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Physical activity and older adults: a review of health benefits and the effectiveness of interventions

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The purpose of this multidisciplinary review paper is to critically review evidence from descriptive, efficacy and effectiveness studies concerned with physical activity and older people. Both levels of fitness (aerobic power, strength, flexibility and functional capability) and measures of physical activity involvement decline with age, and the extent to which this is due to a biological ageing processes or disuse (physical inactivity) is critically examined. The review will consider the evidence for a causal relationship between sedentary behaviour/physical activity programmes and cardiovascular, musculoskeletal and psycho-social health, independent living and health-related quality of life into old age. The review also considers the effectiveness of different physical activity interventions for older people and issues relating to cost-effectiveness. The implications for future policy in terms of research, health care services, and education and training are briefly discussed.

Keywords: ageing, cardiovascular, exercise, health promotion, musculoskeletal, psychological well-being, quality of life.

Introduction

There has been growing interest in recent years in the effects of physical activity on the ageing process (US Department of Health and Human Services, 1996; Shephard, 1997; World Health Organization, 1997; Department of Health, 2004), and for good reason. Contextually, the number of people over the age of 80 and 90 in the UK is expected to increase by 50%, and to double, respectively, between 1995 and 2025. In 1998–99, the UK National Health Service (NHS) spent about 40% of its budget on older people, and social services spent nearly 50% in the UK (Department of Health, 2001a). If these costs rise in line with demographic changes, then the financial implications are enormous. It has been estimated that if the whole population adopted the national guidelines for physical activity, health care costs for hip fractures alone could be reduced by about 50% (Nicholl *et al.*, 1994). The aim of this article is to provide a critical review of research evidence on the effects of sedentary behaviour on health, for an ageing society, and whether trends towards increasing sedentary behaviour can be reversed and at what economic cost. Finally, we make recommendations for public policy.

In the first section, we consider the quality of data available on physical activity patterns among older people. National guidelines for participating in physical activity have been produced for young people and healthy adults. Recommending specific volumes of activity for older people remains a contentious issue, due to large variation in the ageing process and the capacity to engage in physical activity because of disability. For example, chair-based exercise may be all one 75-year-old can perform, with some demonstrated health benefits, while others of a similar age may have much greater functional capability, who would only gain health benefits from a much larger dose of exercise. If public policy is to be evidence-based (e.g. driven by evidence that shows declining physical activity patterns), then there is a need for regular surveillance and monitoring, using consistent, reliable and valid

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measurement tools. We draw on the most current UK national data to identify a need for a better understanding of physical activity patterns and secular changes among older people.

We then turn to the question of efficacy: What do we know about the effects of sedentary behaviour, and exercise training, on physical and psycho-social dimensions of health? A challenge for exercise scientists interested in these effects is to differentiate between how the natural ageing process contributes to functional decline and avoidable change due to physical inactivity. We focus on the implications for the cardiovascular system, given that coronary heart disease is the largest cause of premature mortality and morbidity in the UK. We then focuses on muscle function and bone health, with implications for falls prevention and independent living. Next, we consider how physical inactivity affects psycho-social dimensions of health, including psychological well-being, and health-related quality of life (i.e. emotional, cognitive and social functioning).

Next, we turn to the question of effectiveness: Will physical activity interventions work in natural settings when behaviour change may be challenging for an older person? We consider the evidence for the effectiveness of different interventions aimed at promoting physical activity among older people. Related to this question, we briefly consider cost-effectiveness: If there are known societal costs associated with physical inactivity, then how much would it cost to create appropriate opportunities to facilitate increases in physical activity that would reduce these costs and have health-enhancing effects for individuals? The latter is, of course, dependent on knowing a precise dose–response relationship between physical activity and health for older people. We do not consider the question of efficiency. For example, what is the cost of physical activity interventions compared with other interventions that may produce the same effect? Pharmaceutical, surgical and non-invasive therapies (e.g. art therapy) may provide similar benefits, but cost more or less than a physical activity intervention. Given the potential range of health-enhancing effects of physical activity across physical and psycho-social dimensions, the question of efficiency becomes extremely complex, and is beyond the scope of this article. It does, nevertheless, remain an important issue for public health.

Finally, we briefly consider the implications of this evidence for public policy in areas of research, service delivery, and education and training.

Prevalence of physical activity

In this section, we report on the prevalence of physical activity in older adults (aged $\geqslant$65 years) in England. The results are mainly based on the most recent cross-sectional data from the 1998 and 2000 Health Surveys for England (HSE) (Department of Health, 2000, 2002). In the 2000 HSE, physical activity was only assessed for older adults living in care homes and not in private households. Care homes included residential homes that provide board and personal care only and nursing homes that are intended to accommodate those requiring frequent or constant daily nursing care. The 1998 HSE was a nationally representative sample of adults living in England. Respondents to both surveys were asked about the frequency, duration and intensity (whether or not the activity made them out of breath and sweaty) of different types of activity (including occupational physical activity, walking, sport and recreation, and domestic physical activity) in the 4 weeks before being interviewed. The results in this section are based mainly on data from the 1998 HSE.

Walking is the most popular form of physical activity for all adults and arguably most amenable to change (Department of Health, 2000). Of the respondents aged 65 years and over, 3.9% reported not being able to walk at all (see Table 1). The proportion increased sharply with age, particularly over the age of 80, rising to 13% of adults aged 85 and over. Overall, 8 out of 10 older adults walked for a period lasting at least 5 min in the 4 weeks before the interview, reducing from 88% to 52% across age bands. Three-quarters of older adults walked for a period lasting at least 15 min in the 4 weeks before being interviewed, again with a significant decline with age.

Self-reported usual walking pace is independently associated with a reduced risk of premature mortality (Manson *et al.*, 2002). In older adults, few walked at a pace described as fairly brisk or fast, the pace associated with a reduced risk (see Table 2). Just 16.4% usually walk at this pace, with 30% usually walking at a slow pace. Over 90% of adults aged 85 and over describe their usual walking pace as ‘steady average’ or ‘slow’. Substantially fewer older adults in care homes walk for 15 min continuously at least once per month at a brisk/fast pace than older adults living in private households (see Table 3).

To give an indication of the proportion of older adults who walk at a level that may benefit their health, Table 4 shows the proportion of older adults walking for an accumulation of at least an hour per week, independent of usual walking pace, and at least an hour a week at a fairly brisk or fast pace. While just over a sixth of older adults walk for an hour or more per week, approximately half that number do so at a usual walking pace that is fairly brisk or fast. It is likely that to confer significant health benefits, the usual walking pace needs to be at least brisk.

Table 1. Percentage of older adults participating in at least one 5-min and one 15-min bout of walking in the 4 weeks before their interview, by age group

	Age group (years)					
	65–69 ($n = 982$)	70–74 ($n = 820$)	75–79 ($n = 741$)	80–84 ($n = 436$)	85+ ($n = 291$)	All ($n = 3270$)
Walked 5 min	88.0	85.9	81.5	74.8	51.5	81.0
Walked 15 min	80.4	78.0	75.8	66.6	57.3	75.7
Unable to walk	2.1	2.0	2.7	7.6	12.7	3.9

Source: Department of Health (2000).

Table 2. Self-reported 'usual walking pace' of older adults, by age group

	Age group (years)					
	65–69 (%)	70–74 (%)	75–79 (%)	80–84 (%)	85+ (%)	All (%)
A slow pace	21.3	24.6	32.0	47.5	61.3	30.1
A steady average pace	58.7	56.8	52.8	44.2	31.3	53.5
A fairly brisk pace	18.2	17.8	13.7	7.1	6.0	15.0
A fast pace (at least 4 miles$\cdot$h^{-1})	1.9	0.9	1.5	1.2	0.7	1.4

Source: Department of Health (2000).

Table 3. Percentage of older adults participating in at least one 15-min bout of brisk/fast-paced walking in the 4 weeks before their interview, by age group within care homes and private households

	Care homes				Private households			
	65–74 years	75–84 years	85+ years	All	65–74 years	75–84 years	85+ years	All
Men	4	1	1	1	16	9	6	13
Women	1	3	0	1	15	8	—	10

Source: Department of Health (2000, 2002).

