Chapter **6**

Ageing and older people

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CHAPTER CONTENTS

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

1. Gain insight into the demographics of ageing.
2. Understand and distinguish between the current theories of ageing and the predictors of successful ageing.
3. Understand the impact of ageing on the major physiological systems.
4. Gain an insight into the impact of chronic disease and sedentary lifestyle on the progressive age-related physiological decline.
5. Understand the benefits of regular physical activity on age-related physiological changes, on disease, on function and on independence and quality of life in older people.
6. Gain an insight into the relationship between physical activity and cognition.
7. Gain an insight into the psychological and sociocultural aspects of physical activity in later life including the myths, stereotypes and the barriers to participation.
8. Understand the benefits of physical activity on self-efficacy, psychological well-being and quality of life.
9. Gain an insight into the appropriate adaptations when conducting pre-exercise and health screening and physiological, functional and psychological assessments for older people.
10. Gain an insight into the appropriate programming adaptations when prescribing exercise for older people, including goal setting, motivation and communication.
11. Gain an insight into the adaptations that need to be made in teaching, instructing, coaching and leadership skills when delivering physical activity and exercise to older participants.

INTRODUCTION

That which is used develops and that which is not used wastes away.
Hippocrates (Source of quote, Raric 1973)

With an ever-increasing older population, health and leisure professionals are now commonly dealing with patients who have poor functional mobility and co-morbidities commonly associated with an inactive lifestyle (Dinan 2001). A healthier old age requires less risk of disease, better physical and mental function, richer opportunities for social interaction and a greater sense of control over, and responsibility for, one's own health and well-being. Participation in regular physical activity or exercise contributes to all five of these interrelated determinants of health (WHO 1958). Regular physical activity that includes specific balance, aerobic and strength exercises has been shown to play an important part in enabling older people to remain above critical thresholds by preventing and managing disease, preserving and restoring function, reducing factors conducive to falling (falls risk factors) and maintaining an active, independent and functional later life (Skelton 2001, Taylor et al 2004, WHO 1997, Young 1997, 2001). The recent *National Service Framework for Older People* discusses the use of physical activity in the prevention and management of disease in five of its eight standards of care (Department of Health 2001).

AGEING IS NOT A DISEASE

Ageing is a natural, universal, complex and highly individual process, characterized by progressive declines in the function of most physiological and psychological systems, that leads to increasing frailty, a declining capacity to respond to stress, increasing incidence of disease and eventually death. Within a single individual, each biological organ and system ages at different rates and individual functional status depends not only on age and rates of ageing, but on gender, genetics, lifestyle, health behaviours and socioeconomic influences (Shephard 1997). Some people live longer and have a higher quality of life; they are more successful at ageing than others (Katz et al 1983, Spirduso et al 2005). Understanding something of the demographic trends and the processes and causes of ageing is fundamental to appreciating these differences and to recognizing that older people, far from being a homogeneous group, become increasingly diverse in their medical, psychological and physical status; physiological or 'body age' is as dubious a concept as chronological age (Young 1997). This understanding is also crucial in determining which interventions can delay or slow the ageing process, compress morbidity (physical dependence and poor health) and ensure enhanced quality as well as quantity of life.

Definitions of ageing – when is 'old'?

A consensus definition of ageing is 'a process or group of processes occurring in living organisms that begins with birth and, with the passage of time, leads to a loss of adaptability, functional impairment and eventually death' (Spirduso et al 2005). Definitions of 'ageing', 'old' and 'the older person' differ among nations and socioeconomic classes (Spirduso et al 2005). In many countries, demographers, insurers and employers have set the threshold of old age at 65 years, in others 55 years, yet, in contrast, geriatricians see their specialty as commencing at 75 years (Gill 2002). An increasingly popular way to describe older adults is as sexagenarians (60–69), septuagenarians (70–79), octogenarians (80–89), nonagenarians (90–99) and centenarians (100 and older) (Spirduso et al 1996). The term 'the elderly' is not helpful as it implies a uniformity that belies the considerable differences that result from a broad age range, inter-individual differences in the rate of ageing and a rising prevalence of chronic disease (Kirkwood & Young 2001). Spirduso's Age Categories descriptors are regarded as sufficiently generalizable and give an indication of the role of physical activity at different ages (Spirduso et al 1996; Table 6.1).

The term 'older' has changed its designation remarkably over the last 100 years; far from being in nursing care, many people over the age of 70 years are still in the

Table 6.1 Age categories and role of physical activity

Description	Age	Decade	Role of physical activity
Middle-aged	45–64	5th–7th	Self-esteem, maintenance (function, job)
Young old	65–74	7th–8th	Maintenance (mobility, job) recreation, social interaction
Old	75–84	8th–9th	Mobility, ADL, eating, bathing, dressing, walking, social interaction, IADL, cooking, washing clothes, gardening, shopping
Old old	85–99	9th–10th	Mobility, ADL, independent living
Oldest old	100+	11th	Mobility, ADL, independent living

Adapted from Spirduso et al (1996).

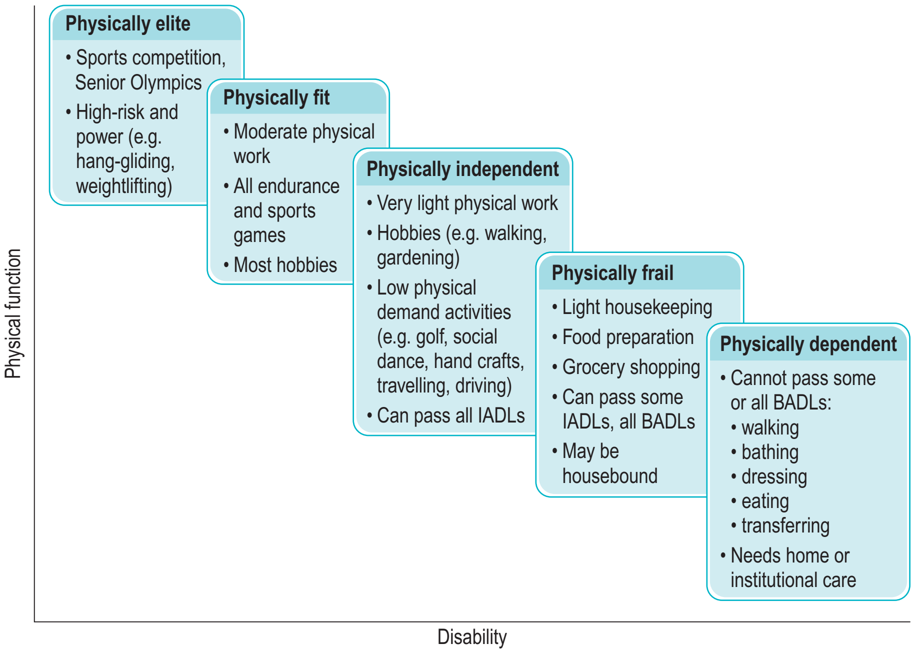

Figure 6.1 Functional ability in older people, as a function of physical activity. IADLs, instrumental activities of daily living; BADLs, basic activities of daily living. Adapted from Spirduso et al (1996) by kind permission of Human Kinetics.

workforce and some 85-year-old women have an aerobic endurance capacity appropriate to the 60–64 age category (Jones & Rose 2005, Malbut et al 2002, Puggaard et al 2000). Spirduso's hierarchy of physical function is highly regarded and effectively describes the diverse range of physical activity in older people, but it must be remembered that some older people defy categorization (Spirduso et al 1996; Fig. 6.1).

The ageing process

Ageing processes (primary ageing) differ from the process or syndrome of ageing (secondary ageing), but the interaction is strong (Kennie et al 2003). Primary ageing represents universal changes that occur with age within a population (e.g. puberty, menopause) and are independent of disease and environmental influence. Secondary ageing refers to clinical symptoms related to deterioration and includes the effects of environment and disease, which can accelerate the process and inherently increase vulnerability to further disease and environmental stress (Kennie et al 2003). Even in healthy individuals, the resulting progressive decline in the function of most physiological systems lowers the threshold of an individual's ability to respond effectively to any challenge and gradually narrows the safety margins between maximal function and critical threshold levels of function that were so generous in youth (Kirkwood & Young 2001, Young 1997). Examples include the decline of bone mineral content (towards a threshold for likelihood of fracture), of glomerular filtration rate (towards a threshold for susceptibility to clinical renal failure), or of physical capacity (e.g. maximal oxygen uptake towards a threshold necessary for everyday mobility; see Figs. 6.2A and 6.2B; Table 6.2) (Kirkwood & Young 2001, Skelton et al 1999).

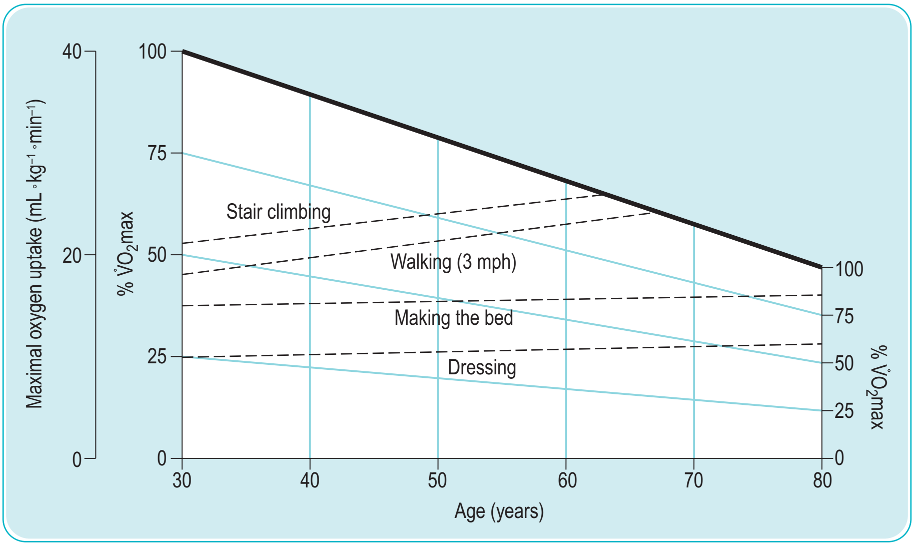

Figure 6.2A Schematic representation of the loss of $\dot{V}O_2$max with age (between the ages of 30 and 80 years) and the relative percentage of $\dot{V}O_2$max used by an individual to perform everyday tasks. Translated and adapted from Saltin (1980).

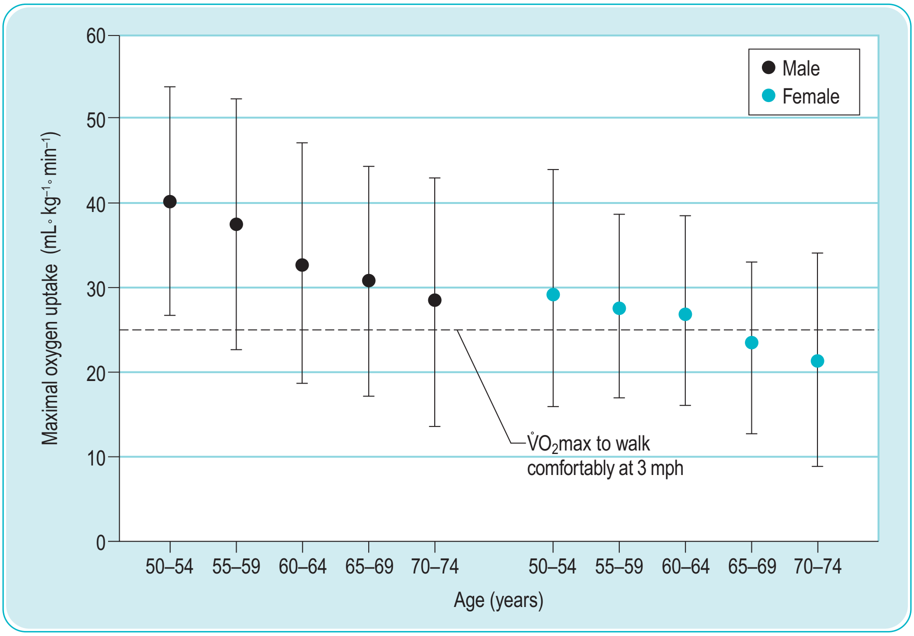

Figure 6.2B $\dot{V}O_2$max in a representative sample of older adults in the UK. The threshold of $\dot{V}O_2$max necessary for comfortable walking at 3 mph is illustrated by the dotted line. Many women over the age of 65 will get breathless walking at slow walking speeds purely because of unfitness. Adapted from Skelton et al (1999).

Table 6.2 Functional abilities of older people in the UK

Functional task	Ability within over 50-year-olds in the UK
Walking	• 9% of men and 38% of women could not be confident of walking comfortably at a 20 minute a mile pace (3 mph) • To illustrate the marked age effect, 35% of men and 80% of women aged over 70 would not be confident of walking comfortably at this pace with their current aerobic capacity
Step climbing or use of public transport	• 7% of men and 28% of women aged over 50 lacked the leg power to be confident to step 30 cm (some bus and train step heights) without having to use their arms • Age-related decline was evident in women, with 47% aged 70–74 having muscle power below the assumed threshold for climbing stairs without using their arms
Washing hair	• 14% of men and 20% of women aged over 50 do not have the flexibility in their shoulders to comfortably be able to wash their own hair
Getting out of a low chair or off the toilet	• 8% of men and 19% of women aged 70–74 were unable to get out of a low chair without using their arms

Adapted from Skelton et al (1999).

The result is that the older person becomes increasingly vulnerable to environmental threats such as extremes of heat and cold, fluctuations of blood sugar and circulatory disturbances associated with physical effort (Morgenthal & Shephard 2005, Skelton et al 1999). These will, inevitably, affect an older person's response to exercise.

Quantitative aspects of ageing

The *rate* of ageing is the change in the function of organs and systems over a unit of time. In normal ageing, these changes follow a linear sequence over the lifespan; however, males age steadily whereas females have periods of accelerated and slowed ageing rates (Ekonomov et al 1989). Disease and sedentary behaviour accelerate the rate of ageing. Restriction of calorie intake (Kinsella 1992, Walford & Crew 1989, Weindruch 1995), genetic manipulation (Shephard 1997) and regular general physical activity and moderate amounts of physical exercise (Taylor et al 2004, Young 2001) are the only three interventions that have been effective in changing the rate of ageing.

The maximum human lifespan potential is 115–120 years, based on Jeanne Calment who died aged 122 in 2000 (Spirduso et al 2005). The average biological human lifespan is limited to about 85 years with only 12% of the population exceeding that age and, unlike life expectancy (the average lifespan from birth), it has remained relatively stable (Fries 1980, Grundy 2003). Life expectancy, for both sexes and for most countries, has almost doubled since the beginning of the 20th century from 40 to approximately 80 years of age (Kinsella 1992, WHO 2002). The low, middle and high projections for life expectancy in 2050 are 74.8, 82.0 and 89.4 years, respectively (US Census Bureau 2001). It is different for different ages, cohorts (eg. 1946–1960 post World War II 'baby boomers'), genders and economic and geographical backgrounds, gender being the most significant. Worldwide, life expectancy for those born from 1946 is 73 for males and 79 for females (WHO 2002). Worldwide, women outlive men by 4–10 years; this gender gap is attributed to genetic, hormonal and social behavioural factors (Grundy 2003).

The 'greying' of the population

The demographic transition and permanent shift to an older age structure ('primary population ageing') is a consequence of long-term downward trends in fertility (Grundy 2003), alongside 25–30-year gains in average life expectancy, due to the reduction in infant and maternal mortality in the first half of the 20th century; advances in medicine, surgery and sanitation; improved availability of comprehensive healthcare and public health programmes; improved working conditions, nutrition and general hygiene; and a higher standard of living (Kinsella 1992, Shephard 1997). The resulting rapid growth in the ageing population is a global phenomenon (Grundy 2003). By 2050, in most European countries, the 85+ group will be 10% of the population, a projected increase of almost 70%, with the 60+ group constituting one in three of the population and outnumbering children under 15 by a ratio of 2.6 to 1 (Grundy 2003, ONS 2000, United Nations 2001). In poorer countries and continents the proportion of people aged 65 and over is small but increasing slowly and is resulting in unprecedented and significant growth in the absolute number of elderly people (Grundy 2003, United Nations 2001).

However, this increased quantity of years has not been accompanied by increased quality of life. The simultaneous deterioration in activity levels and increase in unhealthy lifestyles has resulted in increasing chronic disease, disability and morbidity (Close et al 2005, Kinsella 1992, Taylor et al 2004). This brings a number of major health, social and economic challenges for individuals, families and governments worldwide. In 1998–1999 the UK National Health Service spent approximately 40% and Social Services almost 50% of their budgets on older people (Kennie 2003, Taylor et al 2004). This is set only to increase.

Theories of ageing

There are three main theories of ageing: biological, psychological and sociological (Spirduso et al 2005). An understanding of them enables us to be more accurate in communication about how much of the process of ageing is within our control.

