-1}. Assuming an estimated resting VO_2 is 3.5 ml.kg^{-1}.min^{-1}, he/she will have a VO_2 reserve of 16.5 ml.kg^{-1}.min^{-1}. If he/she exercised at 65% of VO_2max (13 ml.kg^{-1}.min^{-1}) this would require using 79% of his/her VO_2 reserve. For a younger to middle-aged individual, typically with a VO_2max of 35 ml.kg^{-1}.min^{-1}and thus a VO_2 reserve of 31.5 ml.kg^{-1}.min^{-1}, exercising at 65% of VO_2max (22.8 ml.kg^{-1}.min$^{-1,}$) would require using 72% of his/her VO_2 reserve. For the same %VO_2max the older/clinical individual is actually using more of his/her VO_2 reserve than the younger/fitter individual.***

The recommended exercise dose that leads to an increased aerobic capacity is to activate large muscle groups in a rhythmical manner, for at least 20 minutes three times per week at an intensity greater than

50% of VO_2max or 40% $\dot{V}O_2$ reserve (ACSM, 1998). A period of at least 8 to 12 weeks is often cited as the length of time over which a significant change occurs. These ACSM recommendations, for some individuals who are very sedentary or fall within a clinical population, have stated intensities as low as 40% VO_2max as being an adequate physiological stimulus to bring about change. Within the various chapters, where aerobic fitness is low due to a clinical condition, the minimum 20 minutes of exercise may be achieved through an interval approach giving clients and participants periods of lower intensity active-rest in-between bouts of moderate-to-vigorous bouts of exercise.

In more advanced clinical settings or research work, aerobic exercise intensity is established using actual VO_2max measures. However, in many practical settings, exercise intensity will be set using surrogates of VO_2 and %VO_2max (or %$\dot{V}O_2$ reserve), which include: heart rate, ratings of perceived exertion (RPE) and estimated metabolic equivalents (METs). It has long been established that heart rate is closely linked with $\dot{V}O_2$ (Astrand et al., 2003), which is why it provides the best indirect indication of $\dot{V}O_2$. This association includes that fact that $\dot{V}O_2$max and maximum heart rate coincide and where maximum heart rate is estimated by substracting one's age from 220 (Robinson, 1939). However, the error of this estimation is on average +/- 10 beats.min^{-1} (ACSM, 2006). Heart rate reserve and %heart rate-reserve maximum, similarly provide a practical correlate for $\dot{V}O_2$

reserve. Determining heart rate reserve is typically known as the Karvonen Method (Karvonen et al., 1957), which is described in most standard exercise physiology texts and clinical exercise guidelines.

Borg's RPE scales are the most widely cited scales, which have been validated against relative physiological correlates (e.g. % maximum heart rate, blood lactate, %$\dot{V}O_2$max) during numerous modes of exercise in healthy, athletic and clinical populations (Noble and Robertson, 1996; Borg, 1998). They have become common-place in exercise laboratories and exercise centers. As with any measurement tool, for it to be valid and reliable, these scales must be "calibrated" properly with each user (see Buckley and Eston, 2006 and Borg, 1998 for guidance on appropriate use). Scale ratings between 12 to 15 on Borg' 6-20 Scale or 3 to 4 on Borg's CR-10 scale, relate to the level of lung and muscular sensations corresponding to the training thresholds described above; these scale points are linked to the anaerobic, lactate or ventilatory thresholds typical described in the exercise physiology literature. A summary of the relationship between VO_2, heart rate and RPE is presented in Figure 3.

Insert Figure 3 near here

Muscular Strength and Endurance

Historically, muscular strength and endurance training that focuses on exericsing specific individual muscle groups, falls under one of three traditional categories:

- "Body building" for purely aesthetic goals (Chapman, 1994),
- Swedish remedial/medical gymnastics for health and rehabilitation (Kleen, 1921), or
- Athletic performance enhancement (Kraemer et al., 2002; www.nsca-lift.org)

It is beyond the remit of this text to delve into the specific physiological and biomechanical principles of muscular strength and endurance training. The reader may be required to review, from other texts, some underpinning elements that relate to the evidence and its application to specific populations. The three main types of muscular contraction used in strength and endurance training are of specific note: isotonic, isometric and isokinetic. Some biomechanists may actually question the theoretical constructs of each of these types of contraction but from a practical perspective they are assumed to describe the type of exercise being performed. Typically ***isotonic activity*** involves using a fixed amount of weight (e.g. a dumbbell or barbell). In this case, the challenge of moving this given amount of resistance will be dependent upon the angle of the joint (s), which in turn effects the length and tension of the muscle at its tendons.

Isometric activity assumes the presence of a muscular contraction where there is no joint movement occurs. ***Isokinetic activity*** refers to muscular work where the amount of resistance changes relative to a given joint angle, which is achieved by employing a device, machine or apparatus. All three types of muscular activity are used in health and rehabilitation based exercise.

An important aspect to remember within health and rehabilitation is that movement and functionality, not just muscular strength/endurance, is the most important outcome of any training or rehabilitation programme. Often the evidence reports an improvement in muscular strength but this is only of value if it translates into enhance functioning or performance. The movement power which can be generated by a human is not just a function of the size and strength of a muscle. It is also significantly influenced by the neurological motor coordination, dynamic balance, stability and muscle-sensation tolerance of the muscle groups involved in producing given movement. For example, in the chapters on pulmonary and cardiac disease, evidence is presented that increased muscular strength, independent of aerobic exercise training, can enhance walking endurance. The potential mechanisms include improved movement efficiency as a result of improved dynamic stability of the ankle, knee, hip and pelvic-lumbar joints, and the ability to perceptually tolerate higher levels of muscle fatigue sensations.