In the USA, the American College of Sports Medicine and the Centres for Disease Control (Pate *et al.*, 1995) published a landmark paper outlining new physical activity recommendations for health. It stated that all adults should exercise for 30 min on at least 5, but preferably all, days of the week at a moderate intensity. Moderate intensity was defined as any activity with an energy cost of 3–6 METs. This was interpreted as any activity with an effort equivalent to brisk walking for that person. The proportion of older adults in England meeting the current public health recommendations for physical activity is low and declines rapidly with age (see Table 5). Overall, nine out of ten older adults are not active at the recommended level, with a marked drop in participation rates over the age of 74 years. Table 5 also shows the proportion of older adults participating in less than one 30-min bout of physical activity per week, often categorized as inactive. Two-thirds are at this level, with nine out of ten of those aged 85 years and over exercising for less than 2 h in the 4 weeks before their interview.

In summary, few older adults participate in levels of physical activity (particularly walking) that may benefit their health. Physical activity levels are similar for adults aged 65–74 years, with a sharp decline from the age of 75 onwards. Participation rates are particularly low in older adults living in care homes. More analysis of the

Table 4. Percentage of older adults walking at least 60 min per week at any pace and at a fairly brisk or fast pace, by age group

	Age group (years)					
	65–69	70–74	75–79	80–84	85+	All
⩾60 min walking per week	22.1	20.0	16.1	10.3	5.2	17.1
⩾60 min walking per week at a fairly brisk/fast pace	11.8	11.6	7.2	4.1	1.4	8.8

Source: Department of Health (2000).

Table 5. Percentage of older adults exercising at recommended levels and 'inactive'* in the 4 weeks before their interview, by age group

	Age group (years)					
	65–69	70–74	75–79	80–84	85+	All
⩾20 occasions of at least moderate intensity physical activity	14.9	13.5	7.4	4.4	1.0	10.2
Less than 4 bouts of at least moderate intensity physical activity *	54.1	59.8	71.7	80.2	91.0	66.3

Source: Department of Health (2000).

data would be required to understand how much of this is due to physical limitations or poor health.

Due to the limited data available on physical activity patterns in this age group, there is no national trend data. A better understanding of participation in physical activity could be gained if future Health Surveys for England, which focus on older adults, did not restrict questions on physical activity to those living in care homes. Further research is needed to understand better how physical activity participation rates in this age group vary according to ethnicity and socio-economic status. This would help guide the development of urgently needed physical activity interventions targeted at older adults.

Physical activity and cardiovascular health

Cardiovascular mortality/morbidity and ageing

The latest figures from the UK National Office of Statistics (2002: www.statistics.gov.uk) suggest that diseases of the circulatory system accounted for 40% of all deaths in the UK in 2001. While these figures highlight the high public and private cost of cardiovascular disease in our society, they tend to mask the fact that cardiovascular disease is a major killer in older populations. For example, of the 240,267 circulatory deaths recorded in 2001, 96% occurred in individuals aged 55 years and over, and 71% in those aged 75 years and over, indicating that cardiovascular disease is predominantly associated with ageing. Of equal concern are the morbidity data that quantify the prevalence of cardiovascular disease in the population. These data estimate that there are currently 1.2 million people in the UK who have had a heart attack at some time (around 63% are over the age of 65 years), and 2 million people that have or have had angina (40% are over the age of 75 years). Cardiovascular disease, therefore, represents a significant challenge to the quality of life experienced by older adults in our society.

Given the demographic shift towards an older and less active population, and the fact that physical inactivity is implicated as a major risk factor in the development of cardiovascular disease, this section will review the changes that occur in the cardiovascular system with ageing, the effect that physical activity/exercise interventions have on the cardiovascular system, and the associated benefit in reducing the risk of developing such disease.

Ageing and the cardiovascular system

With ageing there is a progressive deterioration in the cardiovascular system that results in reduced cardiac output from the left and right ventricles and leads to an associated reduction in oxygen transport to the tissues. This is the result of structural and functional changes in both the central (the heart and coronary circulation) and the peripheral (major conduit vessel and microcirculation) circulations. The combined central and peripheral changes lead to an impairment in cardiac filling, an increased afterload (increased resistance to ejection of blood out of the heart) and altered cardiac function that includes reduced sensitivity to catecholamines and decreased heart rate. Independently, these changes might appear quite subtle, but in combination they contribute to the well-reported decline in maximal oxygen uptake ($\dot{V}O_{2max}$) and cardiac performance observed during maximal exercise in older adults (Lakatta, 1993). However, the interpretation of age-related decreases in endurance capacity is complicated by the generalized reduction in levels of physical activity, the increased prevalence of underlying coronary heart disease (and other pathologies) and changes in body composition that occur with ageing. Despite this, it is evident that apparently healthy individuals experience decreases in endurance capacity and functional capacity of the cardiovascular system with ageing.

Submaximal exercise

The cardiovascular responses of older individuals to submaximal exercise are different to those observed in a younger population. At the same relative work intensity ($\%\dot{V}O_{2max}$), heart rate is reduced and stroke volume is lower, effectively producing a decreased cardiac output (Rodeheffer *et al.*, 1984; Fleg *et al.*, 1995). During exercise at the same absolute intensity, cardiac output is diminished, whereas arteriovenous oxygen difference (a-vO_2diff) is somewhat higher to compensate for reduced delivery of oxygenated blood, and reduced plasma, red cell and total blood volume. In addition, blood pressures are generally higher in older individuals during exercise (Stratton *et al.*, 1994), increasing afterload and further limiting ejection fraction from the left ventricle. Although total peripheral resistance shows a progressive decline during incremental exercise in both young and old adults, afterload in older individuals is increased further with age as total peripheral resistance is generally greater in older than younger individuals at comparable work intensities (Ogawa *et al.*, 1992). This reflects changes in arterial compliance and resistance to blood flow in peripheral circulations.

Maximal exercise

Endurance capacity, as derived from measurements of $\dot{V}O_{2max}$, decreases by 5–15% per decade after the age of 30 years, the degree of change being inversely related to the physical activity status of the individual (Heath *et al.*, 1981). Given the Fick equation ($\dot{V}O_{2max} = Q \times$ a-vO_2difference), such a decline must be due to age-related impairments in cardiac output, oxygen extraction at the tissue or a combination of both. Indeed, since maximal heart rate declines by 6–10 beats·min^{-1} per decade, and that during maximal exercise in populations over 65 years there is a decline in stroke volume of the left ventricle (Mazzeo *et al.*, 1998), it is evident that a large proportion of the decrease in $\dot{V}O_{2max}$ can be accounted for by a reduced cardiac output at maximum. The remainder of the decrease in $\dot{V}O_{2max}$ is due to reduced oxygen extraction that may relate to morphological and biochemical changes in skeletal muscle and age-related sarcopenia.

In addition, the output of the left side of the heart is also compromised by an increase in afterload, due to higher systemic blood pressure and vascular resistance with age (Stratton *et al.*, 1994). Consequently, end systolic volume is increased in older individuals, which results in a reduction in ejection fraction (Rodeheffer *et al.*, 1984; Stratton *et al.*, 1994; Fleg *et al.*, 1995). Many of these changes have been attributed to ageing and the development of cardiovascular pathology. However, the association of a physically inactive lifestyle with the development of these changes is highlighted by the observation that endurance training reverses many of these age-related adjustments.

Endurance training

It is now clear that the capacity of the cardiovascular system to adapt to an endurance training load is not affected by age. 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 offered and also the state of training before the start of the programme (Lakatta, 1993). The degree of trainability also 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 and peripheral changes (increases in Q and a-vO_2diff), 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, 1999).

Both cross-sectional and longitudinal studies have demonstrated that following training older men rely to a greater extent on the Frank Starling mechanism to augment cardiac output (Ehsani *et al.*, 1991; Forman *et al.*, 1992; Seals *et al.*, 1994; Stratton *et al.*, 1994). This is manifested by an increased stroke volume and ultimately an enhanced cardiac output and $\dot{V}O_{2max}$.

