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Importance of characteristics and modalities of physical activity and exercise in defining the benefits to cardiovascular health within the general population: recommendations from the EACPR (Part I)

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Abstract

Over the last decades, more and more evidence is accumulated that physical activity (PA) and exercise interventions are essential components in primary and secondary prevention for cardiovascular disease. However, it is less clear whether and which type of PA and exercise intervention (aerobic exercise, dynamic resistive exercise, or both) or characteristic of exercise (frequency, intensity, time or duration, and volume) would yield more benefit in achieving cardiovascular health. The present paper, as the first of a series of three, will make specific recommendations on the importance of these characteristics for cardiovascular health in the population at large. The guidance offered in this series of papers is aimed at medical doctors, health practitioners, kinesiologists, physiotherapists and exercise physiologists, politicians, public health policy makers, and the individual member of the public. Based on previous and the current literature, recommendations from the European Association on Cardiovascular Prevention and Rehabilitation are formulated regarding type, volume, and intensity of PA and exercise.

Keywords

Cardiovascular health, exercise, prevention, physical activity, physical training, risk factors

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Introduction

Heart and circulatory system diseases (cardiovascular disease, CVD) remain the single most common cause of death in Europe, accounting for over 4.3 million deaths each year.[1] The burden of CVD is progressively expanding with projected deaths currently at 23.6 million (34.8%) of the world population and to 4.7 million of the European population in 2030.[2] The results of the WHO MONICA project showed that the incidence of coronary events increased by 5% over the period 1990–2000. This is likely to increase to 25% by 2030.

CVD cost the European Union (EU) just under 192 billion euro in 2006, almost 110 billion of which were for healthcare costs and 82 billion were from lost productivity and the cost of informal care. The direct healthcare costs alone per resident of the EU amount to 223 euro per annum.[1,3]

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Whereas patients with established CVD have declared themselves to be at high total risk of a further cardiovascular event,[4] several models have been developed to assess the risk for CVD in asymptomatic subjects. The SCORE (Systematic Coronary Risk Evaluation) system is developed and derived from a large data set of prospective European studies, and is currently recommended by the ESC (European Society of Cardiology) to assess cardiovascular risk. It is now widely accepted that a strategy for individuals at high risk must be complemented by public health measures to reduce population levels of cardiovascular risk factors and the new onset of CVD. In this regard, three strategies for the prevention of CVD can be distinguished: population (primary), high-risk (primary), and secondary prevention.[5] The population strategy in particular is critical for reducing the overall incidence of CVD. This is done through lifestyle and environmental changes that affect the whole population without necessarily requiring medical examination. Physical activity (PA) is an essential component of primary and secondary prevention.[5] The time has now come to promote PA and healthy lifestyle habits through aggressive and global health policies.[6] Scientific guidance expressed in a meaningful way is required to enable the public in Europe and those with responsibility for health policy and practice, in order to bring about measurable changes in lifestyle that will eventually contribute to a decreased health burden on European society.

There is no doubt that health policy and practice has set out to inform the public on the benefits of PA. Questions remain about the primary and secondary requirements that are needed to reduce cardiovascular risk and about the differences between PA and exercise recommendations in the context of primary and secondary prevention. The contribution made by existing levels of fitness and the impact of increasing or decreasing these fitness levels has not, to date, been clarified in any European guideline.

This is the first of three papers which aims to make specific recommendations on the importance of characteristics and modalities of PA and exercise in the promotion of cardiovascular health within the general population. The second and third papers will focus on PA and exercise training in the management of cardiovascular health in individuals with cardiovascular risk factors (Part II) and in individuals with cardiac disease (Part III).

After some exercise and physiological definitions and a background on PA and physical fitness (PF), this paper will focus on the current literature regarding the influence of type and characteristics of exercise on cardiovascular health and on lifestyle approaches to increase PA in the general population. The guidance offered in this series of papers is aimed at medical doctors, health practitioners, kinesiologists, physiotherapists and exercise physiologists, politicians, public health policy makers, and the individual member of the public.

Physical activity and physical fitness context

Beneficial effects of regular PA and its role in maintaining cardiovascular health are well established. In order to compare and contrast current studies and make exercise recommendations for the future, it is necessary to provide some basic definitions and descriptions related to PA and physical fitness.

PA refers to any bodily movement produced by skeletal muscles that results in energy expenditure above the basal metabolic level.[7,8] Accordingly, energy expenditure reflects the energy cost or intensity for the given PA.[9,10] Sedentary behaviour is the antithesis of PA and exercise and, although strongly associated with CVD,[11] it is not covered in this paper as it requires very different strategies to alter sedentary behaviour. This paper is aimed at people engaging in PA and exercise.

Health-related physical fitness refers to the extent to which an individual possesses traits and capacities associated with low risk of development of hypokinetic diseases and conditions and includes morphological, muscular, metabolic, motor control, and cardiorespiratory traits. In this paper, the term PF mostly refers to aerobic endurance capacity as measured by peak oxygen uptake (VO_{2peak}). Research suggests that the higher the level of fitness in the field of aerobic endurance, the less likely an individual is to suffer premature cardiovascular death.[12–16]

There are many approaches used to express PA and exercise intensity or demand or to quantify energy expenditure. However, on a more pragmatic level, two traditional approaches are used worldwide. The first term or approach is the metabolic equivalent unit (MET), which expresses energy expenditure in multiples of resting energy cost. One MET is equivalent to an oxygen uptake (O_2) of 3.5 ml per kg body weight, which is the amount of energy expended during 1 minute of seated rest.[17] For comparison, 3 METs is equivalent to the cost of steady state walking at a normal speed, namely 2.5 mph or 4 km per hour. Compendiums have been developed that give considerable detail on MET costs for most physical activities.[18,19] The second approach, kilocalorie (kcal) utilization, uses a more absolute approach whereby the energy cost is expressed as the total energy yield for the activity which is available in various compendia.[20] Both approaches are useful in clarifying total workload and should not be seen as mutually exclusive, but that they are actually two sides of the same coin: kcal can be estimated from MET × time in hours × body weight in kg).