Biological theories

There are three main biological theories of ageing (Spirduso et al 2005):

- *Genetic theories* propose that cell death is in part a genetically controlled, programmed event designed to prevent over-population. They include: the extreme proposal of a 'death gene'; gene dictation of cellular ageing within the cell nucleus; the gradual breakdown of DNA (deoxyribonucleic acid) sequences causing incomplete cell reproduction and leading to chromosomal pathologies (Kirkwood & Young 2001); the accumulative influence of numerous genes on the development of diseases; the biological 'cell clock' or 'computer' theory where 'wear and tear' is programmed into each body cell and is turned on in middle age as in 'puberty' in youth (Hayflick 1997).

- *Damage theories* propose that irreversible, accumulative molecular defects are caused by internally produced reactive chemicals in response to both normal intrinsic body functions and extrinsic invading chemical pollutants (e.g. ultraviolet radiation (Shephard 1997), free radical, viral and traumatic damage, and tobacco smoking) (Spirduso et al 1995). Another proposal is the cross-linkage of proteins, where circulating glucose molecules are thought to randomly attach themselves to proteins in connective tissue, interfere with transport of nutrients and chemical messages and decrease the elasticity of muscles, ligaments and tendons, lung, kidney, vascular and gastrointestinal systems (Morgenthal & Shephard 2005).
- *Gradual imbalance theories* propose that the highly integrated central nervous, endocrine and immune systems begin to age at different rates and cause imbalances and failures in the regulation and integration of cellular and organ function in all biological systems (Finch 1976).

Genetic effects are believed to account for between 30–40% of 'ageing'. Epidemiological studies have shown that poor early growth in utero is associated with poor muscular strength and frailty (Sayer et al 1998), cardiovascular, immune and mental health diseases and poor cognitive function (Shenkin et al 2004, Taylor et al 2004), therefore suggesting that premature ageing is pre-programmed (Rowe & Kahn 1998).

Psychological theories

The psychological theories of ageing explore the psychological development of individuals, the degree of control and the psychological trials associated with successful ageing. There are three prominent psychosocial theories (Spirduso et al 2005):

- *Maslow's 'hierarchy of needs' theory* – the attainment of wisdom through a sense of completeness, realizing one's potential, together with assisting others (e.g. volunteering), is widely believed to be a predictor of successful ageing (Rowe & Kahn 1998).
- *Erickson's eight stages of psychosocial development of personality* are believed to enable the forging of close relationships and a productive family and/or work life and the ability to look back with pride and satisfaction on one's life.
- *Baltes and Baltes' 'optimization selective compensation' theory* promotes training in specific behavioural strategies to improve functional competence such as the ability of older adults to adapt to physical, mental and social losses in later life.

The psychological factors identified as determinants of how successfully we age include intelligence, cognitive capacity, self-efficacy, self-esteem, personal control, coping style and resilience (Spirduso et al 2005). Bandura positions self-efficacy as crucial for successful ageing as it impacts on thought patterns, emotional reactions, lifestyle choices and behaviours (Bandura 1997). Improving functional competence by developing and agreeing personally tailored, realistic, attainable goals, communicating respect and supporting new skills are regarded as crucial competencies when aiming to build self-esteem and self-efficacy in older adults (Jones & Rose 2005).

Sociological theories

There are two main sociological theories of ageing (Spirduso et al 2005):

- *The activity theory* promotes staying engaged in mental and physical activities of daily living throughout the lifespan (Atchley 1972, Fisher 1995).

- *The continuity theory* – people who carry positive health habits, preferences, lifestyles and relationships from mid to later life age most successfully (WHO 1997) and, conversely, inadequate environments are associated with an increase in mortality and morbidity and a decrease in overall health and well-being (Seeman et al 2002). In addition, positive cumulative social experiences and emotional supports are also associated with lower biological risk for morbidity and mortality (Seeman et al 2002).

Quality of life

Quality of life is a psychological construct that is most commonly defined as an individual's conscious judgement of satisfaction with his or her life and is the term used to describe a constellation of characteristics related to physical and psychological health (Spirduso et al 2005, Yardley et al 2003).

Extending years is only of value if quality of life can be maintained. Without improvement in health and health behaviours, we are increasing the potential for suffering one or more of the major chronic diseases that eventually lead to a morbid condition in which the individual is so physically and mentally disabled that he or she becomes immobile and dependent on the care of others. The challenge must be not just to delay mortality but to compress morbidity at the end of the lifespan (Spirduso et al 2005).

Many older individuals have multiple chronic pathologies and polypharmacy regimens. More than 75% of men and women over the age of 70 have one or more chronic medical conditions but chronic disease is predicted to rise by 50% by 2040 in the 65+ age group (Gill 2002). Only 16% have no chronic conditions (Gill 2002). This predisposes older individuals to very poor quality of life and may contribute to the significantly higher rate of suicide amongst these cohorts (65+ age group = 13% of population but 20% of all suicide deaths) (Spirduso et al 2005). The period of time in which individuals live in a state of morbidity can be compressed by adopting a healthy lifestyle earlier in the lifespan to maintain health and function and delay the onset of debilitating disease for as long as possible (Grundy 2003, Katz et al 1983).

Successful ageing

Active life expectancy, or the number of years an individual may expect to maintain the ability to perform the basic activities of daily living (ADLs) without significant disease or disability (Fries & Crapo 1981), is accepted as a key marker of physical, emotional and functional well-being and, therefore, of quality of life as we age (Katz et al 1983). The predictors of successful ageing include physical and mental health, functional and social competence, productivity, personal control and life satisfaction, and depend on the interplay of genetics, personal and social environment, lifestyle behaviours, attitudes, adaptability, social supports and certain personality characteristics (Rowe & Kahn 1998). Interestingly, there is a correlation between sleep quality, survival and successful ageing (Tafaro et al 2007). It is well known that older people who exercise regularly have better sleep patterns (Spirduso et al 2005). Successful ageing is in effect the difference between active living and just being alive (Spirduso et al 1996).

Can the ageing process be slowed?

Factors that influence the human survival curve are medical progress, reductions in levels of environmental pollutants, rates of smoking, drinking, drug abuse, rate of violent crime and increases in the number of people willing to make positive lifestyle changes (Grundy 2003). Increased longevity is associated with regular physical activity, good quality of life, independence, cognitive function and happiness (Spirduso et al 2005). Improving nutrition, decreasing total amount of food consumed and maintaining adequate general activity and moderate amounts of physical exercise have been identified as key to decreasing secondary ageing and increasing life expectancy (Spirduso et al 2005, Young 2001).

IMPACT OF AGEING ON MAJOR PHYSIOLOGICAL SYSTEMS AND PERFORMANCE

Most people, even without the effects of disease or sedentary behaviour, will live long enough to cross a functionally important threshold of fitness that will make an everyday task difficult (Saltin 1980, Young 1986). The effects of sedentary behaviour and disease will accelerate when they cross this functional threshold. Cardiorespiratory, musculoskeletal, endocrine and nervous systems play an important role in the maintenance of functional activities. Bodyweight will also impact on the crossing of such a threshold. Ageing is associated with an increase in percentage of body fat (Jackson et al 1995). In the absence of other changes, the accumulation of 15 kg of body fat in a man with an initial body mass of 70 kg reduces oxygen transport by some 18%, close to a half of the observed age-related loss (Shephard 1994).

For most body systems, the impact of ageing on everyday functional activities becomes noticeable from about the age of 30–40 years (Spirduso et al 2005).

Cardiovascular and respiratory systems

The practical consequences of ageing on the cardiovascular system are a progressive change in the *morphology* and *function* of the cardiovascular system and an increase in the number of age-related cardiovascular disorders (ACSM 1998, Shephard 1994).

The main *morphological* cardiovascular changes with ageing happen in the structure of cardiac tissue and chambers, in the conduction system, and in the coronary and elastic arteries (Shephard 1994). There is a reduction in mitochondrial volume and oxidative enzyme activity of cardiac muscle cells (Lakatta 1993). The reduced ability of the heart to supply the working muscles with sufficient oxygen (because of reduced maximal cardiac output and maximal stroke volume, a decrease in sympathetic sensitivity or outflow and some loss of intrinsic contractility) is a normal feature of ageing (ACSM 1998, Lakatta 1993). The heart becomes slightly hypertrophic and hyporesponsive to sympathetic (but not parasympathetic) stimuli, so that the exercise-induced increases in heart rate and myocardial contractility are blunted in older hearts (ACSM 2000, Hollenberg et al 2006). The aorta and major elastic arteries become elongated and stiffer, with increased pulse wave velocity, evidence of endothelial dysfunction, and biochemical patterns resembling early atherosclerosis (Ferrari et al 2003). Reflexes arising from cardiopulmonary vagal afferents are also blunted in aged individuals (Ferrari et al 2003). Blood pressures are generally higher in older individuals, especially during exercise (Stratton et al 1994).

But cardiac *function*, in healthy older people, is generally adequate to meet the body's needs, at least for submaximal activities (Shephard 1994). However, at the same relative work intensity, heart rate and, to a lesser extent, stroke volume is reduced, effectively producing a decreased cardiac output (Fleg et al 1995). Cardiac output is the product of heart rate and stroke volume. All three are reduced in older people, although it is difficult to isolate whether this is due to inherent processes of ageing, a decrease in habitual physical activity or cumulative pathological change (Brach et al 2004, Jackson et al 1995, Sesso et al 2000).

In terms of lung function, the maximum size of the lungs (total lung capacity) does not change with age, but functional residual capacity and residual volume both increase so that inspiratory capacity and vital capacity both decline with increasing age (Pride 2005). There is also a loss of elasticity of the tissues from greater cross-linkage between collagen molecules, giving rise to stiffness in the joints and changes in elasticity of lung alveoli (e.g. reduced vital capacity). There is a decline in static recoil pressure and also a tendency for the airways to close at small lung volumes (Chaunchaiyakul et al 2004, Pride 2005). The decline with increasing age in forced expiratory volume in one second (FEV_1), FEV_1/VC and in maximum flows at different lung volumes is of wider practical importance (Hollenberg et al 2006, Pride 2005). These changes are, in part, simply due to the smaller vital capacity, but this is not the whole explanation because FEV_1/VC also declines with age. Although this change is often attributed to 'occult' disease of the small airways, (undetected by resistance measurements) all the changes in maximum expiratory flow with increasing age in healthy subjects can be explained by a direct effect of the loss of static recoil pressure of the lungs due to decreased connective tissue elasticity within the lungs. This is without any effects of intrinsic narrowing of airways (Chaunchaiyakul et al 2004, Pride 2005). Recently, it has been found that expiratory flow limitation during resting tidal breathing is common in old age and this may further reduce the available ventilatory reserve during exercise (Pride 2005).

Taking the most readily accessible index of overall cardiorespiratory function (the maximal oxygen intake), values decline from young adult values of 42–50 $mL \cdot kg^{-1} \cdot min^{-1}$ in males and 35–40 $mL \cdot kg^{-1} \cdot min^{-1}$ in women to 25–30 $mL \cdot kg^{-1} \cdot min^{-1}$ in both sexes at the age of 65 years (Shephard 1994). Additional losses are incurred during the 65 years, resulting in tasks that were previously untaxing taking a greater percentage of maximum reserve (Fig. 6.2A) (Paterson et al 1999, Saltin 1980, Young 1986). An elderly man would require greater physical effort than a younger woman to carry out an identical exercise using an absolute scale (Bell et al 1995, Fleg et al 1995, Paterson et al 1999, Stratton et al 1994) (Fig. 6.2A). This narrowing of safety margins, between normal function and the threshold values for functionally important activities, means that even a minor illness could render an elderly person unable to perform such tasks without assistance (Fig. 6.2A). The Allied Dunbar National Fitness Survey (ADNFS) suggested a threshold level of aerobic capacity to walk comfortably at a slow walking speed (3 mph $= 4.8\ km \cdot h^{-1} = 1.3\ m \cdot s^{-1}$) (Skelton et al 1999). The report suggested that 'comfortable' walking requires that the oxygen cost is less than 50% of maximal oxygen consumption. Nearly half of women and a significant proportion of men aged over 55 years do not have the aerobic capacity to walk comfortably at 3 mph (Fig. 6.2B). As people with overt disease were not included in the physical fitness tests, it paints a bleak picture of the nation's fitness (Skelton et al 1999). Indeed, much of the breathlessness associated with ill health in old age may well be due to lack of fitness.

Musculoskeletal system

Muscle

Sarcopenia, the loss of muscle mass associated with ageing, is one of the main causes of muscle weakness and reduced locomotor ability in old age (Bosco & Komi 1980, Young 1997). Although sarcopenia is mainly driven by neuropathic processes, other factors contribute to the decline, including nutritional, hormonal and immunological factors, as well as a reduction in physical activity (Young 1997, 2001). Apart from muscle loss, there is also specific weakness of the remaining muscle of around 20%, shown in comparisons of maximum force with muscle cross-sectional area in the adductor pollicis, particularly around the time of menopause (Phillips et al 1992). Much of the age-associated muscle atrophy and declining strength may be explained by motor unit remodelling, which appears to occur by selective denervation of muscle fibres with reinnervation by axonal sprouting from an adjacent innervated unit (Brooks & Faulkner 1994). Indirect estimates indicate a decrease in the total number of motor units and an increase in the size of the remaining motor units in elderly human muscles (Campbell et al 1973). The process of age-related denervation atrophy in old animals may be aggravated by an increased susceptibility of muscles to contraction-induced injury and by the impaired capacity for regeneration (Brooks & Faulkner 1994).

Sarcopenia alone, however, does not fully account for the observed muscle weakness, as the loss of force is greater than that accounted for by the decrease in muscle size. In addition, a reduction in the force per unit area, both at single fibre and at whole muscle level, is observed. Narici recently suggested that, at whole muscle level, this reduction in intrinsic force is the result of the combined effect of changes in (1) muscle architecture, (2) tendon mechanical properties, (3) neural drive (reduced agonist and increased antagonist muscle activity) and (4) single fibre-specific tension (Narici & Maganaris 2006). Whereas several studies support the role of the last two factors in the loss of intrinsic muscle force with ageing, alterations in muscle architecture and in tendon mechanical properties have also been shown to contribute to the above phenomenon. Indeed, sarcopenia of the human plantarflexors, represented by a 25% reduction in muscle volume, was found to be associated with a 10% reduction in fibre fascicle length and 13% reduction in pennation angle. These architectural alterations were accompanied by a 10% decrease in tendon stiffness, attributable to alterations in tendon material properties (Narici & Maganaris 2006). Most of these changes may be reversed by 14 weeks of resistive training but training has no effect on the estimated relative length–tension properties of the muscle, indicating that the effects of greater tendon stiffness and increased fascicle length cancel each other out. It seems that natural strategies may be in place to ensure that in old age the relative operating range of muscle remains unaltered by changes in physical activity (Narici & Maganaris 2006).

Muscle weakness (loss of strength and power) is one of the underlying mechanisms of poor function and correlates with several measures of functional status (Skelton et al 1994, Skelton 2001, Young 1997, 2001). The loss of quadriceps strength with age means that many older adults have strength close to the threshold level necessary to raise themselves out of a low chair without having to use their arms for help (Skelton et al 1994, 1999) (Table 6.2). Young, taking data from various sources and assuming a chair rise of less than 3 seconds, suggested that the healthy 80-year-old woman is at, or near to, the threshold value of quadriceps strength for rising from a low, armless chair (or lavatory) without having to use her arms (Young 1986) (Table 6.2). The ability to ascend and descend stairs, stand up from a chair, use a bath instead of a shower or use public transport can be significantly compromised (Brill et al 2000, Hyatt et al 1990, Skelton et al 1994). Low muscle mass is also associated with poor immune function and impaired temperature control (ACSM 1998).

After age 30 there is a progressive decline in the strength and power of skeletal muscle, which accelerates after the fifth decade and declines by 10–15% per decade after that (Skelton et al 1994). Critically, the reduction in strength with age is most notable in the weight-bearing lower limb muscles, and muscle power output (the ability to produce force quickly) declines more rapidly than strength (Skelton et al 1994). While cross-sectional data suggest that healthy women in their 70s retain

40–50% of the handgrip strength found in young adults (MacLennan et al 1980). They may retain as little as 26% of power, assessed by squat jumps (Bosco & Komi 1980). The decline in power is steeper than force because it is magnified by the loss of velocity due to the selective loss of both size and number of type II fibres with ageing (Bosco & Komi 1980, Lexell 1995). Especially vulnerable to immobilization and inactivity are the anti-gravity muscles of the lower extremities and the faster type II muscle fibres, especially in older people (Lemmer et al 2000).

Greater mitochondrial dysfunction is evident in muscles with higher type II muscle fibre content, which may be at the root of the preferential loss of type II fibres found in elderly people (Conley et al 2006).