Following 12 months of training in men, Ehsani *et al.* (1991) reported a 23% increase in $\dot{V}O_{2max}$, a significantly greater ejection fraction and an associated reduction in end-systolic volume, despite similar increases in systolic blood pressure and therefore afterload. In addition, there were proportional changes in end-diastolic volume and posterior wall thickness. This suggests that the mechanisms responsible for these changes relate to modification of cardiac structure, possibly due to an expansion of total blood volume. Several studies also report enhanced diastolic filling, possibly due to enlarged ventricular chamber size (Levy *et al.*, 1993). Ejection fraction is also enhanced after training due to increased contractile function of the left ventricle. This change in inotropic status of the left ventricle after training in older men is abolished by ß-adrenergic blockade, suggesting that any improvement in post-training systolic function is attributable to an enhanced response to ß-adrenergic stimulation (Spina *et al.*, 1998). Increased ejection fraction is also facilitated by a reduction in afterload. With ageing there is a progressive increase in vascular stiffness and aortic impedance, which can dramatically increase afterload (Vaitkevicius *et al.*, 1993). However, vascular stiffness is inversely related to $\dot{V}O_{2max}$ (Vaitkevicius *et al.*, 1993), implying that as levels of physical activity and endurance capacity increase, vascular stiffness and therefore afterload decrease, allowing for an augmentation of stroke volume. The combination of increased responsiveness to ß-adrenergic stimulation and reduced afterload, therefore, help explain the increase in cardiac output after endurance training in older men.

The improvement in $\dot{V}O_{2max}$ in women is similar to that in males following a training programme, but this is achieved solely by an expansion of a-vO_2diff, as there are no exercise-induced increases in left ventricular mass, cardiac output, ejection fraction, stroke volume or end-diastolic volume during maximal exercise. To study this phenomenon further, Spina *et al.* (1993) subjected older males (63 years) and females (64 years) to 9 months of endurance training and found increases in $\dot{V}O_{2max}$ of 19 and 22%, respectively. In the men, two-thirds of the increase was attributable to a greater cardiac output and one-third due to an expansion of a-vO_2diff; in the women, peripheral adaptations such as increased capillarization and increased activity of mitochondrial enzymes accounted for all the observed improvement in $\dot{V}O_{2max}$. In young men and women and older males, exercise-induced increases in cardiac output are associated with ventricular hypertrophy following endurance training (Spina, 1999). However, this is not observed in post-menopausal women, and may partially explain the observation of no change in cardiac function (Spina *et al.*, 1993). Alternatively, the lack of oestrogen in post-menopausal women may increase vascular stiffness and increase afterload, which may operate to counteract any increase in ventricular performance seen as a result of training. In addition, oestrogen and progesterone have been shown to improve endothelial function in both the coronary (Gilligan, *et al.*, 1994) and peripheral circulations (Taddei *et al.*, 1996), and consequently the post-menopausal deficiency of these hormones may be associated with increases in central and peripheral arterial impedance, thereby limiting blood flow to certain circulations. Further research is required to elucidate the exact mechanisms responsible for these observations of reproductive hormone-related changes in cardiac and peripheral function.

Peripheral circulations and ageing

In addition to the deleterious effect that ageing has on the central circulation, the peripheral circulation is also exposed to change in older populations. The maximum reactive hyperaemic flow (the maximum flow achieved after 5 or 10 min of total occlusion of a given circulation, e.g. the forearm) is diminished with age (Martin *et al.*, 1995). This measure provides an index of the structural status of the peripheral blood vessels and provides evidence that there are decreases in lumen size of the peripheral vessels, as a result of increases in arterial stiffness and perhaps the progression of atherosclerosis. In addition, there is also evidence of endothelial dysfunction with ageing. The endothelium plays a crucial role in the control of vascular tone and structure through the release of nitric oxide (a smooth muscle relaxing factor) and therefore is a key regulator of systemic blood pressure (Vallance *et al.*, 1989). With ageing there is a reported impairment in endothelial-dependent vasodilation, which has been shown both in the peripheral forearm circulation (Gerhard *et al.*, 1996) and the central coronary circulation (Egashira *et al.*, 1993). This impairment has been reported to be secondary to an oxidative stress-induced reduction in the release of nitric oxide from the endothelium (Taddei *et al.*, 2000).

Physical exercise has been shown to improve endothelial-dependent relaxation in healthy older humans (Taddei *et al.*, 2000) and also in patients with chronic heart failure (Hornig *et al.*, 1996). This important exercise-induced effect on the endothelium has many potential clinical implications for older populations. Improved endothelial function can protect the vessel wall from the development of atherosclerosis and thrombosis, whereas dysfunctional endothelium can actively promote vascular damage and consequent plaque formation (Ross, 1993). By protecting the endothelium, physical activity could therefore be responsible for the beneficial effect of exercise and the decreased risk of cardiovascular disease demonstrated in older people that walk further than 1.5 miles per day (Hakin *et al.*, 1999) and at a brisk pace (Manson *et al.*, 2002).

Effect of endurance training on cardiovascular risk factors in older healthy men and women

Since cardiovascular disease is the major cause of death in older men and women, the impact of endurance training on the modification of morbidity and mortality rates is of prime importance. However, to date there have been no long-term prospective primary prevention data available to examine any such association in an older population. Consequently, research has addressed this question by investigating the effect of endurance training on modifiable risk factors, such as low cardiovascular fitness, blood lipid profile, insulin resistance/glucose tolerance, hypertension and obesity in older individuals.

Both cross-sectional and intervention data indicate that several risk factors are changed for the better. As previously mentioned, endurance capacity had been reported to increase by an amount that is dependent on both the intensity and duration of the training programme. Low-intensity (40–60% $\dot{V}O_{2max}$) prolonged training produces improvements of 12%, compared with a 20–30% increase after training at 75% $\dot{V}O_{2max}$ (Lakatta, 1993). In terms of any modification of total cholesterol and its various subfractions, the data remain equivocal in older populations. 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 positive 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 (Hurley and Hagberg, 1998). Relatively few long-term studies have addressed the effect of endurance training on the modification of hypertension in older adults. Following 9 months of training, Hagberg *et al.* (1989) reported similar decreases in systolic and diastolic pressure to those seen in a younger population after low-intensity training (50% $\dot{V}O_{2max}$).

The prevalence of glucose intolerance, insulin resistance and hyperinsulinaemia increases with age (Muller *et al.*, 1996), and with the increased deposition of adipose tissue in the abdominal region. Although these are both independent risk factors for the development of cardiovascular disease, they are also the precursors to the cluster of pathologies (insulin resistance, obesity, hyperlipidaemia, hypertension) known as metabolic syndrome, or syndrome X. The prevalence of this form of 'lifestyle' type II diabetes is increasing in all age groups in our society, but particularly in those aged over 50 years. However, just as there are encouraging improvements in lipid profile and blood pressure with endurance exercise, training is also reported to enhance glucose disposal, due to an increase in insulin sensitivity (Dengel *et al.*, 1996) in obese sedentary men. Endurance training is also associated with reductions in central body fat stores (Kohrt *et al.*, 1992) in 60- to 70-year-old men and women, leading to reductions in body fat, fat mass and waist-to-hip ratios.

Despite a lack of prospective studies addressing the impact of exercise/activity programmes on risk of cardiovascular disease in older populations, the data reported above demonstrate that many of the important independent risk factors can be positively modified in older men and women. Most studies with older adults (age 60–85 years) have used exercise intensities that ranged from 50 to 70% $\dot{V}O_{2max}$ and exercise durations that ranged from 6 to 12 months. An important question to be addressed in future exercise/activity prescription research in this population is the exact dose of exercise required to see the modification of risk factors outlined above. However, given that in the population in general moving a person from the lowest quintile of cardiovascular fitness to the next quintile (still a level of below-average age-related fitness) is associated with the greatest reduction in all-cause mortality (Blair *et al.*, 1989), perhaps exercise practitioners need only encourage low- to moderate-intensity exercise.

Summary

It is evident that healthy ageing is associated with many central and peripheral changes in the cardiovascular system. These adaptations are exacerbated by the presence of pathology and physical inactivity and increase the risk of developing some form of circulatory disease. However, it is also evident that these age-related changes can be reversed by increasing levels of physical activity, suggesting that the functional capacity of the central and peripheral circulations are equally responsive to exercise-induced adaptation in old and younger populations. Although specific prospective studies are not yet available, such endurance training is associated with positive modification of the major risk factors for cardiovascular disease. Future research should examine the integrity of the cardiovascular system as a whole (by investigating both central and peripheral adaptations) during the ageing process, and specifically identify the effect of training and hormonal status on the central and peripheral cardiovascular response to exercise in older women.

Physical activity, sarcopenia, bone health and falls prevention

Prevalence and aetiology of sarcopenia

It is widely recognized that the loss of muscle mass associated with ageing (sarcopenia) is one of the main determinants of musculoskeletal frailty and reduced locomotory function in old age. The prevalence of clinically significant sarcopenia markedly increases with age from about 13 to 24% of persons aged 65–70 years to over 50% of those older than 80 years. The prevalence increases in both men and women, but it is actually higher in men older than 75 years of age (58%) than women (45%). However, sarcopenia is believed to be a greater public heath problem in women, since they live longer and have higher total rates of disability (Wang *et al.*, 1989).