Although exercise and PA are often used interchangeably in wider media, it is important to recognize that guidance tends to separate the two. Exercise is considered a subcategory of PA and exercise or exercise training is, by definition, PA that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of PF is the objective.[7]

Aerobic exercise refers to activity performed at an intensity that allows the metabolism of stored energy to mainly occur through the use of oxygen. It involves large muscle groups in dynamic activities, resulting in substantial increases in heart rate and energy expenditure. Good examples are cycling, running, and swimming performed at low to moderate intensity.[21] In contrast, anaerobic exercise refers to movements performed at an increasingly high intensity unsustainable by O_2 alone or requiring the metabolism of stored energy to be mainly processed without oxygen (i.e. energy is predominantly provided by anaerobic glycolysis and stored phosphocreatine) or the use of muscles in a sustained isometric muscle action which are not working maximally but nevertheless do not utilize oxygen during the muscle contraction. Intermittent high-intensity exercise includes such a type of activity.[7]

Measurement of physical activity and fitness

The precise measurement of PA and PF is crucial in order to investigate population trends, make recommendations and explore relations with cardio-metabolic diseases. The method of doubly labelled water is the gold standard of quantifying PA but is time consuming and expensive. PA assessment methods that are particularly suited for use in population-based studies include accelerometry, pedometry, heart rate monitoring, heart rate and accelerometry combined, direct observation, and self-report questionnaires. The accuracy, validity, reliability, and cost effectiveness of each method has been extensively reviewed and found to vary considerably between approaches,[9,22,23] being clear that the choice of method and anticipated outcomes are influenced by age, ethnicity, and cognitive ability of the population. Fitness, defined here as peak oxygen consumption, is measured through more formal exercise testing or through submaximum tests where increments of exercise load are increased every few minutes until the person or exercise professional decide that a representative level of fitness has been reached. Extensive guidance exists on how best to implement fitness assessments in healthy people and those with cardiovascular disease.[24–26]

PA is typically quantified in terms of its frequency, intensity, duration, and time. These dimensions are used to describe the dose of PA or exercise needed to exhibit particular physiological responses and outcomes. Frequency refers to number of activity sessions per day, week, or month. The number of activity minutes in each session is described as time, while total time of activity session or of PA programme is termed duration. Intensity describes energy expenditure associated with certain PA (light, moderate, or vigorous). It can be expressed in many different ways, in relative or absolute terms (Table 1). Within the general population, however, moderate-intensity PA is usually defined as any PA level at which a person experiences some increase in breathing or heart rate and a rate of perceived exertion (RPE) of 11–14 on the Borg scale. The person should be able to carry on a conversation comfortably during the activity.[27] It is typically characterized as energy expenditure of 3–6 METs, for instance, brisk walking. Vigorous-intensity is any type of activity that is intense enough to represent a substantial challenge to an individual and results in a significant increase in heart rate, breathing frequency, and sweating. In terms of energy expenditure, it is equivalent to any activity that corresponds to more than 6 METs, for instance, jogging. Activities corresponding to less than 3 METs are characterized as light activities, but can, if the duration is sufficiently long, contribute to health.[28]

There are many ways to describe PA and the terms 'type and mode of PA' is often used to pull together

Table 1. Relative intensities for aerobic physical activity

Intensity	METs	$\%VO_{2max}$	%HRR	%HRmax	RPE scale	Examples
Low intensity, light effort	2–4	28–39	30–39	45–54	10–11	Light gardening, light walking
Moderate intensity, moderate effort	4–6	40–59	40–59	55–69	12–13	Brisk walking
High intensity, vigorous effort	6–8	60–79	60–84	70–89	14–16	Jogging
Very hard effort	8–10	>80	>84	>89	17–19	Running fast
Maximal effort	>10	100	100	100	20	Maximum sprinting

HRmax, maximum heart rate; HRR, heart rate reserve; METs, metabolic equivalents (1 MET, individual metabolic resting demand when sitting quiet, about 3.5 ml oxygen per kg per min, or 1 kcal [4.2 kJ] per kg per hour in the general population); RPE, Borg rating of perceived exertion (6–20 scale).

related terms. For instance, walking as a type of activity could include walking outdoors, on the flat, up or down hill, or treadmill walking. Typically exercise-related types of PA include walking, cycling, swimming, or running, because they have specific movement patterns and energy expenditure trends related to performing such activities. PA also includes a number of behaviours such as walking to the bus station, gardening, and building a brick wall. Therefore, 'total physical activity' includes all activities from different domains, such as active transportation, household activities, leisure-time physical activities (LTPA), and occupational physical activities. PA is routinely LTPA; occupational PA (time frame over which the activity takes place, e.g., 20–60 min for a fitness workout or 8 hours of daily physical work as done by manual labourers); or mode of exercise (walking, aerobic PA or resistance training, interval training).[15]

Evidence of benefits from meta-analysis and large cohort studies

The overall benefits of higher levels of PA and PF are known and beyond doubt,[12–14,16,29] which allows this paper to summarize these findings and then move on to the contribution made by the mode of PA and exercise.