Bone

At any one time approximately 10% of bone surface in the adult skeleton is undergoing active remodelling whereas the remaining 90% is quiescent. Bone mineral density (BMD) peaks at around the age of 25 years, at around the age of 30 the balance between bone formation and bone resorption is altered so that resorption begins to exceed deposition, and by the age of 50 progressive losses of calcium and deterioration in the organic matrix of bone occur (Morgenthal & Shephard 2005). Bone mass peaks between the ages of 20 and 40 years, with men achieving a greater peak bone mass (Rutherford 1999). After the age of 40, bone mass declines at a rate of 0.5–1% per year with an accelerated period of loss in women for 5–10 years after the menopause (Morgenthal & Shephard 2005). This accelerated bone loss occurs because of the decrease in the levels of the sex hormone oestrogen, which protects the female skeleton from excessive bone resorption (Eastell & Riggs 1988). In total, women lose about 25–30% of the cortical bone and 35–50% of the trabecular bone over a lifetime; men lose at about two-thirds this rate (Riggs et al 1981). This leaves thin cortical bone and thin or interrupted trabecular plates.

Bone density losses mirror losses in muscle strength, although strength declines well before bone density (Rutherford 1999). The muscular forces exerted on bone are probably one of the key factors in maintaining bone health (Rutherford 1999).

Changes in bone strength are both quantitative and qualitative in nature, and include (Kiebzak 1991, Spirduso et al 2005):

- alterations in the dynamics of bone cells, resulting in a change in the normal process of bone resorption and formation
- changes in bone architecture (e.g. rearrangement of trabecular struts) and cross-sectional geometry
- accumulation of microfractures
- localized disparity in the concentration of deposited minerals, with hypomineralization in some areas and hypermineralization in others
- changes in the crystalline properties of mineral deposits
- changes in the protein content of matrix material.

Fragility fractures, particularly those of the hip, vertebrae and distal forearm, constitute a major public health problem. The two ultimate determinants of fracture are bone strength and propensity to trauma. Bone strength depends not only upon bone mass but also upon a variety of qualitative aspects of bone structure (Cooper 1993). These include its architecture, the amount of fatigue damage it has sustained, and changes in its bulk material properties; indices that are collectively subsumed into the term ‘bone quality’ (Cooper 1993). Fragility fractures show differences in their patterns of incidence by age, sex, ethnic group, geographic area, and season. Many of these differences are currently unexplained and disorders of bone quality might contribute to them. There are two fracture sites at which evidence implicates bone quality more directly – the spine and proximal femur (Cooper 1993). Many vertebral compression fractures follow minimal trauma, and controlled studies suggest that vertebral microarchitecture contributes to fracture risk independently of vertebral bone mass. At the hip, observational studies have pointed to a role for disordered trabecular architecture, accumulation of microfractures (fatigue damage), and the accumulation of osteoids. The extent to which these phenomena act independently of bone mass, however, remains uncertain (Cooper 1993).

Serum parathyroid hormone (PTH) rises with age and production of the most active metabolites of vitamin D3 decreases (Visser et al 2003). It has been suggested that this rise may contribute to bone loss in postmenopausal women (Need et al 2004). This rise in PTH has been attributed to declining renal function, declining calcium absorption efficiency, and declining serum 25-hydroxyvitamin D levels (Need et al 2004). These hormonal changes undoubtedly affect the maintenance of normal bone homeostasis. Other important factors which can profoundly influence bone status in elderly are decreased physical activity and dietary inadequacies (particularly in calcium). Losses in bone density do not usually have a substantial effect until about the age of 70; however, when a person's BMD measurement is 2.5 standard deviations below that of a normal young adult, they will be diagnosed with osteoporosis (Rutherford 1999).

Flexibility

Loss of range of motion (ROM) or flexibility is inevitable as a result of ageing but the rate of decline appears to be joint specific (Bell & Hoshizaki 1981). Spinal extension declines on average by approximately 50% and hip extension and knee flexion range of movement (ROM) decline on average by 20% and 2%, respectively, between the second and seventh decades (Bell & Hoshizaki 1981, Einkauf et al 1987). Lower body ROM declines are more evident than upper body and this is consistent with declines in strength. Hamstring flexibility declines in both genders by approximately 14.5% (or one inch) per decade (Golding & Lindsay 1989) while losses of 15% (external rotation) and 11% (abduction) have been reported for the hip joints. Small but significant age-related changes have been reported in ankle dorsiflexion ROM. But ankle dorsiflexion strength has been shown to decrease by approximately 30% between middle age and 70 (Vandervoort et al 1992). Any reduction in ankle ROM and strength increases the likelihood of trips and falls during the swing phase of the gait.

Stiffness (the force required to move a joint through a specified ROM) increases with age in all joints and all muscle tissues and is probably the major cause of loss of ROM and the most common complaint of older adults. Even routinely used muscles (e.g. calf) show an increase in stiffness (McHugh et al 1999). A number of biological factors contribute to increased stiffness. These include an increase in the amount of inter- and intramuscular connective tissue, a change in chemical composition so that connective tissue is less extensible and more resistant to being reformed, a breakdown of articular cartilage that increases arthritis in major joint complexes, and a loss of muscle mass (Golding & Lindsay 1989). These changes make it more difficult to move freely with age.

Nervous system

Age is associated with a loss of neural function, slower complex reaction times and slower central processing (Schmidt & Lee 1999). In people without neurological disease, intellectual performance tends to be maintained until at least age 80. However, tasks may take longer to perform because of some slowing in central processing. Verbal skills are well maintained until age 70, after which some healthy elderly persons gradually develop a reduction in vocabulary and a tendency to make semantic errors (Schmidt & Lee 1999). These changes happen mostly because of a loss of neurons, which cannot be replaced, and also a loss of connective networks in the brain (Lexell 1997). There is preferential loss of distal large myelinated sensory fibres and receptors (Shaffer & Harrison 2007).

With normal ageing, the number of nerve cells in the brain decreases. Cell loss is minimal in some areas (e.g. brainstem nuclei) but is as great as 10–60% in others (e.g. hippocampus). Loss also varies within the cortex (e.g. loss is 55% in the superior temporal gyrus but 10–35% in the tip of the temporal lobe). From age 20 or 30 to age 90, brain weight declines about 10% (Schmidt & Lee 1999).

Problems can arise in the central processing of information despite normal sensory input and normal effector neuromuscular function (Spirduso et al 2005). With normal ageing, changes in neurotransmitter systems (enzymes, receptors and neurotransmitters) occur and cerebral blood flow decreases by about 20% on average, slowing processing times (Schmidt & Lee 1999). Free radicals may have a toxic effect on certain nerve cells (Schmidt & Lee 1999), affecting their function.

Evidence strongly suggests that after the age of 60, muscle undergoes continuous denervation and reinnervation, due to an accelerating reduction of functioning motor units (Lexell 1997), mediated through a loss of motor neurons in the spinal cord and hence of myelinated ventral root fibres. Initially, reinnervation can compensate for this denervation. However, as this process progresses, more and more muscle fibres will become permanently denervated and subsequently replaced by fat and fibrous tissue (Lexell 1997). Thus, an age-related degeneration of the nervous system is one of the main contributors to the gradual reduction in muscle volume and muscle strength that accompanies ageing (Lexell 1997).

There are also ageing changes to the sensory inputs into the nervous system. In a well-lit environment and with a firm base of support, healthy persons rely on somatosensory (70%), vestibular (20%) and visual (10%) information (Horak 2006).

Somatic sensation consists of the various sensory receptors that trigger touch or pressure, temperature (warm or cold), pain and the sensations of muscle movement and joint position including posture, movement and facial expression (collectively called proprioception). *Proprioceptive sensitivity* is reduced by age-related poor ankle flexibility and exacerbated by swelling in the feet or ankles due to disease or injury (Shaffer & Harrison 2007). Particularly common with increased age is impaired distal lower-extremity proprioception, vibration and discriminative touch (Shaffer & Harrison 2007). Diseases, such as arthritis, in weight-bearing joints may contribute to errors in foot placement, whilst distorted or painful feet and poorly fitting shoes may give misleading information on the nature of ground contact during walking. Cervical spine mechanoreceptors contribute to static postural sensation and to awareness of head and neck movements so degeneration of the cervical spine from ageing, disease or injury can disturb postural control (Sinaki 1982).

Vestibular abnormalities are an important cause of dizziness and postural instability in older people. An age-related decline in balance may also occur as a result of the accumulation of minute calciferous particles within the semicircular canals in the inner ear (Horak 2006). There appears to be an age-related loss of ciliated sensory cells and a thickening of the fluid in the semicircular canal of the inner ear and this will adversely affect vestibular sensitivity (Wright 1983). More than half of older people have deficits in their vestibulo-ocular reflex, causing potential dizziness when performing fast, voluntary head movements (Hirvonen et al 1997). Certain medications, prescribed commonly in the older population, may lead to vestibular dysfunction; these include aminoglycosides, aspirin, furosemide and quinine (Lysack et al 1998, Rybak 1985). Finally, major disturbances of the vestibular system are more common in older age (tinnitus, labyrinthitis, Ménière's disease) (Horak 2006).

Visual impairment with increasing age is associated with loss of strength in the eye muscles, a decreased elasticity in the lens, poor hydration of the eye and an observed increase in eye infections (Chaput & Proteau 1996). This can lead to an increased susceptibility to glare, and poor depth perception can lead to misinterpretation of the nature of ground surfaces or misjudgement of distance (Lord et al 2001, Schmidt & Lee 1999). During stair descent, poor eyesight is associated with increased foot clearance, allowing more space for perceptual error in the location of the edge of each step (Chaput & Proteau 1996, Lord et al 2001). There is also an increase in the incidence of structural eye disease in later life and many of the problems above are age related. Poor eyesight rates only a little lower than arthritis and heart disease as a cause of impaired physical function in those aged 70 years and above (Chaput & Proteau 1996).

Endocrine system

Decreasing levels of anabolic hormones and disruptions in hormone metabolism and control may be associated with musculoskeletal atrophy and decrease in function with ageing (Copeland et al 2004, Roubenoff & Hughes 2000, Visser et al 2003). In old age, the endocrine control systems work less efficiently and the output of many of the hormones is less well regulated. In addition some glands produce less of their hormone and sometimes the target tissues become less responsive. Overall, the endocrine system becomes more catabolic (Copeland et al 2004). Also, with increasing age, endocrine and metabolic diseases are more common and there is poorer local circulation. These changes will contribute to the muscle and bone loss and increasing frailty of the older person (Lamberts et al 1997).

The ageing process affects nearly every gland (Copeland et al 2004). The first to consider is the hypothalamus, which is responsible for releasing hormones that stimulate the pituitary gland. During ageing, there is either impaired secretion of some hypothalamic hormones or impaired pituitary response. These changes appear to influence the endocrine system's ability to respond to the body's internal environment. As a result, the body cannot respond as well to either internal or external stresses. Cortisol, produced in response to stress and inflammation, is produced more readily with increasing age and this has detrimental effects on muscle and bone and can also lead to depression (Copeland et al 2004). Increased secretion of cortisol is also significantly associated with impairment of cognitive function during ageing (Lupien et al 2005).

There is a progressive decline of growth hormone (GH) secretion with age, such that by the age of 60 most adults have total 24-hour secretion rates indistinguishable from those of hypopituitary patients (Savine & Sönksen 2000). Patterns of GH secretion in older people are similar to those in younger people but the pulses of GH are markedly reduced in amplitude. Sleep and exercise remain the major stimuli for GH secretion. Daytime sleepiness in older adults is associated with physical functional impairments and decreased exercise frequency (Chasens et al 2007). A short nap (30 minutes between 1300 and 1500 hours) and moderate exercise such as walking in the evening have been shown to increase sleep length and improve sleep quality (Tanaka & Shirakawa 2004). The fall in GH secretion seen with ageing coincides with changes in body composition and lipid metabolism that are similar to those seen in younger adults with clinical GH deficiency (Savine & Sönksen 2000). Physical activity might have an effect on hormone action as a result of changes in protein carriers and receptors (Copeland et al 2004). The effects of activity on the endocrine system are seen in ageing men, where regular moderate physical activity is associated with higher levels of insulin-like growth factor (IGF-1) and improved thyroid function (Ravaglia et al 2001).

Vitamin D deficiency is common both in geriatric patients (30–90%, depending on the deficiency definition) and in independent, community-dwelling older persons (2–60%) (Lips 2001). This is partly due to a lower sunshine exposure and a reduced capacity of the older skin to synthesize vitamin D3 under the influence of ultraviolet light (Lips 2001). Several cross-sectional studies have shown that low 1,25-hydroxyvitamin D (active form of vitamin D3) and low 25-hydroxyvitamin D (25-OHD) (blood calcium form of vitamin D3) are related to lower muscle strength, increased body sway, falls, and disability in older men and women (Lips 2001, Visser et al 2003). This is supported by vitamin D supplementation studies which have shown improvements in physical function and isometric knee extensor strength (Verhaar et al 2000).

Falls and fall-related injuries

Most cross-sectional studies show that with ageing gait patterns have a wider base, there is a slowing in sway, an increased time in double leg support phase of walking as well as a decrease in stride length, a decrease in trunk rotation and an increase in pain and discomfort that limits movement (Lord et al 2001, Skelton 2001). Sedentary older adults are also known to adopt a more cautious walking style with shorter step lengths and slower step velocities than active older adults. When required to increase walking speed, older people tend to increase their cadence rather than their stride length, whereas younger people do the reverse (Lord et al 2001, Rose 2003, Skelton 2001). Diseases such as peripheral neuropathy, arthritis and osteoporosis cause further gait adaptation. Other age-related effects also affect balance: the sensitivity of skin receptors is reduced (oedema, arthritis and medications), reflex speeds and reaction times slow, coordination gets worse (particularly hand/eye), and eyesight and vestibular function decline (often medication related) (Lord et al 2001, Skelton 2001).

Muscle weakness is associated with fall risk (Gillespie et al 2005). A recent meta-analysis observed a tripling of risk of recurrent falls in those with lower extremity weakness (Gillespie et al 2005). Slow reaction time and decreased functional ability owing to lack of practice and/or physical pain, inadequate strength of the muscle-tendon complex, decreased joint flexibility, and lower limb asymmetry in strength and power are considered the main muscle factors involved in postural instability, falls and fractures (Lord et al 1992, 1994, 2001, Skelton 2001, Skelton et al 2002).

Frequent fallers have a very poor prognosis, especially if they live alone and are likely to be waiting hours before they are found or can get attention (Tinetti et al 2003). One problem is often that people fall and, despite there being only a minor injury, they are not able to get up off the floor without help. If they cannot get up without help (long-lie), then they are more likely, on 21-month follow-up, either to have died, or at least to be hospitalized and to have suffered functional decline (Tinetti et al 1993). The role of exercise to maintain core body temperature whilst on the floor, to prevent hypothermia and other complications of a long-lie, should not be forgotten (Dinan & Skelton 2007, Skelton & Dinan 1999). Some of the difficulty of rising from the floor may be shock or injury but for many it is simply lack of familiarity, functional fitness and neuromuscular control and in these instances it can be retrained (Dinan & Skelton 2007, Skelton & Dinan 1999). People aged over 65 who have fallen account for the largest call-out for the London Ambulance, yet 40% of these people are not conveyed to hospital, merely picked up and made comfortable

(Close et al 2005, Skelton 2001). Fear of falling can also lead to avoidance of activities and further detraining and a spiral of inactivity that can lead to further falls and isolation (Yardley & Smith 2003).

Psychological function

The brain remains malleable throughout life and at any age can adapt in response to stimuli and activities. Grey matter can thicken, neural trunks can remyelinate, neural connections can be forged and refined and all these mechanisms can reinvigorate cognitive abilities (Mattson et al 2001, Verghese et al 2003). Cognitive function involves a combination of skills, including memory, attention, learning, goal setting, decision making and problem solving. In old age, poor health and disease impair cognitive performance (Chodzko-Zajko & Moore 1994). Impaired endocrine function, such as an increased production of cortisol, is associated with declining cognitive function, thereby illustrating the strong association between the nervous and endocrine systems (Lupien et al 2005). Natural age-related decline begins in the 30s and accelerates after 50. It is often characterized by memory lapses, slower thinking and growing difficulties in communicating with others (e.g. words sticking on the tip of the tongue, inability to recall telephone numbers). This functional decline is caused by negative brain plasticity (i.e. changes that slow or impede cognitive performance). Keeping the brain active has been shown to maintain cognitive fitness (Verghese et al 2003).

There are four components to the effects of ageing on cognitive functioning (Bao et al 2003):

- *Disuse* (lack of practice).
- *Noisy processing* where the older brain becomes 'noisier' (in the information theorists' sense that more meaningless pseudo-information is signalled) due to the deterioration of sensory inputs. The term has no specific connection with hearing. Nevertheless a specific example, which does concern hearing, is that as the inner ear deteriorates it sends the brain increasingly unclear signals about outside sounds. The brain adjusts its sampling rates and time constants and slows down to decipher these unclear signals. The result is poorer memory and less agile thinking.
- *Weakened neuromodulatory function* (reduced production of the brain chemicals that play vital roles in learning and memory).
- *Negative learning* (feeling less mentally sharp often leads to compensatory strategies that accelerate functional decline, e.g. paying less rather than closer attention).

Quality of life decreases with increasing age (Spirduso et al 2005), depression and anxieties increase (Chodzko-Zajko & Moore 1994) and social isolation occurs more frequently, due to death of spouse and friends and reduced physical activity (Spirduso et al 2005).