Although the aetiology of sarcopenia is rather obscure, the fact that it occurs even in master athletes who maintain very high levels of physical activity suggests that ageing *per se* is the main cause of the loss of muscle mass (Roubenoff and Hughes, 2000) and that disuse contributes by accelerating this process. Furthermore, simple disuse leads to reversible muscle atrophy but not to a loss of fibre number, whereas sarcopenia involves both (Lexell, 1995). Disproportionate type II muscle fibre atrophy is typically found in old age, whereas the proportion of type I and type II fibres is generally unaffected.[1] Neurological changes, hormonal changes and cell death (apoptosis) are believed to be the main mechanism responsible for sarcopenia (Dirks and Leeuwenburgh, 2002). A progressive loss in the number of excitable motor units occurs with ageing. This is consistent with the observation of a reduction in both number and diameter of motor axons in the ventral roots and is associated with drop-out of the larger nerve fibres following segmental demyelination (Vandervoort, 2002). Recently, much attention has been given to the role played by growth hormone and insulin-like growth factor (IGF-1) in the development of sarcopenia, since both hormones are required for maintenance of muscle mass during adulthood (Hameed *et al.*, 2002). Both growth hormone and IGF-1 secretions decline in old age, and growth hormone replacement therapy in old men with low initial concentrations of IGF-1 has been shown to normalize IGF-1 concentrations and significantly increase lean body mass and lumbar vertebral density (Rudman *et al.*, 1991). However, the increase in rate of protein synthesis produced by strength training combined with growth hormone administration to older men with low concentrations of circulatory growth hormone and IGF-1, is not greater than that achieved with training alone (Yarasheski *et al.*, 1995). In men, a reduction in testosterone is a contributing factor to the loss of muscle mass in old age and testosterone administration has been shown to promote protein synthesis (Editorial 1992). In women, there is evidence of accelerated loss of muscle mass (and gain in fat) around menopause, suggesting that oestrogen could have a role in supporting muscle mass (Roubenoff and Hughes, 2000). Also, oestrogen and testosterone have been shown to inhibit the production of catabolic cytokines such as interleukin-1 and interleukin-6, suggesting that low concentrations of these hormones may have both a direct and indirect catabolic effect on muscle (De Sanford and Wood, 1992; Pottratz *et al.*, 1994). However, more research on the effects of oestrogen on muscle mass is needed before clear-cut conclusions may be drawn. The action of insulin, one of the major anabolic hormones with respect to muscle, also appears to decline with age. The action of insulin on protein turnover appears to be primarily that of inhibiting protein breakdown rather than stimulating protein synthesis. An increased insulin resistance with age may thus potentially contribute to sarcopenia.

Apoptosis is undoubtedly a major cause of sarcopenia. In young men aged 20–29 years, cell mass represents 59% of lean body mass, whereas in men aged 80–89 years cell mass is only 46% of lean body mass. Although cell death may occur via several mechanisms, the common pathway involves denervation, resulting in neuronal cell death with subsequent loss of muscle fibres by apoptosis and failure to regenerate. In this process, mitochondria have been indicated as major regulatory centres for apoptosis (Green and Reed, 1998). It cannot be excluded that motoneuron death is the result of cessation of the alleged neurotrophic retrograde effect of muscle fibres on the motoneuron (i.e. denervation), resulting in neuronal cell death with subsequent loss of muscle fibres by apoptosis and failure to regenerate (Wang, 1999).

Functional significance of sarcopenia

The most obvious consequence of sarcopenia is a loss of muscle strength and power. It is noteworthy that across the age range of 65–89 years, the rate of fall of muscle power (3.5 % per annum) is greater than the rate of fall of muscle strength (1–2% per annum) (Skelton *et al.*, 1995). Functionally this is extremely relevant, since most daily activities, such as the displacement of body weight during walking or rising from a chair, require the

[1] With ageing, there is a loss of both type I and type II muscle fibres. Each population of muscle fibre decreases in size, but this phenomenon is more marked for type II fibres. However, the *proportions* of type I and type II fibres need to be maintained, at least up to about the mid-seventies.

generation of power rather than strength alone. Indeed, a positive correlation has been described between muscle power and activities of daily living, especially if power is normalized for body weight (Bassey *et al.*, 1992; Skelton *et al.*, 1994). Since lean body mass decreases with old age with a concomitant increase in fat mass, displacement of the body, such as during walking, will place a greater metabolic load on muscle fibres leading to a rise in the energy cost of walking (Martin *et al.*, 1992; Minetti *et al.*, 2000). Hence sarcopenia not only leads to muscle weakness and reduced mobility, but is also associated with an increased metabolic cost of movement. From the second to the seventh decade, the strength of the main extensor muscles of the lower limbs declines by about 40% (Harridge and Young, 1998); however, the loss of muscle strength is much greater than that of muscle size – that is, there is a decrease in the intrinsic strength of skeletal muscle. Although neural factors, such as a decrease in neural drive, contribute to this phenomenon, muscle fibres themselves are able to generate less force per unit size. Recent evidence suggests that this may be due to a decrease in myosin content as a result of ageing as well as disuse (D'Antona *et al.*, 2003).

Muscle weakness and bone loss

Muscle weakness in old age may compound the problem of brittle bones by increasing the risk of falls (Marcus, 1995). Also, muscle weakness appears to have a direct effect on bone status, since muscle strength and age together were found to explain approximately 30% of the variation in spine and distal femur bone density and 16% of that in cortical bone density (Rutherford and Jones, 1992). However, the close association between muscle and bone changes was not explained by declining physical activity levels (Rutherford and Jones, 1992).

Lower limb muscle weakness has been found to be highly predictive for the incidence of falls (Chu *et al.*, 1999). This relationship is extremely important given that approximately 30% of individuals aged over 65 years fall at least once per year. A great proportion of these falls results in fractures and more than 90% of hip fractures are due to falls. The outcome of these fractures is fatal in 12–20% of cases. In the UK, for the year 2000 alone, the estimated hospital costs related to hip fractures amounted to £1.3 billion (Carter *et al.*, 2001).

Although controversy still exists as to whether osteoporosis can be prevented, or mitigated, by physical exercise in old age, recent evidence suggests that high-impact aerobic exercise is effective in maintaining bone mineral density in post-menopausal women and men over 50 years old. Indeed, aerobic exercise has been shown to lead to an increase in bone mineral density of the lumbar spine (Dalsky *et al.*, 1988; Snow-Harter, 1992), forearm (Smith *et al.*, 1989) and proximal femur (Welsh and Rutherford, 1996). Furthermore, high-impact aerobic exercise in individuals over 50 years has been found to inhibit bone resorption, or even enhance bone formation, as judged by a reduction in urinary secretion of pyridinoline and deoxypyridinoline cross-links (Welsh and Rutherford, 1996). Although the use of urinary pyridinoline for the assessment of bone resorption is still widespread, it has been found that *N*-terminal telopeptides of type I collagen (CTx) is a more specific marker of bone resorption than pyridinoline. Modifications of type I collagen structure are in fact likely to be involved in decreased bone strength associated with osteoporosis. Indeed, several biochemical studies performed on bone specimens taken from patients with osteoporosis have shown abnormalities in post-translational modifications of type I collagen molecules (Boskey *et al.*, 1999). These age-related transformations can be detected *in vivo* by measuring urinary excretion of the corresponding CTx using specific antibodies (Garnero *et al.*, 2002).

To date, the age-induced changes in bone mineral density induced by physical activity have been investigated in the lumbar spine, the radius and ulna, and the proximal femur, whereas there is a paucity of data for the tibia, one of the main bones of the locomotory system. However, a recent study using peripheral quantitative computed tomography has demonstrated a significant association between physical activity levels and bone mineral density of the tibia in post-menopausal women of mean age 67.3 years (Uusi-Rasi *et al.*, 2002). One of the main advantages of peripheral quantitative computed tomography is that, compared with dual-energy X-ray absorptiometry, it enables the differentiation of cortical from trabecular bone (Rittweger *et al.*, 2000).