Criteria of studies included

A large number of studies and meta-analyses have been published the last 30 years on PF and PA. For this updated literature summary, a computerized systemic literature search was performed in EMBASE, PUBMED, and MEDLINE databases to identify meta-analyses on the relationship between PF, PA, and cardiovascular outcomes for the period from January 2008 to October 2011. We used the search terms physical fitness, physical activity, mortality outcome, and meta-analyses. A total of eight relevant meta-analyses, each including more than 100,000 individuals, were selected. Also, results from large cohort studies ($n > 1000$ individuals in each study) published in the same period were taken into account to provide complementary information. Studies, published until 2007, were used by different authors in different meta-analyses and the latter were used in the present literature update.

Physical fitness and cardiovascular health

Over the past 20 years, it has become clear that measured aerobic capacity (for simplicity, we refer to it as PF) is strongly associated with all-cause mortality, coronary heart disease (CHD), and CVD events.[12–14,16]

In a recent meta-analysis, Kodama et al.[16] evaluated in detail PF as a quantitative predictor (measured by maximum METs performed) of all-cause mortality and cardiovascular events in healthy men and women. Based on an analysis of 33 studies including 102,980 participants, the authors concluded that a higher level of PF was associated with a lower risk of all-cause mortality and CHD/CVD events. Additional sensitivity analysis indicated that better PF was independently associated with longevity, while the inverse association between PF and risk of CHD/CVD was explained partly by the established coronary risk factors.

According to their subsequent dose–response analyses, a 1-MET higher level of maximal aerobic capacity (corresponding to approximately 1 km/hour higher running/jogging speed) was associated with 13 and 15% reductions in risk of all-cause mortality and CHD/CVD events, respectively. Their analyses suggest that the minimum PF level that is associated with significantly lower event rates for men and women is approximately 9 and 7 METs at 40 years old, 8 and 6 METs at 50 years of age, and 7 and 5 METs at 60 years of age, respectively.[16]

Physical activity and cardiovascular health

Already in the period 1990–2001, three systematic reviews[12,13,29] indicated a clear positive impact of PA on all-cause mortality. Since then, a large number of prospective cohort studies have been published. In 2008, Nocon et al.[30] provided a systematic review and an updated meta-analysis on the association of PA with all-cause and cardiovascular mortality. The authors included 33 studies with 883,372 participants with a follow up ranging from 4 years to over 20 years. Most studies included in this meta-analysis reported risk reductions of 30–50% for cardiovascular mortality and of 20–50% for all-cause mortality, with pooled risk reductions of 35% (95% CI 30–40%) for cardiovascular mortality and 33% (95% CI 28–37%) for all-cause mortality comparing high with low levels of PA, even after adjusting for other relevant risk factors. The most important reason for heterogeneity among risk reductions was the differing methods used to assess PA. Studies that used patient questionnaires to assess PA reported lower risk reductions than studies that used more objective measures/measurements of PA.

To quantify the association between walking and the risk of CVD and all-cause mortality, Hamer and Chida[31] performed a meta-analysis on 18 prospective studies which included 459,833 participants free from CVD at baseline with 19,249 cases at follow up. The pooled hazard ratio of CVD in the highest walking category compared with the lowest was 0.69 (95% CI 0.61–0.77, $p < 0.001$) and 0.68 (95% CI 0.59–0.78, $p < 0.001$) for all-cause mortality. Leitzmann et al.[32] evaluated the effectiveness of following PA guidance in 252,925 men and women and found favorable outcomes for those that adhered to guidance which was evident across different risk factor groups. Wen et al.,[33] in a prospective cohort study, found that as little as 15 min a day of moderate-intensity exercise (including PA) is associated with reduced premature death in 416,175 men and women in Taiwan. Taken together, the results of large cohort studies and recent meta-analyses show a very clear positive effect of PA on reducing risk of CVD and cardiovascular and all-cause mortality.

Based on the present data, it is clear that poor PF and inadequate PA are predictors of cardiovascular morbidity and mortality. Studies that have compared the effects of PF and PA on cardiovascular morbidity and mortality have generally shown that PF is more strongly correlated with outcome than PA.[12,13,34–36] A large cohort study by Lee et al.[37] that evaluated 31,818 men and 10,555 women confirmed that PF was more strongly associated with all-cause mortality than PA. Moreover, studies investigating the associations of PA and PF with CVD risk factors all conclude that the associations were most pronounced for PF.[38–42] However, as already pointed out by Blair et al.,[12] there are often quite different methodological approaches used when comparing different studies. Fitness can be measured more accurately by exercise testing and spiro-ergometry. PA however, especially when registered or observed over many years by questionnaires, may be less precise giving larger variations of estimated caloric expenditure.[11] Whether genetics may explain partly the better preventive effect of PF compared to PA remains to be elucidated.

Mode and characteristics of PA and exercise in defining outcome

Type/mode of physical activity

Most studies examining the effects of PA on CVD prevention have focused primarily on aerobic modes of exercise. However, over the last decade, resistance training has gained popularity and was recognized as beneficial, since it has the potential both to increase cardiorespiratory and muscular fitness and to decrease the risk for CVD.[43] Indeed, in healthy individuals with a low endurance exercise capacity, cardiorespiratory fitness may be improved effectively by resistance training.[44] Additionally, resistance training was found to have favourable effects on body composition, glucose tolerance, insulin sensitivity, and management of obesity.[45,46]

Although there are clear differences between aerobic and resistance exercise and continuous and interval training, there are no data in the population at large that show independent contributions of resistance or interval exercise to mortality reduction.