IMPACT OF CHRONIC DISEASE AND SEDENTARY LIFESTYLE ON PROGRESSIVE AGE-RELATED DECLINE

50% of the decline frequently attributed to physiologic aging is, in reality, disuse atrophy resulting from inactivity.
(Jette et al 1999)

Physical inactivity is a major under-recognized risk factor for chronic health problems, loss of functional reserve, and disability. It remains difficult to distinguish unavoidable effects of ageing from the consequences of chronic disease or sedentary behaviour (Shephard 1997). However, the impact of sedentary behaviour on an ever-broadening variety of health problems is clear, particularly in old age (ACSM 1998, CDC 1996, 2002, Department of Health 2001, NIA 1998, Nicholl et al 1994, WHO 1997).

The contribution of sedentary behaviour to prevalence and cost of chronic illnesses exacts a significant burden in terms of morbidity and mortality and is a contributing factor for extended hospital stay and/or need for subsequent post-hospital care in skilled nursing facilities (Department of Health 2001, Hoenig et al 1997, Inouye et al 1993, Kane et al 1996, Sager et al 1996).

If the predicted morbidity statistics prevail, there will be a 600% increase in healthcare costs by 2040 (Guralnik et al 1993). One-third of the total healthcare expenditure is for older (65+) adults but the annual direct medical costs of physically inactive older adults (with no physical limitations) are significantly higher than those of their physically active peers (CDC 2002).

Conversely, regular physical activity is associated with significant reductions in average monthly Medicare expenditures ($196 over a 12-month period for walking or swimming; $241 for participating in active sports; and $162 for regular gardening over a 4-month period) (Stearns et al 2001). It has been estimated that if the whole population adopted the national guidelines for physical activity, healthcare costs for hip fractures alone could be reduced by about 50% (Nicholl et al 1994).

The effects of age vary from one individual to another and can be exacerbated by inactivity or ameliorated by regular physical activity. Unfortunately inactivity after middle age is prevalent. Forty per cent of people aged 50 or over in the UK perform less than half an hour of moderate activity in one session in a week (Skelton et al 1999). Over half of those people who are sedentary believe they are doing enough exercise to maintain adequate function. These people are likely to have 'inactivity determined' disability.

It is known that a few weeks of immobilization or disuse has a detrimental effect on muscle mass, muscle strength and power (Bloomfield 1997). The decrease in muscle strength is greatest, 3–4% per day, during the first week of immobilization and up to a 40% decrease in isokinetic muscle strength has been seen after 3 weeks of immobilization (Bloomfield 1997). Bed rest causes an increase in calcium excretion and bone mineral loss in the weight-bearing bones such as the calcaneus, iliac crest and lumbar spine (Whedon 1984). Prolonged periods of bed rest lead to the loss of 0.9% of bone mineral per week (Frost 1990, Krolner & Toft 1983). High rates of inactivity in older people, especially those in residential or nursing accommodation, will lead to an increased loss of bone with increasing age. Nursing home residents spend up to 90% of their time either sitting or lying down (Tinetti 1994). This will mean that extremely sedentary people will see an 'active' loss of bone and muscle over and above the 'ageing' loss.

The good news is that regular, appropriate exercise training has been shown to improve the functional abilities and psychological well-being of both healthy older people and patients with disabling symptoms common in old age. In older athletes, rate of decrease in maximal oxygen intake appears to be some 80% of that seen in sedentary individuals, peak heart rate 10 beats/min slower than in sedentary individuals, and muscle strength is similar to sedentary young adults (Pearson et al 2002, Shephard et al 1995). Therefore, it has been suggested that with a higher level of physical activity the rate of decline of $\dot{V}O_2$max could be reduced by half (Hagberg et al 1989).

THE EVIDENCE FOR EFFECTS OF EXERCISE TRAINING AND PHYSICAL ACTIVITY IN OLDER PEOPLE

Exercise of some kind or other is almost essential to the preservation of health in persons of all ages – but in none more so than in the old.

(MacLachlan 1863)

Physical health includes three components: *physical condition* (objective diagnosed health problems), *perceived physical condition* (subjective health status) and *physical function* (limitations in the ability to carry out basic activities of daily living (ADLs) such as self-care, dressing, washing, and instrumental activities of daily living (IADLs) such as shopping, gardening, cooking, going outside and taking part in hobbies, recreation, social activities) (Spirduso et al 2005). Even in frailer, older participants there is evidence that habitual physical activity can preserve *functional independence* by counteracting some of the age-related decline in performance, counteracting the effects of disease and increasing the sense of control over personal health and well-being (Spirduso et al 2005, WHO 1997, Young 1986, 2001).

Regular physical activity, more than any other intervention, has been shown to extend life, reduce disability, and improve quality of life in older adults (ACSM 1998, Buchner 1997, CDC 1996, Guralnik et al 1993, LaCroix et al 1993, Wagner 1997). Not only does it reduce risk for cardiovascular disease, osteoarthritis, osteoporosis, obesity, diabetes and insomnia but regular physical activity also significantly reduces risk for falls, depression and incontinence (ACSM 1998, CDC 1996, Coleman et al 1996, Gardner et al 2000, Nicholl et al 1994, Singh et al 1997). Because of the high prevalence of chronic conditions, frailer older people have the potential to gain most from regular physical activity (ACSM 1998, Buchner 1997, Buchner et al 1997, CDC 1996, Fiatarone et al 1990). Older adults with chronic illness can potentially reverse loss of mobility (ACSM 1998, CDC 1996, Young & Dinan 2005). Here exercise training takes on less of a disease prevention and more of a symptom alleviation role (Table 6.1) (Spirduso et al 1996, 2005).

Effects on the cardiovascular and respiratory systems

It is clear that the capacity of the cardiovascular and respiratory system to adapt to an endurance training load is not affected by age. Even women in their 80s and 90s can improve their $\dot{V}O_2max$ as much as 17% after 24–32 weeks of aerobic training (Malbut et al 2002, Puggaard et al 2000). Aerobic endurance training also improves older adults' ability to sustain exercise at a fixed, submaximal level of energy expenditure. Similar increases in $\dot{V}O_2max$ have been reported for young and old adults, with the magnitude of improvement (20–30%) being based on the intensity of the training stimulus and previous exercise history (Cress et al 1991, Malbut et al 2002). Interval endurance training has been suggested as more effective than continuous endurance training in older adults and in other special populations (Ahmaidi et al 1998, Bell 2001, Brooks 1997, Dinan 2001, Dinan et al 2004, Vogiatzis et al 2002). Interestingly, in older people, 12 weeks of strength training or combined strength and aerobic training are as effective as 12 weeks of aerobic training alone to improve relative $\dot{V}O_2max$ (Aniansson & Gustafsson 1981) and 24 weeks of low- or high-intensity resistance training lead to similar improvements in aerobic capacity (DeVito et al 1997, Vincent et al 2002). Comparing modalities, walking is more effective than calisthenics at improving $\dot{V}O_2max$ in women over the age of 70 years (Warren et al 1993).

Both resting heart rate and heart rate during submaximal activities can be reduced with aerobic training (DeVito et al 1997, Morey et al 1989, Spina 1999). Maximal voluntary ventilation and submaximal exercise ventilatory response are also improved with a low- and moderate-intensity aerobic programme (50–75% of heart rate reserve) after 12 weeks (DeVito et al 1997, Yerg et al 1985) in older men and women. In strength training, eccentric resistance exercises place less cardiopulmonary demands, and may be more suited for older people with low exercise tolerance, than concentric exercises (Vallejo et al 2006). A comparison between qigong and Tai Chi Chuan (TCC) practitioners in cardiorespiratory responses showed tai chi chuan, with its higher exercise intensity, to be more effective in terms of $\dot{V}O_2max$, but that qigong enhanced breathing efficiency due to the training effect on diaphragmatic breathing (Lan et al 2004).

The age-related decrease in cardiac mass and changes in composition of the myocardium are slowed but, probably, not abolished by regular physical activity (Saltin 1986). Regular physical activity can lead to an appreciable decrease in systemic blood pressure, particularly in individuals with hypertension, thus decreasing afterloading of the left ventricle (Shephard 1994). The degree of trainability appears to be unrelated to gender, although the mechanisms by which the change is produced are somewhat different. In older males any improvement in $\dot{V}O_2max$ is a function of both central (enhanced β-adrenergic stimulation, enlarged ventricular chamber size) and peripheral changes (Ehsani et al 1991, Levy et al 1993, Ogawa et al 1992, Spina et al 1998), whereas in women improvements in $\dot{V}O_2max$ occur exclusively due to changes in oxygen extraction at the tissue without any changes in cardiac function (Spina et al 1993). Exercise has been shown to improve endothelial-dependent relaxation of vascular smooth muscle in older people (Haykowsky 2005). This important exercise-induced effect on the endothelium has many potential clinical implications for older populations. Improved endothelial function can protect the blood vessel wall from the development of atherosclerosis and thrombosis, whereas dysfunctional endothelium can actively promote vascular damage and consequent plaque formation (Ross 1993, Taddei et al 1996). Therefore, by protecting the endothelium, physical activity may be responsible for the beneficial effect of exercise and the decreased risk of cardiovascular disease demonstrated in older people who walk further than 1.5 miles (2.4 km) per day and at a brisk pace (Manson et al 2002).

In general, the majority of studies suggest that following endurance training, there is a reduction in the concentration of total cholesterol, an increase in the concentration of high-density lipoprotein (HDL) cholesterol and a favourable modification of the total cholesterol:HDL ratio. However, there is greater ambiguity concerning the influence of training on the concentration of low-density lipoprotein (LDL) cholesterol (Hagberg et al 1989, Hurley 1989).

Effects on the musculoskeletal system

Muscle

An octogenarian's remaining muscle still shows a normal response to physical training. The improvements are equivalent to 10–20 years' 'rejuvenation' (Skelton et al 1995). Strength training has also provoked valuable enlargement of muscle fibres even though the age-related reduction in number of muscle fibres appears to continue (Aniansson & Gustafsson 1981). Skeletal muscle hypertrophy, or reversal of sarcopenia, requires at least 8–12 weeks of training in older adults (Aniansson & Gustafsson 1981, Brill et al 2000, Fiatarone et al 1990). For older individuals, the absolute resistance required to overload the musculoskeletal system is typically surprisingly low. So although strength training is traditionally performed in a gym environment with resistance exercise machines or free weights, home-based resistance programmes have been increasing in popularity. Home-based resistance training that uses bodyweight exercises, or a weighted belt, to increase bodyweight resistance, limb weights, elastic resistance bands, and dumbbells have been reported to increase strength and bone mineral density (BMD) (Judge et al 2005). After a year-long home-based strength and balance programme using bodyweight and ankle weights, the risk of falls is reduced in older people (Robertson et al 2001). However, whilst home-based training may have advantages in terms of convenience, potential disadvantages include suboptimal loading and a lack of supervision that may reduce motivation and adherence. Supervision has been found to increase the rate of improvement in muscular strength in response to training (Mazzetti et al 2000).

Because functional ability is highly related to strength, it might be reasonable to assume that an increase in muscle strength would lead to an improvement in function (Hyatt et al 1990). However, improvements in strength do not always translate into improvements in daily functioning (Skelton et al 1995). Combining strength training with more functional training has resulted in more functional gains both in non-frail elderly (Skelton et al 1996) and in frail elderly (Fiatarone et al 1990, Jette et al 1999) and this combination should, therefore, be integrated into the programme.

Resistance training is highly effective at countering the decline in muscle strength and power, with significant increases in strength and power after only a few weeks of training, even in very elderly participants (Fiatarone et al 1990, Skelton et al 1995). Increases in strength and power are attributed to improvements in the nervous system (muscle activation, overall coordination) and morphological changes within the trained muscles (primarily muscle fibre hypertrophy). Resistance training can improve everyday function and mobility including factors such as walking speed and time to stand up from a chair (Skelton & McLaughlin 1996).

Some studies of low-intensity strength training have shown that it increases muscle strength in nursing home residents, frail elderly and elderly people with comorbidity (Fiatarone et al 1990, McMurdo & Rennie 1994) but has very little effect in healthy elderly people (Jette et al 1996). Traditional resistance training with a relatively slow movement velocity and use of resistance exercise weight stack machines has been criticized for having a lack of specificity for the mobility requirements of older people. Older individuals may benefit more from improvements in power than strength (Skelton et al 1995). Performing mobility-specific exercises appears to produce greater improvements in functional outcomes than traditional resistance exercise (Skelton & McLaughlin 1996). The duration of training is important. In the first 8–12 weeks of resistance training in nonagenarians, just as at earlier ages, there are huge improvements in strength but little change in muscle mass (Fiatarone et al 1990). In the first 8–12 weeks, all improvements in strength are neurally mediated, so for changes to muscle bulk, longer training periods must be considered (Itoi & Sinaki 1994). Finally, the importance of duration of training is highlighted by evidence suggesting that the preservation of muscle mass and/or reversal of sarcopenia through exercise could be a useful anabolic method to provide a protein reservoir for later use when the older person is exposed to infection, inflammation and/or severe trauma (Spirduso et al 2005) and as padding if they fall (Rutherford 1999).

Bone

Much of the initial work aimed at improving bone mineral density (BMD) concentrated on the types of endurance activity that had been shown to be beneficial for cardiovascular health (Rutherford 1999). There is increasing acknowledgement that the same type of exercise may not be optimal for bone health or for reduction of falls risk. Bone loading is necessary, but bodyweight by itself is not sufficient to create the loading levels necessary for an osteogenic response (Kohrt et al 2004, Rutherford 1999). Bone health requires the following basic principles of training (Kohrt et al 2004):

- Principle of specificity: only sites loaded by the exercise will respond as the effects are localized.
- Principle of overload: the training stimulus must exceed the normal loading experienced by the skeleton in everyday activities and, as the bone responds, the stimulus must be increased progressively.
- Principle of reversibility: any positive effects of training on BMD will only be maintained as long as the exercise is continued.
- Principle of initial values: the most benefit is likely to be achieved in those with the lowest initial BMD.

The forms of exercise shown to be beneficial for slowing or reversing the age-related loss of bone include brief bouts of weight-bearing exercise such as intermittent jogging (Kohrt et al 2004), exercise classes (Welsh & Rutherford 1996) and also weight training using weights in excess of 80% of personal maximum (1-RM) (Kerr et al 1996). However, walking alone does not increase bone density, it merely helps maintain it (Cavanaugh & Cann 1988). Regular exercise could delay the point at which osteopenia progresses to clinically significant osteoporosis (Nelson et al 1994, Welsh & Rutherford 1996). Indeed, home-based resistance training improves BMD in women on treatment (Judge et al 2005).

The ACSM suggests that weight-bearing exercises (e.g. weight training, stair climbing, walking, running, jogging, dancing, aerobics, racquet sports, court sports and field sports), three times per week, for 20–30 minutes are required to help maintain a healthy bone mass (Kohrt et al 2004). In all activities, it is important to consider the basic principles of training for bone health (Kohrt et al 2004).

In postmenopausal women, simple daily squeezing of a tennis ball for 30 seconds has significant benefits in the non-injured forearm of women who had already sustained a Colles' fracture (Beverly et al 1989). In addition, a set of dynamic bone loading exercises for the distal forearm results in increased bone strength at the wrist (Ayalon et al 1987). Total body calcium is improved in postmenopausal women training at a repetitive low force, as well as in those who train at a similar level with the addition of light weights attached to their wrists and ankles during the exercise classes (Chow et al 1987). In postmenopausal women, Tai Chi Chun exercise has been linked with a three- to fourfold slowing down in the rate of bone loss in both trabecular and cortical compartments of the distal tibia compared with a sedentary lifestyle (Chan et al 2004). Interventions to reduce the effects of immobilization or bed rest have found that quiet standing for a daily total of 3 hours (as opposed to an exercise intervention) prevents the changes in mineral metabolism (Issekutz et al 1966). Whether shorter total periods of standing would be equally effective is unknown.

Whole body vibration (WBV) has recently been considered as a possible modality for skeletal loading. In older adults, WBV at 35–40 Hz three times weekly for 24 weeks (Verschueren et al 2004) has been linked with increased bone strength. However, at 20 Hz for 4 minutes once a week for 12 months, microvibrations appeared to have no additional positive bone strength effect (compared with a course of 5 mg daily of alendronate), in postmenopausal women (Iwamoto et al 2005). More work is needed on this type of bone loading, not least on the potential side effects that may occur from the vibration to the head and neck region.

For postmenopausal women with substantial thoracic kyphosis, progressive back strengthening exercises for 2 years have been found to decrease kyphosis and improve posture (Itoi & Sinaki 1994). In a follow-up study, women who had participated in back strengthening exercises for 2 years, but none thereafter, were found 8 years later to have greater back extension strength and bone mineral density of the lumbar spine, and less than half the incidence of vertebral fractures, compared to a control group of comparable women who had not performed back strengthening exercises (Sinaki et al 2002). This suggests that a prolonged period of resistance training can provide musculoskeletal health benefits for a considerable period even after cessation of the exercise. Even frail older patients with osteoporosis gain benefit from exercise. However, when working with these patients, exercise must be low risk and low impact for safety. For example, those with a previous history of vertebral fractures should avoid unsupported spinal flexion, such as abdominal curls (Sinaki 1982). These patients are likely to have weak back extensor muscle strength and must focus on back extensor strengthening and start with the lowest workload and progress slowly (Sinaki 1982).