From a review of the literature, it would appear that most studies on bone mineral density have been performed on young and middle-age to old populations, with very few having investigated whether physical activity may increase or maintain bone mineral density even in very old age; hence the interest in the effect of physical activity in the very old and oldest old individuals.

Effects of physical activity on muscle weakness and incidence of falls

Although the benefits of aerobic exercise in mitigating the loss of aerobic capacity and reducing hypertension, the risk of cardiovascular disease and development of type II diabetes have long been recognized, this form of exercise is not effective in preventing the loss of muscle strength with ageing. In fact, individuals who maintain high level of endurance-based aerobic training in old age do not show a slower rate of decline of muscle strength of the main extensor muscles of the lower limbs (Harridge *et al.*, 1997). Also, the question of whether physical activity in young and middle age may contribute to mitigate the loss of muscle strength in old age has attracted many investigators in this field. Disappointingly, a recent survey (as part of the InCHIANTI study) carried out on 200 men and 232 women aged $\geqslant$65 years found no relationship between physical activity level in young and middle age and muscle strength in old age (Benvenuti *et al.*, 2000). In fact, once regular physical activity has been interrupted, three-quarters of the force gained is lost within 12 weeks, averaging to a rate of fall of about 2.5% per week (Taaffe and Markus, 1997). As a rough guide, it could be stated that about 75% of the benefits of strength training are lost within 3 months of ending training. Instead, regular resistive exercise has been shown to be highly effective in increasing muscle mass and strength, even in very old age. Significant improvements of muscle strength in old age have been observed in response to training with loads greater than 65% of the maximum load that can be lifted once (1-RM). Depending on age, gender, mode, duration, intensity and frequency of the training, initial level of fitness, and method of assessing muscle strength, increases of 8–174% have been reported (Rogers and Evans, 1993). In general, programmes involving 2–3 sessions per week at an intensity of 65–85% of 1-RM have been successful in improving muscle strength in old age. It is also noteworthy that elderly individuals display relative strength gains similar to those observed in young adults (Narici, 2000). A significant correlation has also been found between the increase in muscle strength and functional mobility, such as gait speed (Fiatarone *et al.*, 1990).

Physical activity, and in particular strength training, has been found to be effective in reducing the incidence of falls (Gillespie *et al.*, 2003), but further research is needed to determine if these effects can be sustained. Strength, flexibility, balance and reaction time can be effectively modulated by training to produce a reduction in the risk of falls. Since all of these factors are associated with risk of falling, much attention has recently been given to more holistic type of exercises based on strength, flexibility, proprioception and coordination. The interest in Tai Chi as a form of physical exercise particularly suited for the elderly has been steadily increasing over the last 10 years, and since the start of 2001 more than 20 SCI-cited papers have been published on the use of Tai Chi in old age. The following benefits have been reported after Tai-Chi training: (1) an increase in self-efficacy and physical function (J.X. Li *et al.*, 2001); (2) a reduction in the frequency of falls inside and outside the home, with some studies reporting a 48% reduction in falls in individuals in their seventies (Wolf *et al.*, 2001); (3) an increased cutaneous microcirculatory function during exercise (Wang *et al.*, 2001); (4) a 65% improvement across functional status measures ranging from daily activities such as walking and lifting to moderate-to-vigorous activities such as running; (5) an enhancement of cardiorespiratory function, immune capacity, mental control, flexibility and balance control (F. Li *et al.*, 2001); (6) better postural stability during complex dynamic balance tests, but no improvement in static balance (Wong *et al.*, 2001); and (7) an increase in aerobic capacity, thoracic/lumbar flexibility, strength of the knee extensors and knee flexors, and muscular endurance (Lan *et al.*, 2000). Tai Chi seems to be an alternative, but effective, form of exercise to prevent frailty in old age. Its use, in combination with strength-training exercises, may prove particularly useful for increasing strength as well as balance and coordination, with a measurable reduction in the incidence of falls.

Physical activity and psychological and social health

Many definitions of health-related quality of life have been proposed which are inclusive of different outcome measures (see Rejeski *et al.*, 1996; Spirduso and Cronin, 2001). We shall focus on the effects of physical activity as a prevention and adjunctive treatment of depression, and then consider its role in the prevention of premature loss of emotional, cognitive, social and perceived physical function, and physical symptoms, and in enhancing health-related quality of life among older people with disability and disease.

Depression

Copeland (1999) contends that depression is a powerful destroyer of quality of life in the elderly. Depression increases the risk for cardiac mortality in individuals with and without cardiac disease at baseline (Penninx *et al.*, 2001), and depressive symptoms have a considerable impact on the well-being and disability of older people while having clear economic consequences (Penninx *et al.*, 1999; Beekman *et al.*, 2002). Physical activity in alleviating depression in older adults has received growing research attention.

Epidemiological studies examining exercise and depression in the elderly tend to report an inverse relationship between level of physical activity and depression scores (e.g. Ruuskanen and Ruoppila, 1995; Hassmen *et al.*, 2000), with physical activity possibly performing a protective function against developing symptoms of depression (Mobily *et al.*, 1996; Lampinen *et al.*, 2000). A recent prospective study in a community-based sample of older men and women (aged 50–89 years in 1984–87) in southern California confirmed that exercisers had less depressed mood (Kritz-Silverstein *et al.*, 2001). However, exercise was not found to protect against future depressed mood for those not clinically depressed at baseline when physically disabled individuals at baseline were excluded. In contrast, Strawbridge *et al.* (2002) found a strong longitudinal protective effect for physical activity. This effect was not attenuated when physically disabled individuals were excluded in their prospective study of 1947 adults from the Alameda County Study aged 50–94 years at baseline in 1994. A one-point increase in the 1994 physical activity scale was associated with nearly a 20% reduction in the likelihood of becoming depressed in 1999.

Meta-analytic and experimental studies, including five randomized controlled trials (e.g. Blumenthal *et al.*, 1999; Singh *et al.*, 2001), consistently show a large antidepressant effect for exercise in older adults with clinical depression (Biddle and Faulkner, 2002). A recent study in the UK found that a significantly higher proportion of participants in an exercise group versus a control group (55 *vs* 33%) experienced a greater than 30% decline in depression according to the Hamilton Rating Scale for Depression (odds ratio = 2.51) (Mather *et al.*, 2002). On the basis of existing epidemiological and experimental evidence and that 'depression and poor physical function are mutually reinforcing, causing a progressive downward spiral in the physical and psychological health of older adults' (Penninx *et al.*, 1998, p. 1725), Biddle and Faulkner (2002) concluded that the potential of physical activity to have an antidepressant effect outweighs the possibility that it may not.

Emotional functioning and mental health

Petruzzello *et al.* (1991) provided the most comprehensive review of the anxiety-reducing effects of exercise. Only 6 of the 62 effect sizes used in their meta-analysis, with trait anxiety as the outcome, involved individuals over 45 years of age. The mean effect size for this age group was 0.41, similar to that in other age groups. With a variety of psycho-physiological correlates of anxiety as the outcome, 26 of the 138 effect sizes involved individuals over 45 years and the effects tended to be less than for other age groups. Taylor (2000) concluded from a review of reviews and a systematic review of recent research that more studies had involved older people but only half had shown aerobic exercise to reduce anxiety or psycho-physiological indices. There was also insufficient evidence to ascertain any effects of training on psycho-physiological reactivity to psycho-social stressors among older people. Most studies did not consider co-existing morbidity.

In terms of broader psychological well-being, national survey data from England show that positive mood (global set of affective states individuals experience on a day-to-day basis) is more common in frequently active older adults than those showing more sedentary lifestyles, even when excluding those who assessed themselves to be in poor health (Skelton *et al.*, 1999). Arent *et al.* (2000) conducted a meta-analysis with 32 studies of older people and found that exercise produced on average moderate improvements in mood (effect size = 0.34) in studies comparing an exercise training group with a control group. This appears to both reduce negative mood states as well as enhance positive mood states (effect size = 0.35 and 0.33 respectively), while both acute and chronic exercise are associated with effect sizes significantly greater than zero. The largest effects were found for resistance training (average gains effect size = 0.80). Several other programme characteristics seemed to produce more consistent desirable outcomes. In a systematic narrative review of studies published since 1995, Biddle and Faulkner (2002) similarly concluded that clear effects were evident for enhanced psychological well-being from physical activity in older adults, thus confirming earlier findings reported by McAuley and Rudolph (1995). These effects, often moderate in magnitude, appeared independent of research design, age, gender, length of physical activity intervention, psychological measures and nationality. Less research has examined the role of physical activity in improving self-esteem and physical self-perceptions of older adults, although existing research is supportive (e.g. Fox, 2000; McAuley *et al.*, 2000a). For example, in a randomized controlled trial, Taylor and Fox (in press) reported significant improvements in self-perceptions among 40- to 70-year-olds after a 10-week primary care exercise referral scheme, as well as 6 months later. Changes in self-perceptions were not related to change in fitness parameters, but were positively correlated with change in various anthropometric measures.