Establishing the strength training prescription

The standard reference point for muscular strength and endurance training is the one-repetition-maximum (1-RM) (www.nsca-lift.org). Similar to aerobic exercise, this is a practical surrogate measure for the physiological standard of the maximal voluntary contraction (MVC). The MVC requires accurate measurement devices where as the 1-RM is determined using the exercise resistance equipment used within the training regime. As with VO_2max, in health and rehabilitation populations, it may not be advisable, safe or even necessary to determine a 1-Rep Max from which to establish an exercise prescription. If a weight causes a muscle to fatigue in eight or fewer repetitions then the individual is likely to be working at >80% 1-RM, whereas for a weight which allows between 8 to 15 repetitions to be completed, the individual will be working at ~65% 1-RM (Kraemer et al., 2002; www.nsca-lift.org). For untrained individuals, older or clinical populations strength gains can be attained in working at 50% 1-RM for 12 – 15 repetitions but this must be progressed towards higher intensities in the range of 8 – 12 repetitions (Kraemer et al., 2002). With regard to populations covered in this text, the recommended training dose is a frequency of two to three times per week, at an intensity of >50% 1-RM, for a duration of 8 to 15 repetitions and involving 8 to 10 major muscle groups (ACSM, 1998; Kraemer et al., 2002; Pollock et al., 2000). When the number of repetitions exceeds 15, then the resulting training adaptations are more likely to be increased metabolic endurance with smaller amounts of strength gain and related histological hypertrophy.

Flexibility

Performing flexibility exercises (e.g. stretching) pre- and post- training or sports performance has taken on almost a ritual format for most recreational exercisers or competitive and elite participants (Herbert and Gabriel, 2007). The two aims of performing flexibility exercises are either preventing muscle/joint aches or injury, or improving joint flexibility to enhance movement capability or performance (Thacker et al., 2004). There is still a continued debate on the effectiveness of pre- and post-event stretching as a means of preventing injury (Thacker et al., 2004; Hart, 2005). There is however consensus that flexibility exercises performed regularly two-to-three times per week lead to increased joint range of motion by improving the viscoelastic properties of the muscle tendon (ACSM, 1998). The benefit of improved flexibility is muscle and movement performance. For individuals with joint trauma, this may increase amounts of pain-free movement.

The ACSM (1998) recommend one of three modes of training: static stretching, proprioceptive neuromuscular facilitation stretching (PNF), or ballistic stretching. The two latter techniques are recommended to be used under expert supervision and with healthy athletic populations. Static stretching would seem the most prudent mode of stretching for health-based training within the general population or in non-athletic and clinical populations. The static stretch is recommended to be held between 10 to 30 seconds (no added benefit for holding for longer durations) and repeated four times for each muscle group, two-to-three times per week.

There again is some problem with finding practical means of accurately measuring changes in joint range of movement. The standard measurement technique within the evidence base is electrogoniometry (Gerhardt and Rondinelli, 2001). From a clinical perspective, client feed-back on incidence of symptoms or enhancements in movement performance are always the most important element and goal for both the practitioner and client/client.

Balance/coordination/proprioception and movement control

In many exercise physiology recommendations and documents, this area of health related balance/coordination/proprioception/ and movement (discussed subsequently as movement control) is often overlooked. It rarely officially features as a component of fitness and yet much evidence is published on the "trainability" of the neuro-muscular interface. Typically it is included in the area of skill acquisition related to sport performance. However, it does not seem to feature highly within the more discrete elements of health related sports medicine and exercise science even though the evidence confirms that skill acquisition relates clearly to improved functional performance (or improved performance of everyday activities) and confidence. The three chapters in this text, which exemplify the area of movement control, include exercise in spinal injury, neurological disorders and the ageing process. A good example of its importance can be drawn from people who suffer a stroke or a brain/head injury. The effects in some individuals may mean that their muscles may well have power but due to a loss of motor control of this power, simple functional movements are impaired or lost.

Within Western society, the average age of the population is increasing and the integration of balance and strength into exercise programming is gaining prominence as a key component of fitness related to maintaining functional independence and quality of life. At present, the bulk of the populations in Western society are under the age of 60 years and this goes someway to explaining why the present health promotion (primary prevention) focus is more on aerobic and metabolic health and fitness; both of which have strong links with the chronic diseases that consume much of the present day health service resources and influence general economic productivity (cardiovascular disease, diabetes, obesity, cancer and back pain). As the population ages, however, the potential of exercise to maintain and restore function to live a good quality of life will be come more prominent as a result of the growing retired population. It will be interesting to see in the future how health is perceived by a population dominated by older people. Will they be interested in issues of extending life beyond the age of 85 years or will more interest be placed on the "quality of life"? So much of the present science related to health care focuses on adding "years to life" as opposed to adding "life to years".

Due to the lack of discrete prominence within the fields of sports medicine and exercise science, there appears to be a paucity of reviews and published "consensus statements" on exercise prescription guidelines for maintaining control throughout the life span. The chapter on older people, does in fact go a long way to fulfilling much of this need. Unlike measuring levels of cardio-respiratory, muscular strength, and metabolic fitness, more discrete tools to measure movement control are still to be developed for use in health promotion and exercise settings. At present, these assessment tools are restricted to use within secondary care settings as used by medical and therapy professionals. As health promotion work increases (e.g. to prevent falls) with frailer older people, it would be helpful for these assessment tools to be used as a means of risk screening and prevention as opposed to waiting until an individual has an “event” (e.g. a fall) before such tools are employed.

Summary

A fully integrated approach to applying principles of exercise physiology, either for research or practice must include all seven components of fitness that have been discussed so far. A balance between the use of each of these seven components must then be integrated into a needs analysis that dovetails with the client's/client's personal psychological and social motivations and limitations.

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