Flexibility

There is plenty of evidence that older adults can increase their range of motion and flexibility. It does not seem to matter what type of exercise is used as long as it works the joint through its full range of movement. Improvements have been found with traditional range of movement and static stretches, aerobic sessions, resistance training, yoga, dance, tai chi and aquatic exercise (Jones & Rose 2005).

Effects on the nervous system

Despite the paucity of human research, basic animal models and clinical data overwhelmingly support the notion that exercise treatment is a major protective factor against neurodegeneration (Kiraly & Kiraly 2005). Unfortunately this is an under-researched area and there are no clinical guidelines on exercise modes or intensities for retaining neuron integrity in older adults. However, significant increases in brain volume, in both grey and white matter regions, were found for aerobic fitness training group but not for the older adults who participated in the stretching and toning (non-aerobic) control group (Colcombe et al 2006). Improvements in muscle steadiness, decreases in muscle relaxation time and reaction times and generally improved neural control of movement have been found with a variety of exercise modalities including tai chi, functional strength training, aerobic classes and balance training (Skelton 2001, Spirduso et al 2005). Exercise may help protect older people from depression, not only by increasing blood flow to the brain but by directly enhancing neurotransmitters and neuronal growth factors (Cotman & Berchtold 2002).

To help prevent, slow or even reverse the effects of cognitive decline, activities must specifically target the cause (Verghese et al 2003).

- To combat disuse, activities must repeatedly and progressively engage the brain in new and demanding tasks.
- To improve input, activities must require careful attention and focus.

- To improve regulation and production of neuromodulators, activities must include rewarding, surprising and focusing.
- To re-pattern maladaptive compensatory behaviours, activities must require confrontation rather than avoidance of challenges.

Learning to play an instrument or sing, learning a foreign language, juggling, dancing, jigsaw puzzles and table tennis and aerobic exercise have all been effective (Colcombe et al 2006, Kramer et al 2002, Verghese et al 2003).

Effects on the endocrine system

Every bout of resistance exercise helps endocrine function. Men and women over the age of 65 have increased circulating levels of IGF-1 and decreased cortisol levels after only two sets of leg extensions, thereby increasing serum anabolic/catabolic hormone ratios (Kostka et al 2003). Aerobic exercise initiates a release of circulating growth hormone that varies by intensity of exercise but is measurable even in older adults at low intensities (Weltman et al 2006). Moderate exercise can help to reverse the adverse effects of ageing on the immune system by increasing the production of anabolic endocrine hormones and reducing the effects of catabolic hormones (Venjatraman & Fernandes 1997). Aerobic exercise can enhance immune function of healthy older people, potentially increasing resistance to viral infections and preventing the formation of malignant cells. It can also reduce the age-related decline in certain aspects of circulating T-cell function and related cytokine production (Venjatraman & Fernandes 1997).

Effects on falls and fall-related injuries

Recent reviews and guidelines suggest multidisciplinary falls assessment and intervention, including exercise, should be considered alongside osteoporosis diagnosis and management to reduce the number of falls and fall-related injuries (Gardner et al 2000, Gillespie et al 2005).

Falls in the home-dwelling elderly take place during periods of maximal activity (Luukinen et al 1995), so there may be a U-shaped relationship between the amount of physical activity and the number of falls, with a higher incidence of falls in the least active and the most active as suggested in one study (Gregg et al 2000). Care must be taken over which activities are suggested to those with poor balance and mobility (Dinan 2001, Skelton 2001, Skelton & Dinan 1999). Indeed, one walking intervention in patients with a previous Colles' fracture actually increased the risk of fractures compared to not walking (Ebrahim et al 1997).

Some exercise-only interventions have shown little or no effect on falls risk despite improvements in known risk factors (e.g. strength). It appears that individualized exercise interventions with balance training at the core of the programme are most effective for those at risk of falls (Robertson et al 2001, Skelton et al 2005, Wolf et al 1996).

In New Zealand, a targeted home exercise programme, for women aged over 80 years, a population at high risk of falls, was taught to participants in their own homes by a physiotherapist (and then repeated with specially trained nurses) and compared to social visits only as a control (Robertson et al 2001). Exercises were individually prescribed from a set number of warm-up, muscle strength and balance training exercises to perform three times a week for a year. The subjects were also encouraged to walk outdoors at their desired pace, building up to 30 minutes two to three times a week. The physiotherapist visited each intervention participant four times over the first 2 months, following on with regular telephone contact. The exercise group had a significantly lower rate of falls and the intervention was cost-effective in the group concerned (Robertson et al 2001).

In those aged over 65 years, with poor strength and balance, modified Tai Chi appears effective as a group exercise programme to reduce the risk of the first fall (Wolf et al 1996). A modified programme of Tai Chi (which took account of poor balance in the subjects) over a 48-week period, however, was not beneficial in reducing falls in an older (aged 70 years and over) group with signs of frailty (Wolf et al 2003).

In the UK, independent-living frequent fallers halved their risk of falls (incidence rate ratio (IRR) 0.46, 95% CI 0.34 to 0.63) with 9 months of weekly group balance and strength exercises, led by a postural stability exercise instructor, combined with twice weekly home exercises (Skelton et al 2005) (Fig. 6.3). The women undertaking this falls management exercise (FaME) had significantly lower mortality and morbidity at 3-year follow-up than the randomized control group (Skelton et al 2005). The exercise intervention consisted of progressive resistance, gait, balance, functional activity, floor work, endurance and flexibility training. The exercise was individually tailored in both type and intensity, with most exercises in weight-bearing positions, reducing upper limb support. There were also significant improvements in strength, power and bone mineral density at the lumbar spine and one area of the hip (Fig. 6.3).

On a population/public health basis, encouraging physical activity and the provision of exercise sessions as part of a wider campaign including literature, medication reviews and environmental changes has been shown to decrease fall-related injuries (McClure et al 2005). One large population approach trial, over 10 years, has seen a reduction in fracture rate by advocating increased physical activity and other lifestyle changes (Grahn Kronhed et al 2005).

Effects on psychological function

Physically active and fit older adults have been found to process cognitive information more efficiently than less fit individuals of the same age (Kramer et al 2002). The results were independent of sex, self-rated health and level of social activity. Both aerobic exercise and combined aerobic and strength exercise are associated with improvements in cognitive function, with the combined aerobic and strength exercises being most effective (Kramer et al 2002).

There is a strong association between self-esteem, self-efficacy and long-term exercise; it is strongest in cross-sectional studies; it is less clear whether short-term exercise training causes changes in global aspects of self-esteem. A number of comprehensive reviews (Biddle & Faulkner 2001, Boutcher 2000, McAuley & Rudolph 1995) have covered the literature on research studies on exercise and psychological well-being in people over the age of 45. Moderate-intensity has been shown to be more effective than high- or low-intensity training (King et al 1993) and training programmes of more than 10 weeks have greater effect than shorter programmes (McAuley & Katula 1998, McAuley & Rudolph 1995). There is a very clear positive effect for physical activity on psychological well-being (Table 6.3) in older adults, with 86.7% of studies reporting positive results, only 13.3% showing no effects and, of particular note, no studies showing negative effects.

The studies have diverse measurements of psychological well-being (46.7% assess stress, 50% assess positive well-being, 23.3% mood, 36.7% life satisfaction and 23.3% other variables) as well as diverse age ranges (86.6% of studies investigating the

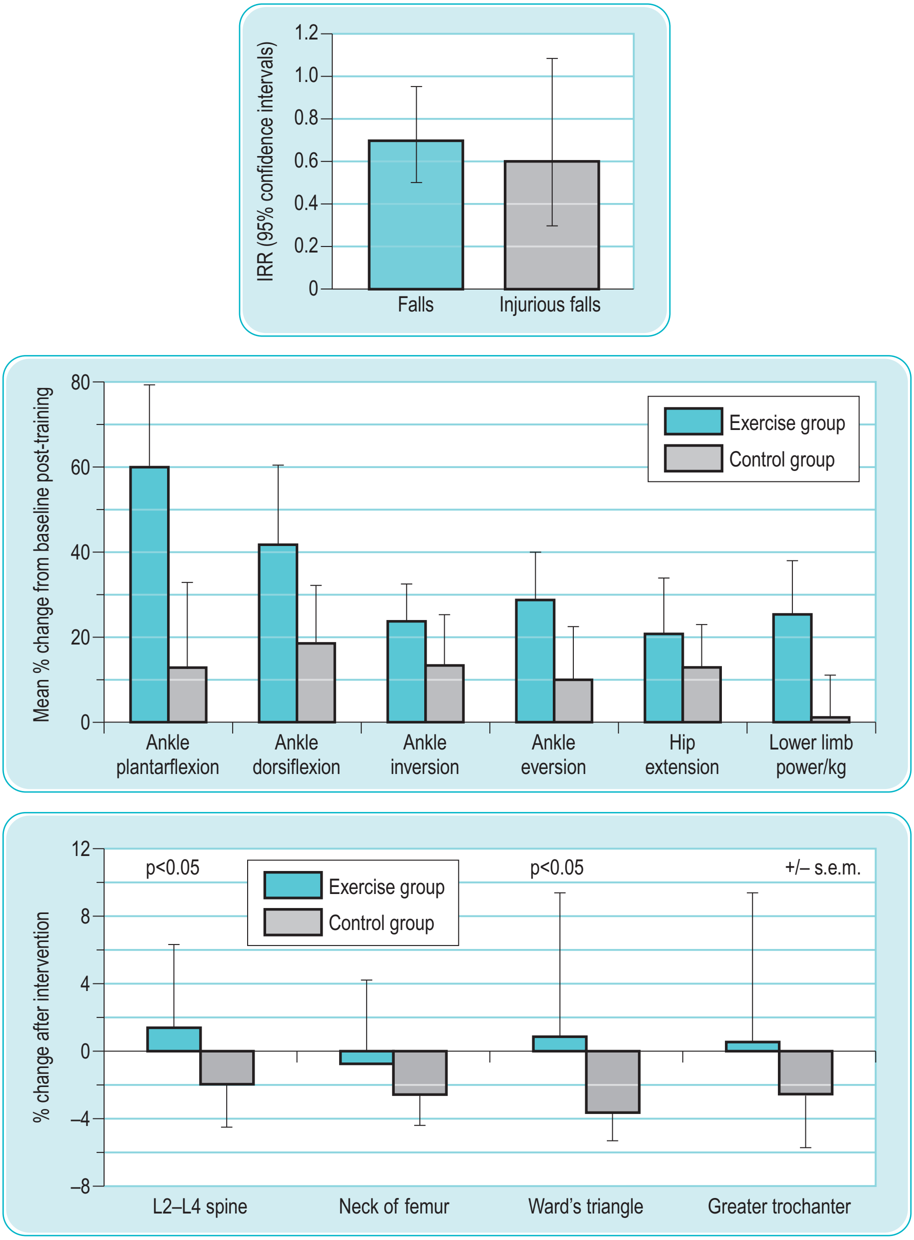

Figure 6.3 Effect of 9 months of FaME group exercise on falls, strength and bone. Adapted from Skelton et al (2005) and unpublished data.

'young old' (60–75 years), 63.3% the 'middle old' (76–85 years) and 36.7% the 'old old' (>85 years)) (Biddle & Faulkner 2001).

A recent trial considered different intensities of resistance training versus normal GP care in clinically depressed older adults and found high-intensity progressive

Table 6.3 Psychological and cognitive benefits of physical activity for older people

Immediate benefits
Relaxation
Stress and anxiety reduction
Enhanced mood state
Regular physical activity
Long-term benefits
General well-being
Regularly active individuals have stronger self-esteem and self-efficacy
Greater sense of control
Improved mental health: regular activity can help in treatment of depression and anxiety
Cognitive improvements: can help to postpone age-related declines in cognitive performance
Motor control
Prevent or postpone age-associated decline in both fine and gross motor control
Skill acquisition
New skills can be learned and existing skills refined through physical activity

Adapted from AARP (2001), Chodzko-Zajko & Moore (1994), WHO (1997).

resistance training (PRT) more effective than GP care or low-intensity PRT (Singh et al 2005).

Self-efficacy is defined as situation-specific self-confidence and is typically studied as a determinant of exercise. However, more recently it has been suggested that self-efficacy can be changed as a result of physical activity and therefore can also be seen as an outcome variable (Biddle & Faulker 2001). For example, increasing physical activity confidence in older adults could have a significant impact on physical and psychological functioning and quality of life. Biddle & Faulkner (2001) concluded that positive effects on self-efficacy are evident across all age groups. Their final conclusions were that: physical activity has a significant and large antidepressant effect in depressed older adults (e.g. O'Connor et al 1993); there is evidence linking physical activity with improved cognitive functioning, particularly in older adults who achieve an increase in aerobic fitness (Hill et al 1993, Lavie & Milani 1995). Social factors may influence participation in physical activity as well as mental health and quality of life, but there is no evidence that the positive psychological effects of physical activity are due to social factors alone (Brown et al 1995, Hassmen et al 2000).

Physical activity also helps older people to adjust to their changing roles by providing opportunities to widen their social contacts, stimulate new friendships and acquire positive new roles in a contracting social network (Chodzko-Zajko & Moore 1994, McAuley et al 2000). This can help older people gain a sense of control, especially at a time when major health challenges may otherwise foster a sense of helplessness (Young 2001).

EVIDENCE-BASED GUIDANCE ON THE ROLE AND TYPES OF ASSESSMENT

The prevalence of chronic and degenerative disease and, in particular, the higher rates of underlying coronary artery disease mean that the rationale for exercise testing of the elderly may be even greater than that for the general adult population

(ACSM 2000). Indeed, exercise prescription and dynamic assessment of exercise ability and function for older adults may require subtle differences in protocol, methodology and dosage as compared with younger and middle-aged people (ACSM 2000).

A systematic and multifaceted approach to pre-exercise and health screening and assessment is essential to optimize the older adult's safety during performance testing and exercise and to develop effective exercise prescriptions across the functional continuum (ACSM 2000, Jones & Rikli 2005). The frailer the individual, the more relevant the need for assessment and the greater the importance of safe, functionally relevant and validated assessment tools (Jones & Rikli 2005). An example of this is the use of body mass index (BMI). If there is high muscle mass (veteran athletes) BMI can give the impression that the person is obese. Or if there is very little muscle and more fat mass, characteristic of sedentary, frailer, older adults, BMI can give the false impression that the person is in the correct range (Rogers 2005). However, even correctly calculated BMI can give totally misleading indications of obesity.

Screening and assessment principles

Pre-activity screening has different meanings for different older adults, resulting in potentially different motivational implications for adopting more active lives (Resnick et al 2005). For many, screening increased their sense of confidence and served as a positive motivator whilst for others screening was irrelevant and actually hindered their motivation to join an activity group (Resnick et al 2005). To avoid creating a barrier or over-medicalizing the process, it is important to emphasize that the aim of the assessment is not to exclude those at risk, but rather to ensure inclusion of each individual in an appropriate exercise programme, setting and level of supervision (Dinan 2001).

Initial screening must establish:

- the health and disability status, including current medications
- signs and symptoms associated with certain diseases
- risk factors that predispose to certain diseases (Rogers 2005)
- risk factors that contraindicate performance testing and exercise or adaptation and tailoring to minimize risk during exercise (Table 6.4).

In addition, for older participants, we need to include a range of assessments to establish:

- nature and degree of physical impairment
- specific functional limitations (e.g. restriction in rising from a chair or climbing stairs (Jones & Rikli 2005); inability to get down to and up from the floor (Skelton & Dinan 1999))
- activity history, current interests, preferences and means
- current readiness to exercise (Dinan 2001)
- ability to get to the session (transport/carer) (Dinan 2001).

The specific pre-exercise assessment provides the opportunity to identify (Dinan 2001, Dinan et al 2006, Jones & Rikli 2005):

- who is, or will be, at risk of decreased mobility or disability
- which programme, instructor and setting is appropriate for a particular older person
- what motivates the person (information needed in order to set behavioural goals)

Table 6.4 Contraindications to pre-exercise assessment and exercise participation for older people requiring specific direction from the referring clinician and subsequent programme adaptation by exercise practitioner

Absolute contraindications
Severe coronary artery disease/unstable angina pectoris and acute myocardial infarction
Decompensated congestive heart failure
Uncontrolled ventricular arrhythmias
Uncontrolled cardiac arrhythmias (compromising cardiac function)
Severe valvular heart disease including aortic, pulmonic and mitral stenosis
Uncontrolled systemic hypertension (e.g. >200 mmHg/105 mmHg)
Pulmonary hypertension
Suspected or known dissecting aneurysm
Acute myocarditis
Acute pulmonary embolus
Acute infections
Uncontrolled acute systemic illness
Significant drop in blood pressure during exercise
Recent injurious fall without medical attention
Uncontrolled vestibular or visual disturbances
People with proven inability to comply with the recommended adaptations to the exercise programme
Relative contraindications
Coronary artery disease
Congestive heart failure
Significant valvular heart disease
Cardiac arrhythmias including ventricular and atrial arrhythmias and complete heart block
Severe arterial hypertension (>200 mmHg/>105 mmHg)
Fixed-rate, permanent pacemaker
Cyanotic congenital heart disease
Congenital anomalies of coronary arteries
Cardiomyopathy including hypertrophic cardiomyopathy and dilated cardiomyopathy
Marfan's syndrome
High-degree atrioventricular heart block
Ventricular aneurysm
Peripheral vascular disease
Severe obstructive or restrictive lung disease
Electrolyte abnormalities, especially hypokalaemia
Uncontrolled metabolic disease (e.g. diabetes, thyrotoxicosis, myxoedema)
Any serious systemic disorder (e.g. mononucleosis, hepatitis)
Neuromuscular, musculoskeletal or rheumatoid disorders exacerbated by exercise
Marked (gross) obesity
Idiopathic long-QT syndrome

Adapted from ACSM (2000), Dinan (2001), Rogers (2005).