There is growing evidence that exercise for cardiac rehabilitation patients can have a small to moderate effect in reducing anxiety (effect size = 0.31) and depression (effect size = 0.46) (Kugler *et al.*, 1994). Fewer studies have involved other clinical groups, but reductions in anxiety have been shown for coronary obstructive pulmonary disease patients (Carrieri-Kohlman *et al.*, 1996), newly diagnosed breast cancer patients (Mock *et al.*, 1997) and patients with osteoarthritis (Penninx *et al.*, 2002). In the latter controlled trial with 439 patients over 60 years with osteoarthritis of the knee, aerobic but not resistance exercise reduced depression over 18 months, and the effects were evident for both low and high initial depressive symptomatology. Consequently, the potential psychological benefits associated with physical activity participation are not restricted to otherwise healthy older adults. In summary, evidence is consistent across a wide range of meta-analyses, randomized controlled trials and epidemiological surveys that physical activity can make older adults feel better.

Cognitive functioning

Several reviews have considered the effects of physical activity (as both a single session and training) on cognitive functioning among older people, but the different dimensions of both independent and dependent variables make this task complex. Some of the reviews have considered effects on both young and older people. Etnier *et al.* (1997) reported greater effects in a meta-analysis for 45- to 60-year-olds than both younger and older people, with significant effect sizes of 1.02 and 0.19 for those aged 45–60 and 60–90 years, respectively. However, one may question the value of such a meta-analysis, which collapsed evidence from nearly 200 (across all ages) acute and chronic exercise studies (often with poorly controlled exercise doses) with outcomes as varied as perception, reasoning, reaction time and memory tasks.

Tomporowski and Ellis (1986) focused on the effects of different intensities and durations of acute exercise and concluded that although several studies provided evidence that exercise produces short-term facilitative effects on mental tasks, there are methodological complexities that make the findings equivocal. Such effects may have an important role in preventing falls and accidents, but training studies may point to more lasting effects on delayed decline in cognitive functioning among older people. Chodzko-Zajko and Moore (1994) and Boutcher (2000) have reviewed the effects of chronic exercise on cognitive functioning among older people. Cross-sectional evidence showed that fit, older adults exhibited better cognitive functioning (reaction time, memory and fluid intelligence) than unfit older adults (Boutcher, 2000). The results of intervention studies designed to improve cognitive functioning have been equivocal (Boutcher, 2000; Biddle and Faulkner, 2002).

One reason for such inconsistency may be the wide range of cognitive processes addressed. Kramer *et al.* (1999) have argued that decline in performance is differentially distributed and greater in executive control processes such as planning, scheduling and working memory. Their randomized controlled trial with 124 adults aged 60–75 years compared aerobic exercise (walking) with anaerobic exercise (stretching/toning). The results showed that even small improvements in aerobic fitness improved performance on tasks primarily requiring executive functioning, while there was little improvement on other tasks. Future studies in this area need to control for medication, health status, initial activity level and dose of physical activity, and focus on specific outcomes that are significant to the functionality, health and well-being of older people.

Epidemiological evidence is also emerging. Yaffe *et al.* (2001) reported findings from a 6–8 year prospective study of nearly 6000 women over 65 years of age. Using the Mini-Mental State Examination, they reported that cognitive decline occurred in 17, 18, 22 and 24% of those in each quartile of both blocks walked per week and total energy expended per week (most active to least active), with an odds ratio of 0.66 (95% confidence interval = 0.54–0.82) for walking and 0.74 (95% confidence interval = 0.60–0.90) for total energy expended, comparing lowest and highest quartiles. This association was not explained by differences in baseline function or health status.

One mechanism proposed for these effects is increased cerebral blood flow or neurobiological processes during exercise (Cottman and Berchtold, 2002). There is some epidemiological evidence to suggest that physical activity may also be associated with the prevention or delay in development of dementia and Alzheimer's disease (Laurin *et al.*, 2001; McDowell, 2001; Schuit *et al.*, 2001). Using prospective data on over 9000 adults (> 65 years) from the Canadian Study of Health and Aging, Laurin *et al.* (2001) demonstrated that high levels of physical activity reduced the risk of cognitive impairment, Alzheimer disease and dementia by nearly a half. At least one trial is also under way to explore the treatment effects (Teri *et al.*, 1998) on patients with diagnosed Alzheimer's disease.

Social functioning

Spirduso and Cronin (2001) concluded that there was only scant evidence that physical activity programmes led to changes in social networks and participation in social groups. However, the study criteria for entry into this review may have been prohibitive. In the UK, the opportunities for social interaction provided by physical activity was an important motivation and benefit associated with physical activity in a qualitative study of English adults over 50 years of age (Finch, 1997). Other studies by Riddoch and colleagues (1998) and Hardcastle and Taylor (2001, in press) have also reported positive social benefits from exercise interventions involving older people.

Experimentally, the social relations developed within the exercise components of a randomized controlled trial in the USA were related to increases in satisfaction with life and reductions in loneliness in a sample of 174 adults (McAuley *et al.*, 2000b). In a meta-analysis of a series of randomized controlled trials examining the benefits of exercise in the frail elderly, exercise produced a small but significant improvement in the emotional health component of a quality-of-life measure but only trends towards an improved social component (Schechtman and Ory, 2001) were identified. While research directly examining the social benefits of exercise is limited, such benefits do appear plausible.

Perceived physical functioning

Elsewhere we consider objective physical functioning and ageing. Some authors (e.g. Rejeski *et al.*, 1996) suggest that objective and subjective indicators of physical functioning are only partially congruent and we therefore consider perceived physical functioning here. Reviews by McAuley (1994), Rejeski *et al.* (1996), Rejeski and Mihalko (2001) and Spirduso and Cronin (2001) have all emphasized the importance of considering an older person's self-efficacy to exercise or engage in activities of daily living as a critical indicator of health-related quality of life. There is strong evidence that initial low self-efficacy (as a component of emotional functioning) is one of the most important determinants of functional decline with chronic disease (e.g. Rejeski *et al.*, 2001), risk of falling (Tinetti *et al.*, 1988) and of future engagement in physical activities. Exercise programmes that aim to increase self-efficacy through a cognitive-behavioural approach have been successful (King *et al.*, 2000) in changing behaviour and outcomes but are relatively rare.

Tai Chi was discussed in a previous section in terms of its role in preventing frailty in old age. In one randomized controlled trial, 94 healthy older adults were randomly assigned to either a 6-month, twice weekly Tai Chi condition or a wait-list control condition (F. Li *et al.*, 2001). Participants in the Tai Chi condition experienced significant improvements in both self-efficacy and physical function over the course of the intervention. Furthermore, Tai Chi participants with lower levels of physical function at baseline benefited more from the Tai Chi training programme than those with higher physical function scores (F. Li *et al.*, 2002).

Physical symptoms

The effects of physical activity interventions on physical symptoms such as pain, fatigue, energy and sleep have all been considered by researchers. Rejeski *et al.* (1996) identified several studies that supported a beneficial effect of exercise on joint pain among patients with rheumatoid arthritis, knee osteoarthritis and other restrictive symptoms (e.g. breathlessness among patients with chronic obstructive pulmonary disease). There is increasing evidence for these effects (Ettinger *et al.*, 1997; King *et al.*, 2000; Miller *et al.*, 2001; Vuori, 2001). In their meta-analysis of the effects of aerobic exercise training on mood, McDonald and Hodgdon (1991) reported significant increases in vigour (effect size = 0.40) and reductions in fatigue (effect size = −0.27) but only two studies included older people. Recent randomized trials have shown positive effects on fatigue and energy in patients with heart failure (Oka *et al.*, 2000), chronic obstructive pulmonary disease (Foy *et al.*, 2001) and healthy older people (Cochrane *et al.*, 1998; Taylor and Fox, in press). However, in studies involving people with medical conditions, it has been shown that an ever improving standard of care makes it more difficult to show that exercise interventions make a difference. For example, Oldridge *et al.* (2002) calculated that numbers 'needed to treat' to reduce mortality from cardiac rehabilitation programmes had increased from 32 in 1988 to 72 in 2001.