Leisure-time physical activity. The first meta-analyses focusing on the associations of PA on CHD incidence dealt with leisure-time and occupational activity.[29,47] However, PA can nowadays be equated with LTPA in industrialized countries and only LTPA can really be influenced by the recommendations of guidelines. In a specific meta-analysis on LTPA by Sofi et al.,[48] including 26 studies with an overall population of 513,472 individuals (20,666 CHD events), a moderate to high level of LTPA was associated with a reduced risk of CHD. Compared with individuals performing low or nil LTPA, highly and moderately active individuals had a 27 and 12% lower risk of CHD incidence or mortality, respectively.

Commuting physical activity. Active commuting, such as cycling and walking to work, provides a feasible method of integrating PA into daily life activities. In 2000, Andersen et al.[49] demonstrated a protective effect of active commuting on reducing the severity of cardiovascular outcomes. More recently, Hamer and Chida[50] performed a meta-analysis on the effects of active commuting on cardiovascular risk (defined as cardiovascular mortality, incident CHD, stroke, hypertension, or diabetes) based on eight studies (173,146 participants). The overall meta-analysis demonstrated a protective effect of active commuting on cardiovascular outcomes (integrated RR 0.89, 95% CI 0.81–0.98, $p = 0.016$). However, the studies included were mainly from one country (Finland) and used self-report data to assess commuting activity, which is imprecise and can be prone to recall bias. Also, some studies merely assessed the mode of transport used for commuting, while others assessed commuting time but not intensity.

Recent prospective research suggests that moderate-intensity active commuting is associated with improved biomarker profiles.[51]

Dose of physical activity

Vigorous-intensity exercise has been shown to increase aerobic fitness more effectively than moderate-intensity exercise, suggesting that the former may confer greater cardio protective benefits. In 2006, Swain and Franklin[52] summarized the epidemiological studies and evaluated the relationship between exercise intensity and incidence of CHD. The authors identified six studies that controlled for energy expenditure or that found a relationship between one intensity level and the incidence of CHD. All these studies reported greater benefits at higher intensities.

More recently, Löllgen et al.[53] performed a meta-analysis on 38 studies, involving more than 271,000 participants, to evaluate the effect of PA intensity on all-cause mortality. The focus was put on studies with three or four intensities of PA (e.g. none, light, moderate, or vigorous activity). A questionnaire was used to estimate the intensity of PA in the majority of these studies. The PA classification in the papers analysed mostly refer to kcal or MET-hours with describing inactive (or sedentary) as less than 200 kcal/week (or less than 1 MET), lightly active as 200–599 kcal/week (or 1–3 METs), moderate activity as 600–1499 kcal/week (or 3–6 METs), and vigorous activities with more than 1500 kcal/week (or >6 METs). This analysis showed that regular PA over longer periods of observation, ranging from 4 to 40 years, is strongly associated with lower all-cause mortality in active subjects compared to sedentary subjects. Importantly, the authors showed a dose–response curve especially from sedentary subjects to those with low and moderate exercise intensity, with only a minor additional risk reduction with further increase in activity level. Similarly, Sofi et al.[48] documented a dose-dependent protective role of LTPA that was independent of confounding variables, such as gender and methods to assess PA.

Likewise, Zheng et al.[54] tried to quantify the dose–response of walking in reducing CHD risk. The authors performed a meta-analysis including 11 prospective cohort studies and one randomized controlled trial with 295,177 participants free of CHD at baseline and 7094 cases at follow up. They showed that an increment of approximately 30 min of normal walking a day for 5 days a week (or 8 MET-hours/week) was associated with 11% CHD risk reduction (95% CI 4–18%). The dose–response relationship between walking and CHD risk in the eight studies where walking was based on a uniform measure of MET-hours/week was even more pronounced: an increment of 8 MET-hours/week was associated with 19% CHD risk reduction (95% CI 14–23%). Regarding walking pace, an increment of 2 km/hour was associated with 21% reduced risk of CHD (95% CI 15–27%). Regarding walking duration, an increment of 3.5 hours/week of normal walking was significantly associated with 32% CHD risk reduction (95% CI 11–48%). The results of this analysis indicate that walking conferred protection against CHD in a dose–response manner, irrespective of walking measures in walking velocity, time, or energy expenditure. Also in the meta-analysis by Hamer and Chida,[31] a dose–response relationship across the highest, intermediate, and lowest walking categories in relation to CVD and all-cause mortality was documented. However, in that analysis, walking velocity was a stronger independent predictor of overall risk compared with walking volume (48 vs. 26% risk reductions, respectively). Accordingly, data from the Copenhagen City Heart Study[55] indicate that the relative intensity, and not the duration of cycling, is of more importance in relation to all-cause and CHD mortality. In that study, the difference in expected lifetime in relation to intensity of cycling was also calculated. Men with fast-intensity cycling survived 5.3 years longer and men with average-intensity cycling survived 2.9 years longer than men with slow-intensity cycling. For women the perspectives were 3.9 and 2.2 years longer, respectively.

In a recent meta-analysis, Woodcock et al.[56] further evaluated the dose–response relationship of non-vigorous PA and all-cause mortality. The authors included 22 studies containing almost a million people and found that 2.5 hours/week of moderate-intensity PA was associated with a reduction in mortality risk of 19% (95% CI 15–24%), while 7 hours/week of moderate-intensity PA compared with no activity reduced the mortality risk by 24% (95% CI 19–29%).