- which goals are realistic/achievable for that individual
- the selection and combination of exercises that address their needs
- the most meaningful feedback approach for that individual if an onward referral to a medical or therapy professional is necessary.

Assessment also provides the opportunity to promote and document the benefits of the physical activity programme and the expertise available and to introduce a few of the key exercises to assist safety and familiarization (Dinan et al 2006, Jones & Rikli 2005). Unfortunately, this assessment session is often little more than an unsupervised completion of a health screening tool, which fails to collect the functional, motivational, social and personal information essential to tailoring the prescription.

Written informed consent must be obtained from each participant to take part in the pre-exercise screening and assessment as well as in the exercise programme (ACSM 2000, Rogers 2005). All information must be stored securely.

Being able to select, administer and interpret appropriate tests/assessment is a necessary skill for all physical instructors of older adults (Cress et al 2005, Jones & Rikli 2005, Zhu & Chodzko-Zajko 2006).

No single assessment tool can measure all factors related to disease and disabilities, physical limitations, balance and mobility problems and falls risks (Close et al 2005, Jones & Rikli 2005).

Assessment of ability to exercise

A common concern when assessing older people for participation in a physical activity or exercise programme is whether or not a medical evaluation is needed (e.g. exercise treadmill testing to assess for the likelihood of adverse cardiac events) (Jones et al 2005, Ory et al 2005) (Table 6.4). For older people with no active cardiopulmonary symptoms embarking on a moderate-intensity programme (as opposed to a vigorous one that causes the person to breathe hard and sweat profusely), formal testing is generally not necessary and is not supported by the current evidence (ACSM 1998, Buchner & Coleman 1994, Gill et al 2000, Heath 1988, Jones et al 2005, Ory et al 2005). It can also deter participation by portraying exercise as potentially hazardous when the opposite message needs to be conveyed. Formal instruments have been developed to identify if further cardiorespiratory testing and ongoing physician monitoring is advisable. The Physical Activity Readiness Questionnaire (PAR-Q) has been adapted for older people (Thomas et al 1992).

The ACSM guidelines on 'Contraindications to exercise testing' and 'Exercise participation without medical clearance from the person's physician' have both been extended to include medical considerations specific to older people (Table 6.4).

If further cardiorespiratory testing is advised, the following special considerations should be taken into account (ACSM 2000):

- For those with expected low work capacities, the initial workload should be low (2–3 METs) and increments should be small (0.5–1 METs) – the Naughton protocol.
- A cycle ergometer may be preferable to a treadmill for those with poor balance, coordination, vision, gait patterns, weight-bearing ability or foot problems. If there is no cycle ergometer, it may be necessary to add handrail support to the treadmill handrail support, but this will impact on accuracy of measurement of peak workload.
- For those who have difficulty adjusting to the exercise equipment, the initial stage may need to be extended, the test restarted or the test repeated.
- Exercise-induced arrhythmias are more frequent in older people than in other age groups.
- Prescribed medications may impact on exercise electrocardiographic and haemodynamic responses.

Despite this long list of special considerations, the criteria for exercise test termination in older people are no different to those in the younger age groups (ACSM 2000, Heath 1988).

Older people with impaired balance or mobility at high risk for falls, but no specific cardiorespiratory risk factors, will benefit from an evaluation by a physiotherapist or occupational therapist prior to initiating a programme of regular physical activity.

Assessment of physical activity

Physically inactive older adults can be identified in many ways (Jørstad-Stein et al 2005). Indeed, the assessment of physical activity can be considered an additional vital sign for all older people, irrespective of health or functional status. For example, PASE, or the Physical Activity Scale for the Elderly, measures total leisure and work activity through a weighted scoring of hours per activity in the previous 7 days (Washburn et al 1993). PACE, or Physician-based Assessment and Counseling for Exercise, measures attitudes and behaviours related to physical activity (Norris et al 2000). The 7-day recall physical activity questionnaire is considered more appropriate for older people (Hayden-Wade et al 2003).

Although no questionnaire on physical activity is going to be as accurate as the use of body-fixed sensors (Jørstad-Stein et al 2005), it is highly unlikely that you will have access to or be able to fund these kinds of objective physical activity measures. The minimum assessment of physical activity should be a history of participation in sport or recreational activities and current activity preferences and dislikes.

Assessment of functional ability

There are literally hundreds of possible functional tests that can be administered with older people (Jones & Rikli 2005). The choice of test depends on the fitness and functional ability of the individual (e.g. a shuttle test is not appropriate for a frail person living in a nursing setting) and whether that test is appropriate to the outcomes of the exercise programme (e.g. a single sit-to-stand is not appropriate if you are interested in seeing the effects of the programme on endurance). It is also important to choose a test that has been validated and has normative values available in the same population group and age (Jarnlo 2003, Jones & Rikli 2005) and to remember that older people are not a homogeneous group so it is unwise to assume that a person of a certain age will always have certain abilities (ACSM 2000).

The Functional Fitness Framework (Jones & Rikli 2005) identifies the physical fitness parameters associated with functional mobility and can be used as a guide in selecting appropriate assessment tools. The Senior Fitness Test (SFT) has seven functional tests and is practical and relevant for older people with a wide range of physical abilities (Rikli & Jones 2001). It consists of the following tests: 30-second chair stand, arm curl, 6-minute walk, 2-minute step, chair sit and reach, back scratch and 8 foot up and go (Rikli & Jones 2001). The Fullerton Advanced Balance (FAB) Scale is a newly developed test to measure multiple dimensions of balance in different sensory environments (Jones & Rikli 2005, Rose 2003). Both the SFT and the FAB have normative values for older people aged 60 to 95 years of age.

If you are working with older adults living in nursing settings, it is highly unlikely that they will be able to perform many functional tests without getting unduly fatigued; therefore consideration must be given to picking one or two tests that reflect the outcomes you are working to improve. If the aim of your programme is to reduce falls risk then the timed up and go or the 180° turn are the two recommended tests (Jarnlo 2003).

EVIDENCE-BASED GUIDANCE ON EXERCISE TRAINING FOR OLDER PEOPLE

Programming adaptations for older people have to consider an extreme distribution that ranges from elite athletic masters accomplishments at one end to physical disability and dysfunction at the other. The general principles of exercise prescription apply to adults of all ages; however, as with the assessment process, older adults will require subtle differences or 'adaptations' in protocol and dosage of exercise prescription (ACSM 2000). Special consideration in order to minimize medical problems and meet the range of fitness and functional levels of this diverse continuum (Dinan 2001). The focus here is on health-related exercise rather than sports performance as, at advanced ages, the emphasis shifts to the preservation of physical performance in activities of everyday life and to maintaining functional independence for as long as possible (Table 6.1) (Spirduso et al 1996). To respect the heterogeneity and assist compliance, whilst aiming high and observing the current exercise prescription guidelines, optimal training for older people needs to shift away from the purely physiological parameters appropriate for younger participants and older athletes towards programmes that emphasize functional relevance, minimum levels of effort, choice of modalities and opportunities to socialize (Dinan 2001).

Exercise guidelines for older people

In the last decade, the remarkable growth in the literature on physical activity and exercise prescription in older people has led to the publication of a number of best practice guidelines and expert texts on the programming of exercise both for relatively healthy older people wishing to engage in regular moderate to vigorous physical activity (AARP 2001, ACSM 1998, 2000, Ecclestone & Jones 2004, Evans 1999, Jones & Rose 2005, NIA 1998, Rose 2003) and for vulnerable older people (Dinan 2001, Mazzeo et al 2000). All emphasize the need to conscientiously adapt exercise for all older individuals in line with the evidence and published guidelines or where insufficient evidence exists, with expert best practice recommendations. All also endorse the importance of specialist training for physical activity instructors of older people (AARP 2001, ACSM 1998, 2000, Ecclestone & Jones 2004, Jones & Clark 1998, Jones & Rose 2005, NIA 1998, WHO 1997). The initial ACSM (1998) primarily health-promotion-based guideline focused on the message that regular exercise and physical activity can improve functional capacity and health and lead to greater independence and quality of life for older adults but had little guidance on how best to programme exercise variables such as frequency and duration. Increasing evidence about specificity, progressive overload, monitoring and motivational strategies has informed more prescriptive guidance on exercise testing and programming (ACSM 1998, 2000, NIA 1998) (Table 6.5).

The ACSM guidelines (1998, 2000) include the following:

- older adults should accumulate at least 30 minutes of moderate-intensity exercise (such as brisk walking and heavy gardening) on most, and preferably all, days of the week

Table 6.5 Exercise prescription for the older person

Fitness component	Type	Modality	Frequency	Intensity	Duration (minutes per session)	Special considerations
Flexibility	• Static[A,B,D,F] • Passive[D,F] • Dynamic (slow controlled)[D,F] • Functionally relevant stretching activities[A,D,F]	• Integrated into endurance/strength training[A,B,D,F] • Flexibility programme[A,D,F] • Tai chi and yoga[A] • Bed/plinth/chair/seated/floor[D,F] • Daily active lifestyle activities – reaching up the wall – reaching into a cupboard – stepping onto a high step (bus)	• Daily • 3–7[B,D,F] • 2–3[A]	• 'Soft exercise'[F] • Maintenance 8–10 seconds[D,E,F] • Developmental 10–30 seconds[A,B,E,F] 10–90 seconds[D] • ×4 reps[A] • ×1[A,B,D,F] maintenance of all main muscle groups • ×1–4 developmental of appropriate muscles (e.g. adductors, hamstring) and/or targeted joint complexes[A,D,E,F]	• Approx 10–15 minutes (i.e. long enough to exercise the major muscle/tendon groups)[A,D,F] • An entire session may be appropriate for older beginners[A,D,F]	• After endurance and strength training[B,D,F] or warm-up[A,B,D,F] • Include as part of warm-up (maintenance only) and as part of a cool-down[A,B,D,F] (maintenance and developmental) • If time limited ensure stretch all major muscles 8–10 seconds once; if flexibility training then multiple reps etc.[D,F] • Use chair or wall for support to reduce balance problems that compromise stretch[F] • Tailor type, repetitions, limb angle to individual[D,F] • Ensure alignment before and during stretch[D,F] • Ease slowly and gradually into and out of stretch[A,D,E] • Stretch to point of mild tension but not pain[D,F] • Do not bounce or force stretch[D,F] • Inhale at start, exhale as move into and breathe regularly on hold[D,F] • Include slow controlled moving/dynamic stretches in warm-up and especially for people with poor body awareness[D,F] • Static only: in people with arthritis or severe adaptive shortening around joint[D,F] • For comfort, ensure long thick, light mats and pillows for neck support[F]

Muscular strength	• Isotonic[A–H] • Controlled (5–6 seconds) Isometric[A,D,E,F] • Closed (and open) chain[A,D,E,F] • Functionally relevant strength activities[D,E,F]	• Resistance bands[D,E,F] • Velcro ankle/ wrist weights[D,E,F] • Free weights[D,E,F] • Fixed machines[D,E,F] • Floor work/standing/ sitting[D,E,F] • Resistance balls/tennis balls[D,F]/Parachutes etc.[F] • Sit-to-stand, lifting, carrying[D,F]	• 2–3[A–H] • 48 hours between sessions (48–72 hours for beginners;[A,B,D,E,F] for advanced 24 hours recovery between some muscle groups or 'split' workout where schedule different muscle groups on different consecutive days[B,D,E,F])	• ×8–10 exercises using all major muscle groups[A,B,D,E,F] • ×10–15 reps[A,D,E,F] @ 45/50% of 1-RM[D,F] • RPE 12–13 (somewhat hard; 3–4 (moderate)– Borg C&CR scales)[A,B,D,F] (Advanced only: ×6–8 reps @60%/80% of 1-RM = RPE 14–15 (hard); 4–5 (strong)) • ×1 set training; build to 2 and maximum of 3 sets[A,E,F] • To fatigue not to failure[A,D,E,F] • Progressive • %1-RM Reps 65% 14–15 70% 12–13 75% 10–11 80% 8–9[D,E,F] • Speed: 6–9 seconds per rep; rest: 1–3 seconds between reps (hard)[D,E,F] • Peak strain to target hold at peak of contraction to target bone[F]	• 20–30[A,B,D–F] • NB sessions lasting longer than 60 minutes may have a detrimental effect on exercise adherence	• Major goal = life related = strength, endurance/power[A–H] • Individualization of prescription is essential[A,D,E,F] • Increase repetitions before increase resistance (i.e. when 15 reps or more)[A,E,F] • When returning from a lay-off start with 50% or less of previous prescription and progress gradually[A,E,F] • Close supervision by trained specialist older person instructors[A,B,D,E,F] • Exercise order – exercises using larger muscle groups at beginning; (multi-joint) single joint or isolated muscle action (e.g. biceps) at end[A] • Multi-joint versus single joint exercises the priority[A,D,E,F] • Do not exercise same muscle groups on two consecutive days[A,B,D,E,F] • One set training initially reduces fatigue and likelihood of muscle soreness[A,E,F] • First 8 weeks minimal resistance to allow for connective tissue adaptation[A,D,E,F] • Bone load by targeting fracture sites, wrist, spine, hip • Utilize controlled isometric work and peak strain (limit hold to 5–6 seconds)[A,F] • Emphasize normal, even breathing pattern • Teach 'strict form' and programming and progression techniques so all major muscle exercises are included[D,E,F] • Emphasize controlled speed on lifting and lowering phase[D,E,F]

(Continued)

Table 6.5 Exercise prescription for the older person—Cont'd

Fitness component	Type	Modality	Frequency	Intensity	Duration (minutes per session)	Special considerations
Muscular strength–Cont'd						• Do not do ballistic movements[D,E,F] • Perform in a 'pain-free arc' or maximum natural range of motion[D,E,F] • Whenever possible, use fixed machines as less skill needed, greater back stability, lower baseline, smaller increments of progression, increased range of movement control[A,D,E,F] • Arthritic patients should begin with isometric work to minimize joint tension[A,F] • Contraindications to resistance training (at any age): uncontrolled angina, uncontrolled hypertension or arrhythmia, abnormal haemodynamic responses during exercise, acute orthopaedic condition, acute systemic condition[A,D,E,F] • For frailer or osteoporotic patients avoid any resisted retraction of shoulder girdle and resisted spinal flexion[A,E,F] • Emphasize benefits of all-year-round resistance training[A–G]
Cardiorespiratory fitness	• Aerobic endurance exercise[A,B,C,D,F,G,H] • Continuous, rhythmic large muscle group activity that can be maintained for a prolonged period[F,G]	• Brisk walking, swimming, aqua exercise, cycling, jogging ergometers, rowing etc., continuous dancing[A,F,G] • Active lifestyle options: gardening/yard work (raking leaves), housework, climbing	• 5–7 'most days'[A,B,C,G,F] • 3 (alternating no exercise and exercise days)[A,B]	• Moderate 40–75% $\dot{V}O_2$max (initially 40–50% building to 75% and advanced vigorous to 85%) RPE 12–14 (Borg 6–20) 3–4 (Borg 0–10) (initially 9–11 building to 11–12 and advanced 12–14)[A,G] • Initial workload should be low (2–3 METs) and	• 30 (×3 of 10 minutes) for health benefits[A,B,G] • longer duration (up to 60 minutes) offers additional health and fitness benefits[A,B,G]	Ensure • Start low and progress duration before intensity (for safety and injury prevention)[A,B,C,G,H] • Progress in small increments of duration and intensity[A,B,G,H] • Low to medium impact[A,B,G,H] • Utilize interval conditioning prior to continuous[G,F] • Avoid moves with high falls risks[D,F]