Finally, sleep problems have been identified as an independent risk factor for falls among community-dwelling older people (Brassington *et al.*, 2000) and are associated with mental health problems. There have been two comprehensive meta-analyses in recent years (O'Connor and Youngstedt, 1995; Kubitz *et al.*, 1996) on the effects of chronic physical activity on sleep, but there were insufficient studies to examine effects specifically for older people. Exercise may be of moderate benefit in improving well-being in the population by improving sleep quality. A larger effect remains plausible for special populations, such as older adults, for whom sleep quality and quantity may be compromised. For example, King *et al.* (1997) and Naylor *et al.* (2000) have both provided evidence that increases in physical activity can improve sleep-related measures. Another randomized controlled trial found that a high-intensity progressive resistance training programme improved sleep quality in depressed elders (Singh *et al.*, 1997).

Summary

In summary, growing evidence supports the antidepressant effect of exercise and its role in improving emotional, cognitive, social and perceived physical function of older adults, and alleviating physical symptoms. There is clear support for the claim that 'physical activity and psychological function in the older adult are related' (ACSM, 1998, p. 1000). Current guidelines for physical activity are generally supported in terms of their potential for improving psychological well-being in older adults. Strength training, in particular, has the largest effect in terms of improving mood to complement its role in potentially reducing the incidence of falls. Further well-designed studies are required that also address comparisons with other psychosocial interventions and issues of clinical and cost-effectiveness. Finally, the role of physical activity in promoting social interactions and reducing the risk of social exclusion of older adults is a potentially rich avenue for future study. The elderly are particularly vulnerable to the effects of inequalities in health care and the environment and further research should carefully consider how these factors can be addressed through promoting physical activity. To maximize the effects of physical activity on quality of life, it is clear that a broad understanding of the social environment in which older people live is critical, in terms of formal and informal social support systems, perceptions of threat and access within the built environment. Only integrated policies that engage a variety of agencies (e.g. health and social services, housing associations, planners) will make a difference to perceptions of well-being and health-related quality of life, resulting from a more physically active lifestyle.

Interventions to increase physical activity

Despite the potential benefits of an active lifestyle, it is difficult to persuade older adults to become more physically active and to sustain this (Resnick and Spellbring, 2000). Adults participating in an exercise programme often fall back into their old inactive habits after the programme ends (Robinson and Rogers, 1994; Rhodes *et al.*, 1999). Furthermore, many physical activity interventions do not reach those older adults who would most benefit from them. Therefore, critical issues such as getting people to initiate and maintain physical activity need to be addressed. Information on the effectiveness of interventions (e.g. participation and change in physical activity levels) and on the factors that influence adherence can help in the design of more effective physical activity programmes for older adults (King *et al.*, 1998).

Effectiveness of physical activity interventions

A recently published systematic review (van der Bij *et al.*, 2002) considered evidence from 38 randomized controlled trials, comprising 57 physical activity interventions, aimed at promoting physical activity in older adults. Two outcomes were documented: (1) participation in the interventions and (2) changes in physical activity levels over time. There was evidence of high adherence to interventions; participation rates were 90% in home-based interventions and 84% in group-based interventions. These high participation rates were not sustained in long-term interventions ($\geqslant$1 year), but the decline was less strong in group-based interventions than in home-based interventions. Only a few of the included studies reported results for long-term changes in physical activity levels. King *et al.* (1998) also published a systematic review of randomized clinical trials using similar criteria for selection and determining participation. They concluded from 29 studies (including three quasi-experimental studies), involving adults over the age of 50 years, that there was evidence of high short-term adherence to interventions (mean = ~75%; median = ~ 80%). Higher maintenance was related to greater on-going support for participants, albeit from evidence with less rigorous follow-up measures. Less than half of the papers reviewed gave details of specific behavioural, educational, social, cognitive or programme-based strategies, but there is evidence that facility-alone strategies are less effective than those involving facility and home-based or supervised home-based interventions.

Van der Bij *et al.* (2002) also evaluated the effect of education or counselling interventions promoting physical activity. The effects of these interventions, however, were more variable, with only a minority of the participants attending all planned counselling sessions. Nevertheless, all six interventions reporting short-term results (<1 year) showed a significant increase in physical activity compared with a control group. Of the studies reporting long-term results, only three out of the nine interventions showed a positive effect on physical activity levels. A review of interventions aimed at promoting physical activity through primary health care identified a few large trials that demonstrated a small long-term effect of counselling (Taylor, 2002). Taylor categorized interventions as involving opportunistic and brief advice giving, exercise counselling, and screening/structured exercise support. It is evident that physical activity promotion in primary care is very variable, but the behaviour of doctors and nurses can be influenced. The merits of at least reinforcing physical activity behaviour were noted in a study by Taylor (1994) of 300 older people (mean age 63 years). Interviews revealed that those who had been advised by their general practitioner to exercise more were much more receptive *in situ* to public walking promotion signs in the community.

A recently published randomized controlled trial examined the effectiveness of two primary care-based one-to-one interventions for promoting physical activity. Participants received a brief negotiation intervention, a direct advice intervention or no intervention. The results showed that for primary prevention (for patients with no known medical condition), physical activity promotion in primary care is not effective (Hillsdon *et al.*, 2002), consistent with some other primary care-based physical activity trials (Bull and Jamrozik, 1998; Taylor *et al.*, 1998; Goldstein *et al.*, 1999; Harland *et al.*, 1999), though not specifically with just older adults. Further evidence is needed for secondary prevention (for patients with known medical conditions).

It can be concluded that high participation rates can be achieved with short-term physical activity interventions (<1 year), and that interventions are effective in increasing physical activity in the short term. However, evidence for long-term effectiveness was either absent (no follow-up) or showed little or no difference between intervention and control groups. The failure of long-term studies to maintain high participation rates and to change physical activity levels suggests that more effective approaches for maintaining exercise participation, especially in the long term, are necessary. Furthermore, the effectiveness of education or counselling interventions appears limited.

Factors influencing participation

It was suggested earlier that home-based interventions may promote equal or enhanced participation when compared with more conventional, supervised, group-based physical activity interventions. Yet, participation rates of home-based interventions and group-based interventions appear to be comparable (van der Bij *et al.*, 2002). Group-based interventions, however, appear to be more effective in the long term in achieving higher participation rates than home-based interventions. A study published by Gillet *et al.* (1996) also found no difference in exercise participation in an intervention group where participants were instructed to exercise individually at home compared to an intervention group that received a group-based exercise programme. Age also appears to influence participation. People aged less than 60 years have lower participation rates than those aged over 60 years. Nevertheless, even the very old ($\geqslant 80$ years) can be motivated to increase physical activity. Gender does not seem to influence participation, but in general more women participate in physical activity interventions than men.

Randomized trials comparing outcomes of different behavioural strategies suggest that some, such as team-building sessions, meetings, reminder telephone calls, and progress reports or other incentives, have a positive effect on participation. However, there is no clear evidence for the effectiveness of social and behavioural reinforcement strategies on the initiation and maintenance of physical activity (van der Bij *et al.*, 2002). Brassington *et al.* (2002) concluded that self-efficacy beliefs and fitness outcome realizations were associated with exercise adherence, whereas social support was not. It would appear, therefore, that interventions should also focus on increasing confidence in the elderly to overcome barriers to exercise and achieving relevant fitness outcomes in physical activity programmes. This view is also supported by a randomized trial conducted by Rhodes *et al.* (2001), who concluded that self-efficacy explained significant variance in adherence, whereas general social support and social support from the programme leaders did not.

Further randomized trials are needed to determine the long-term effectiveness of theoretically driven interventions to guide evidence-based programme development, in different settings and cultures. Multi-level interventions or behavioural strategies (e.g. safe community design, community-level resources, workplace promotion efforts, counselling in healthcare delivery systems, education) are necessary to promote long-term changes in physical activity.