Finally, Chomistek and Rimm[57] reported results from the Health Professionals Follow-up Study, where they evaluated whether vigorous activity, independent of the amount of time spent exercising, was associated with a lower risk of CVD, compared with moderate exercise. Baseline PA levels were first collected in 1986 in 43,647 individuals and assessed every 2 years thereafter until 2004. Individuals were followed for the primary endpoint of combined fatal CHD, nonfatal myocardial infarction, and fatal and nonfatal stroke. The total volume of PA (expressed as METs-hours/week) at all intensity levels appeared to be associated with the largest reduction in risk. Among individuals who exercised the same number of MET-hours/week, vigorous activity was associated with a trend towards lower risk of CVD compared with individuals who performed moderate activity.

Guidance for specific subgroups

Elderly

The majority of meta-analyses reviewed found no evidence of heterogeneity between subgroups of studies defined by age when evaluating the effects of PF and PA on cardiovascular and all-cause mortality.[16,30,31,58]. A study by Ueshima et al.[59] in 10,385 Japanese subjects aged 65–84 also showed that PA was associated with a clear reduced risk of all-cause and CVD mortality in this elderly population. Leisure-time PA was also associated with a 15–35% reduction in all-cause mortality risk in the Leisure World Cohort study (including over 13,000 people with a median age at baseline of 74 years).[60] Higher levels of duration and higher levels of intensity of PA were also associated with lower mortality in a study by Hrobonova et al.[61] that included 1449 participants aged 75–84 years.

There are very few studies on aged populations beyond 85 years and in this population there is little evidence on the effects of PA on mortality.[62] In this subgroup, easily achievable lifestyle habits should be encouraged and further evaluated as preventive measures to reduce cardiovascular events.

Gender

Most large cohort studies in women and the meta-analyses on the effects of PF or PA on cardiovascular and all-cause mortality have shown similar risk reductions in women compared with men.[16,30,31,53,63] Taken together, the effects of PF and PA intensity on cardiovascular outcome seem to be largely comparable in women and in men.

Race

Data on racial differences regarding the prognostic value of PF and PA are scarce and no systematic review or meta-analysis could be identified from the literature search. Albeit a retrospective observational study investigating physical inactivity, Williams et al.[64] found that inactivity in South Asian people living in the UK was associated with CHD mortality. Some other studies documented the prognostic value of PF in black populations[65] or PA in Japanese individuals,[59] but clearly more studies are needed on this topic.

Lifestyle approaches to increase PA in the general population

There is substantial evidence that PA levels in the general population have been decreasing, with more than 60% of the world's population not engaging in enough PA[66] and the reduction in PA from lifestyles of bygone eras.[67] Reasons for this are numerous, but mainly point to the fact that our daily living environments in a number of areas are simply less conducive to PA. Areas influencing this are:[68] transport (e.g. the increased use of cars, and perceived or real danger from walking or cycling), urban planning (e.g. lack of public parks and athletic fields, work places and shopping centres becoming more distant), technical advances (e.g. elevators and escalators rather than stairs), occupational changes (e.g. increasing service sector instead of manual work seen in agricultural/industrial settings), institutionalization of childhood (e.g. longer school hours with increasing academic demands), and changing leisure-time activities (e.g. use of computer-related activities).

Thus, interventions to increase PA in the general population could potentially address all of the above and include incorporating multi-method or 'ecological' approaches, involving a broad range of sectors; targeting individuals (both intrapersonal and interpersonal), institutions, communities, environments, and policies are likely to reap greater benefits than concentrating on individual areas alone.[68] Using this type of approach is likely to echo the success of other multi-method campaigns – such as smoking or the use of seat-belts (albeit the use of legislation seemed to be the most effective methods in these campaigns – an option that may not be available for PA campaigns).

Population interventions for increasing PA can be divided into two main areas – targeting children and adolescents (e.g. at school, during leisure time), and targeting adults (e.g. at work, during leisure time).

Children and adolescents

Several systematic reviews have demonstrated the link between low PA levels and an increase in cardiovascular risk factors also in children (e.g. increased risk of obesity).[69–72] In addition, children are an especially important group to target as evidence suggests that those who engage in PA at young age are likely to continue this habit[73,74] later in life.

Children spend a longer time in school than in previous years, and physical education classes have been reduced over time.[68,75] For example, both attendance at non-vocational schools for adolescents and school PA-related policies were consistent predictors of childhood PA levels in a recent systematic review.[69] Furthermore, cycling or walking to school is on the decrease, due to real or perceived traffic danger,[68,69,76] and lower PA levels can be attributed to these factors. However, given the captive audience, this could be a prime opportunity for intervention, being a 'win–win' situation for a number of reasons:

- there is strong evidence that school-based physical education increases PA to recommended levels;[69,77,78]
- test results in core academic subjects are not reduced by increasing physical education lessons,[79] or may even be increased;[80]
- increasing physical education increases children's health;[69,72]
- there is the possibility of superior cognitive functioning, including better concentration in class, in children and adolescents with higher PA levels.[81,82]

Thus, schools should be a prime target for interventions to increase PA.

School interventions to increase PA in children and adolescents. A Cochrane review has demonstrated that, in 26 moderate-to-high quality studies, school-based PA interventions increased duration of PA, reduced television viewing, increased VO_{2max}, and reduced blood cholesterol. Also, simply increasing the time spent on physical education or activity breaks is effective.[70,78] Furthermore, a later review showed that school interventions may decrease the prevalence of obesity.[83] After-school interventions increase PA levels and fitness, with reductions in blood lipids.[84] Further research is needed on interventions that increase LTPA – although the results suggest that such interventions may not be successful unless implemented outside of school.