	• Interval conditioning (a higher-intensity cardiorespiratory interval followed by a lower active recovery interval[F,G] • Continuous conditioning • Functionally relevant active lifestyle activities[A,B,C,F,G,I] • Low-medium impact to avoid orthopaedic problems[A,F,G,I]	stairs and active recreational pursuits (e.g. bowling)[A,F,G]		increments small (0.5–1.0 METs) • METs – age categorization 'rough' guide: – 'Athletic old' 55+= $\dot{V}O_2$max = 10 METs – 'Young old' 55–75 = $\dot{V}O_2$max = 6–7 METs – 'Old old' 75+ = 2–3 METs[H]		• Transitions between activities should be active low intensity, and longer than with younger people[F] • Longer, more gradual aerobic curve build-up and endurance cool-down[A,B,F] • Longer duration can increase cardiovascular/musculoskeletal risks and reduce compliance[A,B,H] • Shorter duration 10-minute periods can increase compliance and exercise tolerance[F] • Many older people have one or more medical conditions and are more likely to be on medications that can influence peak heart rate response[A–H] • Progress according to individual tolerance and preference to minimize medical problems and promote compliance[A–H] • Including controlled changes of pace, level, direction, e.g. side steps, forward movements and arm movements, can also increase endurance, intensity and balance gains[F] • Simple, few repetitive moves[F] • NB: A measured peak heart rate (HR) is preferable to an age-predicted peak HR when prescribing aerobic exercise for 65+ because of the variability in peak HR and increased risk of coronary artery disease – % of peak HR may provide more accurate estimate of % of peak $\dot{V}O_2$ than the HR reserve method when calculating a target HR range[A,F,G,H]

(Continued)

Table 6.5 Exercise prescription for the older person—Cont'd

Fitness component	Type	Modality	Frequency	Intensity	Duration (minutes per session)	Special considerations
Balance and agility training	• Dynamic balance – prescriptive ways of transferring bodyweight between different points of support[D,F] • Integrated dynamic balance[A,B,D,F] • Functionally relevant 'applied', integrated dynamic balance[D,F] • Sensory integration and organization activities[D,F] • Proprioceptive visual, aural tasks[D,F]	• Falls prevention = – general exercise for the older person session – adapted tai chi[D,F] • Falls management = – specific balance (and strength) exercises[D,F] • Integrated balance training – endurance session with walking and stepping patterns[D,F] – dance, adapted tai chi[D,F] – floor work, functional floor activities[F] – balance circuits/ obstacle courses[D,F] – ball games etc.[D,F]	• 3[B,D,F]	• Degree of support (two hands, one, one finger, no hands etc.)[D,F] • No of steps (reps) and sets[D,F] • Different paces, levels, surfaces, obstacles[D,F] • Carrying different objects[D,F] • Catching and throwing etc. • Increased multi-tasking – number and complexity of tasks[D,F] • Floor work – transfer down to and up from the floor, rolling, crawling[F] • Balancing on uneven, unfamiliar surface, e.g. foam blocks etc.[D,F]	• 30 (i.e. integrated strength and balance)[D,F]	Considerations • In 'static' dynamic balance exercises increase the duration before decreasing the support[F] • In travelling dynamic balance exercises increase the number of steps before decreasing the support[F] • Add balance training as part of lower body strengthening (e.g. toe walks/heel walks)[B,D,F] • Introduce all sensory-specific tasks as single stimulus tasks[D] • Introduce all complex movement skills (e.g. getting down to and up from floor) as single step-by-step links in the movement chain[D,F] • Ensure each link in the chain is mastered competently and confidently before moving on to the next stage or link (backward chaining approach)[D,F] • Poor balance is closely associated with fear of falling and loss of confidence. Ensuring a step-by-step approach, close observation, praise and encouragement is essential[D,F] • Improved balance and strength can result in over-confidence and increased risk taking and increase risk. Therefore ensure postural stability is sufficient before the sensory and social tasks, e.g. ball games[F]

Key: A, ACSM (1998, 2000); B, NIA (1998); C, WHO (1997); D, Rose (2003); E, Kraemer & French (2005); F, Skelton & Dinan (1999), Dinan et al (2004), Dinan & Skelton 2007; G, Brooks (1997); H, Smith (1984).

- additional benefits can be obtained by performing higher-intensity exercise (after discussing this with a physician)
- for strength and muscular endurance gains, older adults need to do resistance training at least twice per week (with at least 48 hours of rest between sessions)
- to maintain flexibility and improve balance and agility older adults need to ensure they have a well-rounded programme that includes stretching at least two to three days of the week; tai chi and yoga are suggested as useful ways of obtaining these particular benefits.

Today, with the benefit of further evidence we can be more specific in relation to balance and tai chi. These have been included in the best practice guidelines summary, Table 6.5.

The NIA (National Institute on Ageing) guidelines (1998) included more specific detail for practitioners, especially on balance training. Illustrations and instruction for specific exercises were also included. It recommended:

- gradually progressing to at least 30 minutes of endurance exercise on most, or preferably all, days of the week and that the 30-minute goal can be accomplished by accumulating time in shorter 10-minute sessions or 'activity snacks'
- for advanced exercisers, 24 hours between sessions was sufficient provided that the same muscle groups are not exercised on two consecutive days
- balance training components should be added progressively as part of the lower body strengthening programme and additional balance exercises (e.g. standing on one leg) can be done any time
- stretching exercises should only be done after endurance and strength training, or after warming up – 3 to 7 days per week for those not participating in other types of exercise.

Importantly, both these guidelines emphasize the need for individualization in relation to cardiorespiratory endurance and resistance training programmes and for pre-exercise and ongoing health and risk assessment and exercise prescription. Both also promote the benefits of additional information on clinical status and functional capacity (ACSM 1998, 2000, NIA 1998).

Best practice begins with the conscientious observance of these guidelines for all older participants, with further specific adaptations being made to session aims, structure, content, programming and teaching methods (Dinan 2001).

Injury prevention

Injury prevention is a high priority. Even stiffness and minor overuse injuries reduce enjoyment, may affect compliance and everyday function, and can be avoided. The design of the session, supervision and monitoring of performance, together with education and guidance of participants can substantially reduce hazards. Overuse or 'too much too soon' injuries are not uncommon in older participants (Carroll et al 1992, Pollock et al 1991, 1997). The risk of an event, an accident or an exacerbation of an existing joint condition can be controlled by ensuring biomechanically sound positions, cautious training loads and by introducing exercises one by one around affected joint(s). All activities must avoid undue spinal stress or disc compression (e.g. sit ups or other exercises that cause spinal loading in flexion (Dinan 2001, Sinaki 1982)); moves with high falls risk (turns of more than 90° or exercises involving lateral movement of one leg across the other (Skelton & Dinan 1999)); and uncontrolled isometric contraction (Bell 2001). Older people with muscular weakness, particularly those with a history of joint, muscular or connective tissue damage caused by overuse injury or disease, should use an especially conservative training load initially with predominantly controlled isometric work at first and then progression to light isotonic work loads (Ettinger et al 1997). Wearing hip protectors during exercise reduces the risk of a hip fracture if a fall does occur and improves both self-efficacy in the participant and confidence in the instructor (Skelton & Dinan 1999). Balance training should be progressed cautiously in frailer older adults, first by increasing the number of repetitions, then decreasing the support (e.g. chair support to no support, bipedal to unipedal base of support, increasing the difficulty of the surface etc.) (Rose 2003, Skelton & Dinan 1999), whilst being aware of potential hazards of asymmetry in lower limb strength and power (Skelton et al 2002) (Table 6.5). Particular care during transitions between exercises and components, particularly floor work transfers, is also necessary (Dinan 2001, Skelton & Dinan 1999).

Specificity

In defining cardiorespiratory overload, the first step is to identify the right type of activity. For a significant training effect, it is essential to select activities that sustain a large volume of venous return. When designing for senior participants, endurance training should be multipurpose. It must have energy-source specificity (aerobic and anaerobic) and everyday life specificity. A combination of walking, stationary cycling, swimming and/or water-fitness will meet most of the criteria for most seniors (Dinan et al 2004, Young & Dinan 2005) (Table 6.5). The combination of activities is as important as the selection in terms of safety, function and adherence.

The type of training approach is also important for successful energy source outcomes for older people. Cardiovascular training can be continuous or it can utilize an adapted interval training approach (i.e. interval conditioning) (Bompa 1999). Although both types have a role to play in long-term cardiorespiratory programming, interval conditioning is recommended as the initial and core approach, because it is the most effective way of achieving overload and meeting functional fitness needs. Everyday tasks such as quickening our pace to catch a bus or climbing a hill during a walk to the shops, and leisure activities such as timed swimming, are examples of 'interval' demands placed on the body during any given day or exercise session. They all involve an effort interval where the work rate is a little harder than 'steady state' or what is comfortable, followed by a moderate recovery interval or time period where activity returns to this comfortable, easily sustained level of effort (Brooks 1997). The physiological benefits of interval conditioning (1–6 minutes) and continuous training (6 minutes or longer of uninterrupted activity, usually performed at a constant submaximal intensity) are similar (Ahmaidi et al 1998, Brooks 1997, Haskell 1997, Shephard, 1991). However, the advantage of interval conditioning is that at any age, the stimulus to physiological change is greater, as the total *volume* of work is greater than when the same intensity of exercise is continuous (Brooks 1997, De Busk et al 1990). This enables the older person to meet the generally lower anaerobic thresholds and to work harder with greater comfort for up to three times longer (Bompa 1999, Dinan et al 2004, Malbut et al 2002, Vogiatzis et al 2002).

In strength training, a wide range of types of activity and equipment is needed to ensure that specificity is met and there are improvements in strength, power, size of muscle, functional strength and quality of life (Dinan 2001, Kraemer & French 2005, Pollock et al 2000). An eclectic mix of resistance bands, free weights, Velcro ankle and wrist weights, fixed resistance machines and bodyweight, cans of food or even parachutes can be utilized to ensure both progression of resistance and functional specificity (e.g. sit-to-stands) that will enable better function in everyday life (Table 6.5).

As noted earlier, resistance training alone, without functional training, does not improve everyday function (Skelton et al 1995, Skelton & McLaughlin 1996). The linear movements of traditional weight training machines are not sufficient to address the more three-dimensional, functional everyday movement patterns that involve acceleration, deceleration and stabilization of joint structures and it is the stabilizer muscles, not the mobilizers, that limit functional strength. In order to improve transfer from and to the floor, this must be practised in the training session in order to retrain the movement pattern and also must be combined with strengthening exercises for the core muscles of the spine, pelvis and scapula (Dinan 2001, Kraemer & French 2005, Skelton & Dinan 1999). For power training, current research suggests including some higher velocity but non-ballistic movements with multiple and single joint exercises (Table 6.5). The recommended type of strength training approach for older people is periodization (the systematic alteration of the training variables of volume and intensity over time to create variation in the physiological stresses, to optimize the training stimulus). Periodization closely mimics the demands of everyday life and is the most functionally relevant approach to strength training (Dinan & Skelton 2007, Fleck & Kraemer 2004, Kraemer & French 2005).

Effective balance training needs to target the multiple sensory dimensions of balance, altering task demands for motor system improvements and environmental demands for sensory improvements (Rose 2003, Skelton & Dinan 1999). Guidelines on the types of exercise and approach for the specificity and overload for balance and flexibility training are given in Table 6.5.

Progressive overload

Overload is influenced most strongly by the type of exercise and then further defined by frequency, intensity and duration, modes of exercise and approaches to training.

Everyday tasks, such as dressing, require as much as 50–75% of a frail 80-year-old woman's $\dot{V}O_2max$ (Fig. 6.2A) (Malbut et al 2002, Saltin 1980, Young 1986); therefore, endurance overload may initially be as little as a 3-minute walk. To maintain improvements, overload must be progressive in nature but, for safety with older participants, must be progressed gradually and cautiously. Recommendations include always allowing a minimum of 3 weeks for adaptation before progressing the overload, progressing duration first and always in 1-minute increments as tolerated (Bell 2001) and progressing intensity by increasing resistance (e.g. incline of treadmill, hill, cycle or resistance and skill, e.g. carrying objects) rather than speed (ACSM 2000).

In practice, with beginners of all ages, most particularly with frailer older participants, it is recommended that resistance training begins with local muscular endurance training to allow time to master the technique of each exercise and feel confident and competent in performing it and then progresses steadily and cautiously up through the recommended strength training ranges. It is important to remember that strength training will maintain local muscular endurance gains but local muscular endurance training alone will not bring the crucial muscle mass, strength and force changes of strength training (Table 6.5) (Fleck & Kramer 2004, Kraemer & French 2005). In people with clinically significant arthritis and those with osteoporosis, progression of resistance training must be slow and cautious (Dinan 2001, Ettinger et al 1997). Where resistance training with vulnerable, older patients is concerned, avoidance of isometric work held for over 5 seconds is preferred (Haskell 1997). Recent studies have reported similar cardiovascular and haemodynamic responses to resistance training in patients both with and without coronary artery disease and indicate that myocardial perfusion may even be enhanced due to the increase in diastolic pressure (Squires et al 1991). Caution must be taken, however, to avoid the risk of rapid rises in systolic and diastolic blood pressure associated with prolonged high-intensity isometric work (Bell et al 1995, Bell 2001, Fleck & Kramer 2004, Kraemer & French 2005). When utilizing isometric (static) work, to achieve a targeted strength gain in specific muscle groups, a moderate workload should be used and each contraction should be held for a maximum of 3–4 seconds (Bell 2001). For patients with hypertension, coronary artery disease or peripheral vascular disease, this would be adapted even further. There is, however, no evidence that brief bouts of moderate-intensity static exercise of 5–10 seconds duration significantly increases the risk of a clinical event in older people (Haskell 1997).

Whatever the type of resistance training or mode selected, the criteria must be that the exerciser can control the movement through the fullest possible range. On some fixed-weight machines, even the lightest resistance is too great and some participants are unable to produce the initial forces to start the movement and the incremental progressions are too large to allow smooth, safe progression. Resistance bands can overcome some of the initial problems, provide easier initiation of movement and, for frailer adults unwilling to travel, may be the only practical and acceptable starting point in some settings (Skelton et al 1996).

Adaptations to session structure

Warm-up and cool-down

For all older participants, sessions should start and finish gradually, providing safe transition to, and adequate recovery from, more vigorous exercise. The warm-up period should be longer than for younger adults (15–20 minutes), gradually progressed in intensity, to safely improve the efficiency of the cardiovascular response and help to prevent ischaemic ST segment changes, arrhythmias, a reduction in left ventricular ejection function and other cardiovascular irregularities commonly brought on by sudden strenuous exercise (ACSM 2000, Bell 2001, Haskell 1997, Malbut et al 2002). Additional advantages of extended warm-up are that it improves blood saturation to, and elasticity in, the muscles, tendons and ligaments, decreases viscosity of the muscles, improves mechanical efficiency and helps prevent musculoskeletal injuries – all considerations which are more important with age (Haskell 1997).

The long, gradual continuous cool-down (a warm-up in reverse) is recommended to preserve venous return and safely decrease heart rate, respiration and catecholamine levels (Shephard 1997), allow muscle and skin vasodilatation to return to resting levels (Dinan 2001) and help prevent the dizziness and cardiac-related irregularities which are more common in older people (Haskell 1997) and other high risk populations (Bell 2001).

Monitoring exercise intensity

The most common method of prescribing and monitoring exercise intensity is by targeting a training heart rate, established as a percentage of either maximal heart rate (HRmax) or heart rate reserve (HRR, defined as maximal heart rate minus resting heart rate). Both of these methods have certain disadvantages, unless a true measure of HRmax has been obtained. Estimates of HRmax and HRR are particularly unreliable in older people (Cooper et al 1977). But maximal tests on older individuals, and/or individuals with risk factors, should only be performed with medical supervision and are, therefore, inappropriate for older people (Kallinen et al 2006). During exercise, the majority older people must slow down or stop exercising in order to take their heart rate and, even then, heart rates self measured by palpitation are inaccurate (Bell 2001). Also HRR may represent a higher percentage of $\dot{V}O_2max$ than expected, so using HRR may result in the older person working at a higher intensity than desired (Dinan et al 2004). The use of medications that may affect heart rate response is common and use of heart rate measures can cause concern and even reinforce ideas that exercise is high risk.

An alternative to using target heart rate to obtain the desired training intensity is the use of Borg's rating of perceived exertion (RPE) scale (Borg 1998), effective in both young and older people (Dinan et al 2004, Malbut et al 2002). This scale of self-perceived effort takes into account both central (e.g. heart rate and breathing) and local (e.g. muscle fatigue) sensations. It also does not require a slowing down or stopping of exercise.

A training intensity between 13 and 15 on the 6–20 RPE scale is approximately equivalent to working at 70–80% of $\dot{V}O_2max$ and an RPE of 11–13 approximates to working at 49–70% of $\dot{V}O_2max$ (ACSM 2000, Malbut et al 2002, Pollock et al 2000). According to the ACSM (1998, 2000) starting with an exercise intensity of 11–13 on the RPE scale and never exceeding a hard intensity (15 on the scale) appears to be most appropriate for sedentary older people. For a frailer older adult, a starting intensity of 9–11 may be preferable (Dinan 2001, Dinan et al 2004). It is essential that the instructor and participant understand what they are assessing and there is clear instruction in the use of the scales (Borg 1998).

The intensity of exercise can also be regulated by selecting activities based on known metabolic equivalent (MET) values. Some activities have a wide range of MET values (e.g. ballroom dancing 4–8 METs, aerobic dance 6–9 METs and skipping 8–12 METs), while others vary little (e.g. walking at normal pace 3–4 METs, cycling 5–6 METs). Ideally for the first 8–10 weeks of a programme, endurance activities should be of a type that is easy to perform and to monitor and can be maintained at a moderate intensity (Bell 2001). Smith's age classification guide raises awareness of the key real need for adaptation: athletic old 55+, $\dot{V}O_2max = 10$ METs; young old 55–75, $\dot{V}O_2max = 6$–7 METs; old old 75+, $\dot{V}O_2max = 2$–3 METs (Smith 1984).