To improve physical activity interventions, it is important that interventions are tailored to an individual's needs (National Blueprint, 2001). Two important factors that influence participation are personal choice and perceived behaviour (Biddle and Mutrie, 2001). Fear avoidance (e.g. fear of falling) may serve as a particularly potent barrier for older people (Bruce *et al.*, 2002). This view is supported by a study by Stewart *et al.* (2001) in which a physical activity promotion programme was set up based on a personal choice model to promote physical activity behaviour. Physical activity regimens were individually tailored by participants with the assistance of trained staff, who promoted activities that could be maintained throughout their lives by taking into account health problems, personal preferences for activities and other factors influencing maintenance on activity. The programme drew upon social cognitive theory and included principles of self-efficacy enhancement, readiness to change and motivational techniques. Results of the one-year programme revealed a significant increase in physical activity compared with control group participants.

Since new recommendations (ACSM, 1998) on regular low- to moderate-intensity exercise have been published for older people, interventions are increasingly being designed that show safe, maintained meaningful increases in activities such as walking, Tai Chi, light resistance training, balance training and chair-based exercise (Young and Dinan, 1994; Wolf *et al.*, 1996; Lan *et al.*, 1998; Hamdorf and Penhall, 1999; Zwick *et al.*, 2000; King, 2001; F. Li *et al.*, 2001; J.X. Li *et al.*, 2001; Mazzeo and Tanaka, 2001; Stewart *et al.*, 2001). However, attention should be given to the development and implementation of more intense and tailored interventions that include policy, environmental and behavioural support.

Cost-effectiveness of physical activity interventions

Finally, it is important to consider the potential economic benefits from increased physical activity, especially since the benefits are greatest for those over 45 years (Nicholl *et al.*, 1994). A variety of approaches have been used to calculate the potential costs and benefits of physical activity interventions, which may be dependent on: the cost of changing a behaviour, health-related quality of life, or quality-adjusted life years; the type of intervention delivered (frequency, duration, type of programme, level of adherence, etc.); and baseline lifestyle, health status, sex and age of the population. With all these possible variables the calculations are challenging, but Munro and colleagues (1997) suggested that it would cost £333 for each life year saved among those over 65 years, for a hypothetical sample of 1000 people with a twice-weekly exercise programme. Hatziandreu *et al.* (1988) had earlier suggested a figure of $11,313 per quality-adjusted life year for a 35-year-old male then exercising over 30 years. These are based on hypothetical estimations if the exercise dose is followed. In reality, the costs of delivering interventions and providing support to maintain a physically active lifestyle, knowing that many people will not become or remain active, are somewhat different. Stevens *et al.* (1998) estimated from their exercise referral intervention that it cost £650 to move someone from being sedentary, and £2500 to move such a person to the national guidelines of 30 min accumulated physical activity at least 5 days a week. Formal exercise sessions for older people may involve a greater cost than for younger people due to the need for higher levels of professional training, and perhaps lower initial levels of activity, influenced by co-existing health problems.

If the aim of exercise promotion is to prolong independent living among older people, then there is growing evidence that the benefits can outweigh the costs. Recent research (see earlier) is helping us to understand the most effective way of helping people become or remain active into very old age. Further research should attempt to calculate the costs of different interventions. As it becomes clearer what the health care costs associated with inactivity among older people are, then interventions can be designed with a cost up to the amount saved. However, these analyses are further complicated by changing normal standards of health care. Oldridge *et al.* (2002) has suggested that because post-myocardial infarction medical treatment has improved so much, it is rapidly becoming more difficult to show the benefits of a health promotion rehabilitation programme. It would be unethical to withhold an ever improving range of medical treatments from control patients in trials designed to test the effectiveness of exercise interventions. These changes make an understanding of the cost-effectiveness of interventions even more important.

Policy implications

Research

A multidisciplinary review that includes issues relating to efficacy and effectiveness (and cost-effectiveness) will inevitably identify wide-ranging consensus and gaps in our knowledge. In terms of prevalence of physical activity, it is clear from cross-sectional data that there is an age-related decline. As measurement techniques become more refined, and different parameters of physical activity (e.g. benefits of short bouts of exercise) become accepted in the efficacy literature, there is an urgent need to set up surveillance and monitoring systems to determine secular trends for physical activity among older people. We do not know, for example, how information technology is influencing physical activity patterns among older people, who are the fastest growing users of personal computers and the fastest growing demographic group. In terms of efficacy, there is strong evidence of the effects of physical activity (resistance, aerobic and other forms such as Tai Chi) on various dimensions of physical and psycho-social health and well-being, but less is known about how society impacts on physical activity behaviour and the effectiveness of interventions at different levels (i.e. community, primary care, individual).

Service delivery

The NHS National Service Framework for Older People (Department of Health, 2001b) identifies ways and standards to improve health services for older people. It focuses on health promotion and care for stroke, falls and mentally ill patients. Standards for patients with cancer and coronary heart disease (including cardiac rehabilitation) are dealt with generically in other national service frameworks. Within the health promotion standard, in the National Service Framework for Older People milestones are identified for influenza immunization, smoking cessation and blood pressure management, but targets are not set for assessing physical activity or developing training programmes that raise awareness of the benefits of physical activity and to deliver interventions. However, primary care trusts are required to develop falls prevention strategies that are inclusive of promoting physical activity. This review has identified bone density and muscle power among post-menopausal women as progressive problems. Falls prevention strategies (e.g.

Health Education Authority, 1999) run the risk of focusing on high-risk older people, which may be inadequate without a longer-term primary prevention perspective. The limited cost-effectiveness research literature clearly points to an economic benefit from physical activity promotion among older people, drawn from evidence on only a few dimensions of health (i.e. muscle power, balance and falls prevention). If calculations also included a reduced risk of coronary heart disease, enhanced psychological well-being (including the possible risk of dementia, depression and loss of independent living) and other health dimensions not included in the present review (e.g. enhanced immune function), then the combined health policy implications for promoting physical activity from middle age onwards would be inescapably large. In terms of secondary prevention (for people with known medical problems that occur largely within older populations), the evidence for physical activity interventions is growing. The implications are that health policy should be revised and resources for service delivery adjusted to reflect the needs of older people.

Exercise referral schemes have grown exponentially in the past 13 years, driven by the National Quality Assurance Framework for Exercise Referral Schemes (Department of Health, 2001b). It has been estimated that over 100,000 patients annually enter such schemes with a wide range of medical conditions. Collaboration between health services and community physical activity programmes is patchy, without any milestones and clear directives. The National Institute for Clinical Excellence could guide best practice for health service delivery of physical activity promotion across a wide range of medical conditions (physical and psychological) for which efficacy evidence exists. Where sufficient evidence does not exist, coordinated research priorities should be developed, with subsequent funding by research councils and health charities.

Education and training

Inevitably, professional practice lags behind research evidence. In the current climate of evidence-based practice, this review has important implications for education and training. There is an opportunity for many professionals who interact with older people to promote physical activity. The National Quality Assurance Framework for Exercise Referral Schemes (Department of Health, 2001b) provides a useful pyramid (see p. 10) in which the degree of risk from engaging in physical activity is matched against the skills and training of the exercise or health professional. The greater the risk to an individual of a particular type of health-enhancing exercise, the greater the need for education and training. In Taylor's (2003) framework for promoting physical activity in primary care, he identified three levels of action: opportunistic advice, counselling, and exercise screening and programming. In other words, most health professionals should recommend older people do more physical activity (at low to moderate intensity with little or no risk). Guidelines should be widely circulated to accompany training on contraindications to low to moderate exercise (e.g. walking) for the small proportion of older people at increased risk. Additional training should be provided to enable professionals working with older people to understand and implement behaviour change strategies during longer consultations and counselling sessions, to promote low to moderate physical activity. When the level of patient health risk increases or additional personal support is needed to facilitate behaviour change, appropriate education and training is needed for those professionals in a position to do this (e.g. those working in exercise facilities as part of a referral scheme, or in sheltered housing). Falls prevention training in the UK has been designed around these principles, with three levels of training, lasting from 1 to 3 days, for people with different baseline skills. There is evidence that those health professionals who are themselves physically active are three to four times more likely to promote physical activity. One strategy may be to focus on increasing awareness and personal physical activity levels among professionals (e.g. social workers, health visitors) and volunteers (e.g. home helpers) who interact with older people in a cascading approach.

Much of this discussion has focused on education and training within continuing professional development. There is also a need to prioritize education and training with respect to physical activity and older people for those individuals on a wide range of professional and non-vocational courses at sub-graduate, graduate and post-graduate level. It is essential to consider ageing as a natural process that can be slowed or speeded up by lifestyle. Understanding and influencing lifestyle requires a complex multi- or interdisciplinary approach.

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