Schools should therefore be mandated to provide recommended amounts of PA each day. Schools and parents should also be encouraged to promote walking or cycling as the main mode of transport when attending school. A variety of organized or unorganized physical activities need to be promoted throughout the school day.[68] There is also a need to promote a commuting infrastructure (see below).

Leisure-time interventions. Non-school-based variables that have been associated with lower PA levels are as follows: low PA levels of the father, less time spent outdoors, less social support, lower education level of the mother, lower family income, and higher rates of crime.[68,69] Thus, taking such factors into account may provide promising opportunities for effective interventions. Indeed, multifactorial interventions have provided the best approaches for increasing PA in adolescents.[74] However, findings from research on increasing LTPA in adolescents is mixed, and better-quality studies are needed.[85,86]

Screen-based activities may also be looked on as an opportunity for PA promotion. Recent reviews demonstrate that PA interventions delivered via the internet appear to provoke a similar response to more established interventions.[87–89] There is also a suggestion from the literature that exergaming (using video-console games that require PA, e.g. games for Nintendo Wii or Xbox360) may provide increased levels of moderate-intensity PA – although not as much as doing the actual activity.[89–95] For example, Leatherdale et al.[91] showed that, when measuring 51 undergraduate students playing active and inactive videogames, estimated kcal energy expenditure was higher among those with active videogames than sedentary ones (97.4–192.4 kcal vs. 42.3–64.7 kcal). However, conclusive evidence is currently unavailable and large randomized controlled trials are required.[87,95]

Adults

Interventions to increase PA need to be targeted at work and towards leisure-time activities.

Interventions for increasing PA at work. There is substantial evidence that work-related PA is decreasing.[75] Given the increasing distances travelling to work and decreasing PA from active commuting, this highlights the need for work-related PA interventions.[68] Interventions for increasing PA at work have been successful. A recent meta-analysis of studies of PA interventions in the workplace ($n = 38{,}231$ participants) showed significant increases (demonstrated by Cohen's d effect sizes) in the following: PA, $d = 0.21$; fitness, $d = 0.57$ (corresponding to VO_{2max} of 3.5 ml/kg/min); lipids, $d = 0.13$; anthropometric measures, $d = 0.08$. Furthermore, these interventions demonstrated positive benefits for work attendance ($d = 0.19$) and job stress ($d = 0.33$).[96] Modest weight reductions (−1.3 kg) can also be achieved, if dietary intervention is added.[97] Evidence-based guidance on promoting PA in the workplace is widely available.[98]

Exercise and corporate wellness. Many corporations have included exercise facilities and/or programmes as a part of their worksite health promotion, fitness, wellness, and cardiac rehabilitation programmes. The Johnson and Johnson 'Live for Life' programme has previously been made available to more than 25,000 employees at 43 locations in the USA, Puerto Rico, Canada, and Europe.[99] This proved to be one of the few programmes that attempted to compare the effectiveness of selected cardiovascular/lifestyle risk reduction interventions through a randomized controlled study. It showed statistically significant improvements in weight reduction, exercise tolerance, and blood pressure control within the treatment population. Healthcare savings of $225 per employee were also found from the 'Live for Life' health and wellness programme.[98] Burton et al.[100] examined the effect of participation on productivity in a worksite fitness programme. Non-participants in this study were twice as likely to report health-related work limitations in the areas of time management and physical work. They also recorded more days absent from work when compared with their more active counterparts. This trial promoted the use of exercise (15–45 minutes every other day) and was a precursor to the Stanford HEAR2T programme, a large part of which targeted cardiovascular risk reduction in the workplace.[101] Subsequently the ADIFIT FOR LIFE programme implemented some of the approaches used in the Stanford HEAR2T programme, showing lack of exercise training to be a significant cardiovascular factor among the 174 employees studied. The ADIFIT FOR LIFE programme has a key focus on the test–retest of key cardiovascular risk factors, with a concentration on healthy nutrition and regular exercise as main interventions for improving lifestyle and exercise tolerance and reducing cardiovascular risk.[102] This has resulted in reducing annual employee absenteeism rates from 6.8 days to 2.6 days per year. Corporate wellness with an emphasis on the promotion and implementation of PA or regular exercise was a key feature within this programme. Coupled with this, compliance to the programme amongst Adidas employees was 65%, compared with an average corporate engagement to fitness and wellness programmes within the UK of 25–30%.[103]

Other programmes that have recently focused on exercise as a key intervention in the corporate setting include Unilevers' 'Fit Business programme', did not have a significant impact on improving the attitude and behaviours of employees towards exercising. Interestingly, 84% of employees responding to the survey at the office site felt that their employer did encourage them to exercise, compared with only 23% at the factory site. The former had an onsite free-of-charge state-of-the-art gym including space for exercise classes, while the factory location has a small gym not on site and not free of charge. Clearly this study suggests that location and cost can have a significant effect upon approaches and attitudes taken towards exercise by employees.[103] A recent review of Brown et al.[104] assessed different outcome measures, grouped in 'workplace wellbeing', 'psychosocial wellbeing', and 'physical wellbeing', with absenteeism being the most commonly assessed outcome measure. Evidence indicated a positive association between PA and psychosocial health in employees, particularly for quality of life and emotional wellbeing. However, findings were inconclusive as to the role of PA in promoting workplace wellbeing.

Active commuting to work. Walking has been shown to be protective of incident CVD, with those engaging in high levels of walking having a 31% reduced risk of developing CVD when compared to those in the lowest walking category.[31] A recent meta-analysis has also demonstrated the benefits of walking or cycling to work.[50] However, subgroup analysis showed that this result was only significant for women, who demonstrated a 13% reduction in cardiovascular risk, whereas the 9% reduction seen in men was nonsignificant.[50] Thus, structural interventions which promote active commuting would be of benefit, such as measures to increase/improve public transport access,[105] but more research is needed to determine appropriate interventions for both sexes (especially men).