Rest and recovery

It is crucial when planning an endurance programme for older people to systematically plan recovery periods between and within each component and between sessions (ACSM 1998, 2000). The use of interval training (Ahmaidi et al 1998, Brooks 1997) and alternating muscle groups is also recommended (Dinan 2001). A fartlek training approach (speed play) is utilized to accommodate the lower anaerobic thresholds found in older people. This allows participants to continue for longer without undue fatigue. Adequate recovery enhances the cardiorespiratory stimulus, improves performance, improves long-term commitment and, above all, prevents overuse injuries, fatigue (Bompa 1999, Fleck & Kramer 2004) and fatigue-related events such as falls (Dinan 2001). Strength training rests and recovery desirable in an older population are quite different to recommendations for a younger population (see Table 6.5).

Observation and interpretation

At any age, it is important not to rely on any single indicator of exertion levels during exercise. The instructor should be alert to the physical signs or symptoms that indicate deterioration in health, or the onset of a new condition and other 'triggers' that signal to the need to refer back to the medical setting for further investigation. It is important to be aware that the frailer the individual, the greater the fluctuation in day-to-day health, energy, mood and anxiety levels, and these may have an effect on general performance, postural stability and, therefore, safety and comfort during the session (Dinan & Skelton 2007).

Group versus home-based exercise programmes

Participation in a structured group exercise programme (e.g. at a healthcare facility or in a community senior centre) versus a home-based programme is a matter of personal preference. Comparable results can be achieved in either setting (Judge et al 2005, King et al 1991, Robertson et al 2001, Skelton et al 2005, Wallace et al 1998). The group setting, however, affords additional benefits by creating an environment for peer support, self-efficacy and increased socialization that can counteract the negative effects of social isolation and associated depression (Leveille et al 1998, Lorig et al 1999). Also, older people who exercise in a group setting may feel a greater sense of personal safety that may reduce fear of injury as a potential barrier to exercise. For those who prefer the convenience or privacy of a home-based programme, specific protocols have been developed that use resistance bands, light weights, stationary bicycles or common household objects such as a chair or a towel (Jette et al 1996, King et al 1991, Robertson et al 2001).

Motivation and adherence to exercise

Multiple studies have shown that physicians are an important source of motivation for people contemplating the initiation of a physical activity programme (Andersen et al 1997, Christmas & Andersen 2000, Damush et al 1999). Also there is increasing evidence that positive images of ageing can reverse the age-related declines in gait, with one trial showing that positive stereotypes of ageing have a powerful positive impact on the gait speed (9%) of older people (Hausdorff et al 1999).

There are multiple barriers to improving physical activity levels in older people (Finch 1997) (Table 6.6). These include intrinsic barriers such as: lack of knowledge or misperceptions about community physical activity programmes; fear of crime (mugging); fear of falling (Yardley & Smith 2003); fear of overexertion; not having someone to exercise with (spouse or friends may have died) (Finch 1997). Extrinsic barriers include weather that is not conducive to physical activity (e.g. excessive cold or heat); influence of significant others (Yardley et al 2006) such as a partner, family, peers, carer or health professional; ease of access to activities, safe streets and neighbourhoods (Finch 1997) (Table 6.6). Finally, myths and stereotypes about exercising in older age (no pain, no gain, etc.) are often cited (Finch 1997).

No single factor will predict whether or not an older person will start and sustain an exercise programme. Participation is determined and regulated by a range of factors, unique to the individual. For many older people this will be a significant change in lifestyle or an unfamiliar experience, and those with the poorest health and the most likely to visit their GP may be the most resistant to change (Chodzko-Zajko & Resnick 2004, Marcus & Forsyth 2003). Readiness to change may be significantly influenced by a referral from a health professional, often following the diagnosis of a chronic disease or following a significant life event such as a fall or heart attack or by individuals recognizing for themselves the tell-tale signs that they are losing function (e.g. having difficulty using the stairs or crossing the road). Exploring the individual's readiness

Table 6.6 Exercise barriers and motivators for older adults

Barriers to exercise	Motivators for exercise
Health and medical	**Health and medical**
○ Illness or injury	○ To feel good physically
○ Pain or discomfort	○ To improve overall health
○ Lack of strength or stamina	○ To reduce risk of disease
○ Fear of a medical event during exercise	○ To maintain or improve mobility
Knowledge	○ To maintain activities of daily living
○ Lack of knowledge or ability	○ To reduce risk of falls
Motivational or psychological	○ To improve fitness
○ Lack of time	○ To improve strength
○ Lack of self-motivation, low self-efficacy or confidence	○ To reduce/manage bodyweight
○ Not a priority	○ For rehabilitation
○ Fear of injury	**Mental health**
○ Exercise perceived as inappropriate, unnecessary or 'not for me'	○ To have more energy
○ Poor body image	○ To reduce stress or anxiety
○ Depression or anxiety	○ To reduce depression
○ Lack of support from family, peers, health professionals	○ To enjoy life more fully
Programme-related	○ To feel more confidence
○ Lack of appropriate classes/activities	**Appearance-related**
○ Intensity too high/too low	○ To maintain/improve appearance
○ Inconvenient times of sessions	○ To reduce/manage bodyweight
○ Programme cost	**Social**
○ Travel to session (availability, cost and fear of travelling alone)	○ For social contact/interaction
Environmental	○ Encouragement by family/friends
○ Poor weather conditions	**Other**
	○ For enjoyment of activity
	○ For competition/personal challenge
	○ Recommendation of health professional
	○ Feel it is appropriate for them

Adapted from Finch (1997), Jones & Rose (2005), Yardley et al (2006).

to change will reveal positive and negative behaviour attitudes towards participation and will determine the strategies to use when setting and agreeing realistic and meaningful goals (Chodzko-Zajko & Resnick 2004, King et al 1998).

Exercise self-efficacy, or confidence in one's ability to undertake regular exercise successfully (even when faced with difficulties), is a strong predictor of exercise adoption among older people (King et al 1998, Marcus & Forsyth 2003, Yardley et al 2006).

Dispelling myths and stereotypes

There are five common myths and stereotypes about physical activity and ageing that need to be dispelled (Jones & Rose 2005). These are described below with reminders on how to assist older people dispel them.

- You have to be healthy to exercise – find appropriate role models of people with chronic disease who have had improvements to their quality of life with exercise.
- I'm too old to start exercising – use appropriate images to show that age is not a barrier to physical activity.
- You need special equipment and clothing – apart from comfortable shoes and loose-fitting clothing there is no special clothing or equipment. However, cultural and generational factors have to be taken into consideration.
- No pain, no gain – reinforce the notion that vigorous exercise is no longer recommended and that moderate physical activity can be easily incorporated into daily life.
- I'm too busy to exercise – help identify opportunities within their schedule.

Induction

An appropriately designed induction session which provides information and reassurance about the level of physical activity, clothing, safety and how the programme is designed to meet individual needs and goals will assist in overcoming many of the concerns a new participant may have. Programme factors (Jones & Rose 2005) cited as motivating amongst older people taking part in group activities include: the mode of exercise, the interpersonal skills and expertise of the instructor and social support from peers (King et al 1998, Stewart et al 2006).

Support strategies

There needs to be a greater emphasis on scheduling, funding and training. Support strategies (e.g. social support from family, peers and other exercisers within a group and professional instructor support), including regular telephone contact to monitor progress, together with regular review of programme goals, are known to improve adherence (Hillsdon et al 2005). A 'relapse' to sedentary behaviour can be avoided by prevention strategies that anticipate high risk of drop-out situations and the understanding that short lapses are normal behaviour (Chodzko-Zajko & Resnick 2004). The importance of involvement of peer mentors in the adoption and maintenance of exercise amongst other older adults and of professional support in adherence to a home exercise programme cannot be underestimated (Robertson et al 2001, Stewart et al 2006).

A recent trial of primary care exercise referral for older adults showed that, with structured support strategies, including transport, it is possible to get high rates of uptake and adherence to exercise programmes even amongst frail older adults (Dinan et al 2006). In people aged 75 and over, 89% took up the exercise programme; 73% completed stage I and 63% made the transition to the community stage II programme (Dinan et al 2006).

Finally and importantly, designing and delivering exercise for older people requires specialist skills and training. Shephard (1991) emphasized that programming physical activity for older people requires more care and more expertise than for any other age group, with only a fine line separating effective from dangerous procedures. The recognition of the importance of specialist skills culminated in the publication and current implementation of the International Curriculum Guidelines for Physical Activity Instructors of Older People (Ecclestone & Jones 2004).

KEY POINTS

Man does not cease to play because he grows old.
Man grows old because he ceases to play.
(George Bernard Shaw)

1. Disease and sedentary behaviour accelerate the rate of ageing.
2. The only three interventions that have slowed the rate of ageing are calorie restriction, genetic manipulation and regular physical activity involving moderate amounts of physical exercise.
3. Life expectancy for both sexes and most countries has almost doubled from 40 to 80 years of age since the beginning of the 20th century. In contrast, lifespan has remained relatively stable and is limited to 85 years, with only 12% of the population exceeding that age.
4. This demographic shift to an older age structure is mainly a consequence of long-term downward trends in fertility.
5. Increased longevity has been accompanied by an increase in unhealthy, sedentary lifestyles, disease and morbidity.
6. There are three main theories of ageing: biological (genetic, damage and gradual imbalance), psychological (Maslow's hierarchy of needs, Erickson's stages of psychosocial development of personality and Baltes' optimization and selective compensation), and sociological (activity and continuity).
7. Active life expectancy is the number of years an individual may expect to maintain ADLs and IADLs.
8. Morbidity can be compressed by adopting a healthy lifestyle early in life.
9. The predictors of successful ageing include: physical and mental health, functional and social competence, productivity, personal control and life satisfaction; these are influenced by the interplay of: genetics, personal and social environment and support, and behaviour, attitudes and personality.
10. In all body systems it is difficult to distinguish between normal body ageing, the effects of age-related decreases in habitual physical activity and the pathology that develops with advancing years and chronic inactivity.
11. Age-related structural changes and effects in the cardiorespiratory system include: increased thickening of the blood vessel and left ventricular walls, increased arterial stiffness, reduced elasticity (greater cross-linkage between the collagen molecules), increased systolic and diastolic blood pressures (aorta thickening and hardening, increased total peripheral resistance), increased hypertrophy and hyporesponsiveness of the heart and vasculature to sympathetic stimulation. Heart rates remain higher and recover more slowly after maximal exertion; postural hypotension increases and appears to be related most closely to high systolic blood pressure.
12. Although cardiac function in most older adults is adequate at rest and for submaximal activities: heart rate, stroke volume and therefore, cardiac output, is reduced. $\dot{V}O_2max$ declines at about 10–15% per year after age 25, but the decline is much less in active individuals with many older exercisers having a higher $\dot{V}O_2max$ than sedentary 20-year-olds.
13. Age-related structural changes in the respiratory system include: a reduction in elastic tissue content (and hence elastic recoil) of the lungs, a decrease in some volumes and capacities (particularly FEV), increased chest wall stiffness,

decreased strength of the respiratory muscles and decreased sensitivity of the respiratory centres in the nervous system.

14. Pulmonary function is satisfactory in healthy older individuals under resting and moderate exercise conditions. The limiting factor in maximal work is the decreased cardiac output.
15. Structural and functional deterioration in the cardiorespiratory systems is attributable to disease rather than the ageing process. Habitual exercise both prevents and remediates cardiovascular disease, hypertension and diabetes and postpones many characteristics of ageing in the cardiovascular and respiratory systems.
16. The capacity of the cardiorespiratory system to adapt to an endurance training load is not affected by age, with similar percentage increases in $\dot{V}O_2max$ being reported for young and old adults.
17. Combined strength and aerobic training, and strength training alone, are as effective as aerobic training alone at improving $\dot{V}O_2max$ in older participants.
18. The age-related structural changes to the muscular system include: reduction in muscle mass; size and number of muscle fibres (with greater atrophy and greater mitochondrial dysfunction in type II fibres); changes in muscle architecture and tendon mechanical properties; strength losses are also due to loss of total number of motor units and a larger innervation ratio (number of muscle cells per motor neuron) in the remaining units.
19. Strength and power declines from 30 years by 10–15% per decade and accelerates after 60 years with power declining more rapidly than strength due to the selective type II fibre loss. Isometric and eccentric strength declines less than concentric. Men and women experience similar losses though women show fewer age-related declines in upper body strength.
20. Older muscle shows a normal response to training with improvements equivalent to 10–20 years' 'rejuvenation'; 8–12 weeks of training can reverse sarcopenia.
21. Functional ability and mobility is highly related to strength; however, strength improvements will only translate into improvements in daily function if functional training is combined with strength training.
22. Bone mass peaks between 20 and 40 years, and then declines at 0.5–1% per year, with an accelerated period of loss in women for 5–10 years after the start of the menopause (leading to a total loss of 25–30% cortical and 35–50% trabecular bone over this period); men lose at about two-thirds this rate. Bone strength depends not only on bone mass but also on bone quality (bone architecture, fatigue damage, bulk material properties).
23. Bone remains responsive to site- and load-specific training throughout the lifespan though the exercise modality needs to be more specific as we age, i.e. high-intensity weight training through intermittent jogging, exercise classes and WBV are effective even in postmenopausal women, but jumping is not.
24. The age-related structural changes in joints include: increased inter- and intramuscular connective tissue, less extensible connective tissue due to a change in chemical composition, and a breakdown of articular cartilage; the combined effect is stiffness and loss of ROM in all joints.
25. ROM and flexibility can be improved in older adults by a wide range of physical activities; frequency rather than type is key.
26. The age-related structural changes in the nervous system include: decline in number of nerve cells, connective networks in, and weight of, the brain, preferential loss of distal, large, myelinated sensory fibres, receptors, enzymes, neurotransmitters and cerebral blood flow.

27. In addition to reduction of volume and strength, the functional changes in muscle include abnormalities in somatosensory (temperature, pressure, pain and muscle/joint position sensation) and vestibular and visual responses together with musculoskeletal changes which increase the risk of falls and fracture.
28. Major disturbances of the vestibular system and eye infections and structural eye disease are more common as we age.
29. Aerobic exercise increases brain volume, in both grey and white matter regions, and, along with functional strength training, tai chi and balance training, improves reaction time and movement control and may protect older people from depression.
30. The endocrine system becomes more catabolic with age as cortisol is produced more readily in response to stress and inflammation, and the target tissues become less responsive, impairing muscle, bone and cognitive function.
31. Regular moderate activity and resistance exercise is associated with higher levels of circulating IGF-1, improved thyroid and immune function and decreased cortisol.
32. Cognitive performance is impaired by poor health, disease and decreased quality of life; keeping the brain active (dancing, playing an instrument, learning a foreign language) has been shown to maintain cognitive fitness.
33. Falls increase with age due to: impaired integration of body systems involved in maintaining postural stability; increased, slower body sway; wider base of support in standing, decreased trunk rotation, stride length and time in single leg support; less sensory sensitivity; poor coordination and reaction times; poor eye sight and vestibular function.
34. Individualized dynamic, balance and strength, group and home-based training can reduce the risk and number of falls, and the severity of fall-related injury and fear of falling.
35. Pre-exercise screening and additional health and functional assessment is crucial to the individual tailoring of exercise prescription for older adults; because of the prevalence of chronic and degenerative disease and chronic inactivity it will require subtle differences in protocol, methodology interpretation and dosage.
36. Pre-exercise screening and assessment should aim to be inclusive, i.e. ensuring each individual is matched to an appropriate programme, setting and level of expertise, undergoes evaluation of functional impairments and risk of injury or disability, and is assessed through utilization of a range of validated outcome measures appropriate for that individual, their setting and level of fitness.
37. No single assessment tool can measure all factors related to disease, disabilities, physical limitations, balance and falls risks.
38. Exercise testing for older adults (embarking on moderate exercise) is generally not necessary, not supported by the current evidence, creates unnecessary and unhelpful anxiety about exercise as a high risk activity. Pre-exercise assessment that includes the ability to perform with equipment, must align with the ACSM's older person specific considerations of METs values, modality, supported balance recommendations and practical guidance on testing those who are unfamiliar with equipment.
39. Exercise prescription for older participants requires adaptation to aims, content, programme and teaching methods, yet to respect the heterogeneity of this group, the prescription must be tailored to individual health, fitness, functional, sociocultural needs, preferences, interests and means.
40. Injury prevention is the highest priority; warm-up and cool-down must be longer and more gradual; modalities and exercises should be functionally relevant; endurance training should aim to utilize interval conditioning approaches and

walking activities and incorporate changes of direction, level and pace; strength training should aim to incorporate functional movement training, balance and flexibility training and programmes should provide a wide range of choice (modality, levels, scheduling, formats, e.g. indoor, outdoor, group, home options) and be varied, comprehensive, accessible, affordable, all year round, include opportunities to socialize and be accessible and inclusive; instructors should have specialist training, qualifications and competencies.

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