Leisure-time physical activity. Levels of LTPA seems to be increasing for adults, whereas work-related PA is decreasing, and these reductions actually outweigh the increases seen for LTPA.[75] A recent systematic review has quantified the association between LTPA and incidence of first CHD in initially health individuals.[48] Meta-analysis from 26 studies ($n = 513{,}472$; 20,666 CHD events) showed that, in comparison to those reporting low or no levels of PA, those who reported high levels of PA were 27% less likely to develop CHD, and those who reported moderate levels were 12% less likely to develop CHD. One methodological issue with this review was the inability to define levels of PA more precisely – the authors had to rely on the original classifications from the primary studies in several cases. A strength of these findings is that the majority of the data reported in primary studies was adjusted for traditional or emerging risk factors. Thus, the overall effects can be considered to be relatively robust and there is the possibility of overadjustment.

Various systematic reviews have demonstrated the effectiveness of several population-based strategies for increasing LTPA.[48,77,106–110] These have been broadly classified recently by the Community Guide as informational approaches, enhanced access to locations for LTPA and social/behavioural interventions.[77]

A systematic review of 10 studies showed that an approximate 4% increase in PA levels, with a corresponding increase in energy expenditure of 16%, are seen in communities exposed to multicomponent, broad-based campaigns which also addressed diet and smoking.[77] There is evidence that interventions delivered without face-to-face contact do provide increases in PA, at least in the short term.[108] Thus, such interventions do not always require direct, one-to-one intervention, and effective results may be achieved relatively inexpensively.

Point-of-decision prompts (e.g. signs encouraging use of stairs instead of lifts/elevators) also have some evidence to suggest effectiveness for increasing PA.[111] A median 54% increase in the use of stairs was demonstrated in one review.[77]

Mass-media campaigns run as single-component interventions do not seem to increase PA levels.[77] However, it is possible that single component interventions such as media advertising or point-of-decision prompts may even be enhanced when combined with other interventions, although further work is needed to evaluate this.

Enhancing access to PA locations (e.g. providing walking routes, access to exercise facilities) was reported to be especially effective in one systematic review of 12 studies.[77] This review demonstrated that PA frequency increased by 48%, energy expenditure by 8%, and aerobic capacity by 5%.

Social/behavioural approaches aimed at population level are also effective in increasing PA levels.[77,105] Some examples of effective interventions are as follows: contract system with peer, or buddy system (i.e. partner to engage in PA with 44% increase in time spent on PA, 20% increase in PA frequency, 5% increase in aerobic capacity); and individually tailored interventions (35% increase in time spent on PA, 6.3% increase in VO_{2max}, 64% increase in energy expenditure, and other increases such as number of PA sessions conducted, proportions of participants commencing PA, frequency of PA). Thus, non-family social support is effective. Interestingly, there was insufficient evidence that family-based social support interventions (often as adjunct to school interventions) were effective.[77] Intervention approaches to promote LTPA may also include strategies that develop self-efficacy, increase enjoyment and intentions, enhance behavioural skills, and provide childcare options.[112] Moreover, the use of pedometers was found to be a useful tool for providing motivation and visual feedback in a workplace PA programme.[113]

Unfortunately, there is a lack of data evaluating interventions to increase participation in sport when delivered by sporting organizations,[114] and this requires more research.

Cost–benefit analysis has shown that active transport, comprehensive worksite approaches, individually-adapted behaviour change, creation of locations for PA along with information services, have shown these interventions to be cost effective,[77,109] but more cost-effectiveness data is required.[115]

Active environments

The significance of our physical environment for promoting or reducing PA should not be underestimated.[116] For example, vigorous PA has been associated with availability of appropriate PA equipment.[105] Furthermore, trail connectivity is associated with the use of active commuting.[105] Such results have implications for both commuting PA and LTPA. However, there are inconsistent findings and limited strength of evidence in this area.[101,117,118] At present, the current evidence generally does not support the hypothesis that multicomponent community-wide interventions effectively increase population levels of PA[118] and, therefore, further research is needed on multicomponent interventions.

Social status and minority groups

Much of the research outlined above may have differential effects across minority groups and socioeconomic classes. For example, multicomponent interventions for increasing PA in children/adolescents seems to be more effective among the middle classes than among lower classes, and commuting activity may be protective for women only.[50,119,120] Also, there is a lack of data on the effects of interventions among minority groups.[120–122] In general, more research is needed on the effectiveness of the above interventions in minority groups.

Overall conclusions and recommendations

Low levels of PF and PA are clearly associated with increased CVD risk and all-cause and cardiovascular mortality. From comparative studies, it appears that these associations seem to be stronger for PF as compared to PA. For PA intensity, a dose–response curve on cardiovascular outcome has been demonstrated in most studies, but the additional risk reduction from moderate to vigorous intensity seems to be small. These results seem to be applicable in men and women as well in the elderly. However, data on racial differences are scarce.

PA interventions can be targeted at children and adults in two spheres: during or commuting to work/school and during leisure time. Effective measures aimed at children/adolescents are increasing physical education and active breaks in school. Evidence for effective LTPA interventions specifically for children/adolescents is more limited. However, it is possible that effective LTPA interventions for adults will also increase family LTPA.

Work-place interventions to increase PA are effective. Improving the health of employees by promoting exercise and healthy eating should be clear corporate and government priorities within the European Union. Furthermore, structural interventions to increase PA during commuting could be considered. There is emerging evidence for the following to increase LTPA in adults: multicomponent interventions based in community-wide campaigns, non-family social support, individually adapted health behaviour change, enhanced access to locations for PA (public parks, athletic fields, fitness facilities, etc.) when combined with information activities, and point-of-decision prompts. Other interventions (e.g. mass media campaigns delivered as a single component) do not have enough evidence for current recommendations. However, it is possible that these other interventions may enhance the effectiveness of the above recommendations in a synergistic way when used in combination,[68,77] but further research is needed to elucidate this.

Cost–benefit analyses have shown that such approaches are cost effective.

Recommendations

General recommendations for PA and exercise

In 2007 the European Guidelines on cardiovascular disease prevention in clinical practice recommended that healthy people, in all age groups, should choose enjoyable physical activities, which fit into their daily routine, preferable for 30–45 minutes, 4–5 times weekly in order to prevent or delay the onset of cardiovascular disease.[5] Accordingly the 2007 ACSM/AHA recommendations state that all healthy adults aged 18–65 years will benefit from moderate-intensity aerobic (endurance) PA (such as walking briskly with a noticeable acceleration of heart rate) for a minimum of 30 minutes on 5 days each week or vigorous-intensity aerobic PA (such as jogging with rapid breathing and a substantial increase in heart rate) for a minimum of 20 minutes on 3 days each week. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation. In addition, every adult should perform activities that maintain or increase muscular strength and endurance a minimum of 2 days each week. Therefore, 8–10 exercises should be performed on 2 or more non-consecutive days each week using the major muscle groups. To maximize strength development, a resistance (weight) should be used that allows 8–12 repetitions of each exercise resulting in volitional fatigue. Muscle-strengthening activities include a progressive weight-training programme, weight-bearing calisthenics, stair climbing, and similar resistance exercises that use the major muscle groups.[15]

Recommendations for mode and characteristics of PA and exercise

Based on previous[30,48] and the current literature overviews, it is clear that PA at a moderate intensity such as walking and cycling have a considerable impact on CHD events. Therefore such activities a few hours per week should be recommended to all adults. The additional benefit of vigorous-intensity aerobic PA can be deducted from the dose–response curve for PA and addition of 2 hours per week high-intensity activities can be recommended. More research is needed to elucidate this.

Before engaging in regular PA, an appropriate evaluation of middle-aged and older individuals should take place as moderate and vigorous physical exertion is associated with a small but significant increased risk for cardiac events. Such evaluation should vary according to the individual's cardiac risk profile and the intended level of PA. For practical recommendations regarding risk assessment, we refer to a recent EACPR position paper.[26] Table 2 summarizes the general recommendations for PA and risk evaluation of PA at the population level. In Table 3, more specific recommendations, derived from several previous recommendations are given according to age, mode of activity, PA intensity and volume, and exercise test results.[15,123–131]

This paper (Part 1) has shown that the mode and characteristics of PA and exercise can influence CVD-related outcomes in the wider population. The key recommendation is that PA and exercise interventions should be tailored, in accordance with the literature, to optimize outcome.

Table 2. General recommendations for physical activity at the population level[22,118–120]

A. It is recommended to perform enjoyable physical activities which fit into daily routine on most days of the week, that consist of the following:
  1. Aerobic training:
    a. Moderate-intensity aerobic PA for a minimum of 30 minutes on 5 days/week. Moderate-intensity PA is equivalent to a brisk walk with a noticeably acceleration of heart rate

or

    b. Vigorous –intensity aerobic PA for a minimum of 20 minutes on 3 days/week Vigorous-intensity PA is equivalent to jogging and causes rapid breathing and a substantial increase in heart rate

or

    c. A combination of the above, to meet the global weekly PA volume
  2. Muscular strength training: should be carried out twice weekly on major muscle groups

B. Evaluation of the risk for performing PA varies according to the intended level of physical activity and of the individual's cardiac risk profile[26]
  a. Self-assessment of the habitual PA level and of the risk factors[a] is recommended for large populations screening
  b. Individuals deemed to be at risk require further evaluation by a qualified physician
  c. In senior/adult individuals with an increased risk for coronary events, maximal exercise testing (and possibly further evaluations) is advocated

[a]Self-assessment of risk factors by revised PAR-Q or AHA/ACSM Fitness Facility Preparticipation Screening questionnaire, as highlighted in Börjesson et al.[26]

Table 3. Recommended components of physical activity for health benefits

	Mode of activity	Frequency (days/week)	Duration (min/day)	Intensity	Volume
Adults[22,118–120]	Aerobic	≥5	≥30	40–60% VO_{2max} or 50–75% HRR	Energy expenditure ≥1000 kcal/week
	Resistance	≥2 non-consecutive	≥30	40–60% 1 RM	1–3 sets; 8–12 reps; 8–10 exercises
Elderly[118,121,122]	Aerobic	≥5	≥30	40–60% VO_{2max} or 50–75% HRR	Energy expenditure ≥1000 kcal/week
	Resistance	≥2 non-consecutive	≥30	40% 1 RM	1–2 sets; 10–15 reps; 8–10 exercises
	Flexibility and balance exercises	≥5	≥10	20–40% HRR	10–30 s for a static stretch; 3–4 reps
Young[123–126]	Aerobic	≥5	≥60	>60–75% VO_{2max} or 50–85% HRR	Energy expenditure ≥1500 kcal/week
	Resistance	2 or 3 non-consecutive	≥30	40–60% 1 RM	Isotonic machines or free weights; 1–3 sets; 6–8 reps; 5–8 exercises

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