Evidence-informed physical activity guidelines for Canadian adults

Darren E.R. Warburton, Peter T. Katzmarzyk, Ryan E. Rhodes, and Roy J. Shephard

Abstract: This review of the literature provides an update on the scientific biological and psychosocial bases for Canada’s physical activity guide for healthy active living, with particular reference to the effect of physical activity on the health of adults aged 20–55 years. Existing physical activity guidelines for adults from around the world are summarized briefly and compared with the Canadian guidelines. The descriptive epidemiology of physical activity and inactivity in Canada is presented, and the strength of the relationship between physical activity and specific health outcomes is evaluated, with particular emphasis on minimal and optimal physical activity requirements. Finally, areas requiring further investigation are highlighted. Summarizing the findings, Canadian and most international physical activity guidelines advocate moderate-intensity physical activity on most days of the week. Physical activity appears to reduce the risk for over 25 chronic conditions, in particular coronary heart disease, stroke, hypertension, breast cancer, colon cancer, type 2 diabetes, and osteoporosis. Current literature suggests that if the entire Canadian population followed current physical activity guidelines, approximately one third of deaths related to coronary heart disease, one quarter of deaths related to stroke and osteoporosis, 20% of deaths related to colon cancer, hypertension, and type 2 diabetes, and 14% of deaths related to breast cancer could be prevented. It also appears that the prevention of weight gain and the maintenance of weight loss require greater physical activity levels than current recommendations.

Key words: active living, chronic disease, diabetes mellitus, dose–response relationships, health, hypertension, ischemic heart disease, mental health, metabolic syndrome, mortality, obesity, osteoporosis, preventive medicine.
Introduction

Overwhelming evidence supports the importance of physical activity in the primary and secondary prevention of several chronic diseases (American College of Sports Medicine 1998a; Blair and Brodney 1999; Blair et al. 1989, 2001; Bouchard and Shephard 1994; Lee and Skerrett 2001; McAuley 1994; Paffenbarger et al. 1986a; Puett and Griffin 1994; Shephard 2001; Taylor et al. 2004; US Department of Health and Human Services 1991; Warburton et al. 2001a, 2001b, 2006a, 2006b). Seven chronic diseases in particular have been associated with physical inactivity: coronary heart disease (CHD), stroke, hypertension, breast cancer, colon cancer, type 2 diabetes mellitus (T2DM), and osteoporosis. Moreover, compelling evidence links physical inactivity to the development of obesity, sarcopenia, arthritis, physical disability, and several psychological disorders (Katzmarzyk and Janssen 2004; Warburton et al. 2006a, 2006b). In all, physical activity is thought to benefit over 25 chronic conditions (Bouchard et al. 1994).

Canada has developed a series of physical activity guides designed for adults, children and youth, and older adults. The recommended guidelines have been widely promoted and adopted. However, much research has been completed since formulation of these guidelines (Figs. 1a and 1b). Accordingly, the primary goal of this review is to create an evidence-informed document evaluating current physical activity guidelines for adult Canadians and, where necessary, to recommend research informing revisions to the guidelines. Particular attention has been directed to literature (including high-quality systematic reviews and (or) meta-analyses of randomized controlled trials) on the role of physical inactivity in the prevention and treatment of CHD, stroke, hypertension, breast cancer, colon cancer, T2DM, obesity, and osteoporosis. The intent is not to replace current Canadian guidelines; rather, the review supports current guidelines or points to a need for improvements. The emphasis is on primary prevention, one particular focus being current literature on minimal and optimal levels of physical activity and fitness needed to control specific disease states. Because of the current high prevalence and the heavy economic and societal costs of obesity and CVD, the secondary and tertiary prevention of these conditions is also given brief consideration.

Current national and international guidelines for physical activity in adults

A variety of national and international guidelines and consensus statements have been developed around the health benefits of physical activity (Tables 1 and 2). Canada has played a leading role in these developments. In 1998, Health Canada and the Canadian Society for Exercise Physiology (CSEP) published Canada's physical activity guide to healthy active living for adults between the ages of 20 and 55 years (Health Canada and the Canadian Society for Exercise Physiology 1998a). This was followed by Canada's physical activity guide to healthy active living for older adults (Health Canada and the Canadian Society for Exercise Physiology 1999), and Canada's physical activity guide for children and Canada’s physical activity guide for youth (Health Canada and the Canadian Society for Exercise Physiology 2002a, 2002b). The adult guidelines are now approximately 8 years old, although still generally consistent with the current international viewpoint (Table 2). These recommendations have been endorsed by more than 65 Canadian national organizations, all provincial and territorial governments, and several international agencies. The central message is that 20–55-year-old adults should accumulate 60 min of daily physical activity or 30 min of moderate or vigorous exercise on at least 4 d/week:

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up (Health Canada and the Canadian Society for Exercise Physiology 1998a).

The 60 min duration was advocated previously by the 1996 Surgeon General’s Report (United States Department of Health and Human Services 1996). The Canadian guidelines promoted the 60 min recommendation on the premise that most sedentary individuals would initially choose to perform light-intensity activities (such as easy walking and gardening). The wide range of activities required for various health outcomes was also acknowledged, with health benefits seen as developing across a continuum from light to vigorous effort (Warburton et al. 2006a, 2006b).

Most international physical activity guidelines support the adoption of moderate-intensity physical activity on most days of the week. Often, an absolute intensity or energy expenditure (such as 3–6 METs) has been specified, based on tables that outline the metabolic costs of various activities, with specification of a total weekly requirement corresponding to a gross energy expenditure of 4.2 MJ (1000 kcal) (Warburton et al. 2006a). This particular dose was chosen mainly on the basis of epidemiological evidence showing associations between such energy expenditures and lower risks of all-cause mortality and incident CVD, colon and breast cancer, and T2DM (Helmrich et al. 1991; Lee and Paffenbarger 1994; Paffenbarger et al. 1986b; Sesso et al. 1998; Shephard 2001; Shephard and Futercher 1997). There are only minor differences in guidelines between countries and associations (Tables 1 and 2); however, a Canadian initiative to harmonize these guidelines would be welcome.

Shephard (2001, 2003) emphasized that basing exercise prescriptions on absolute intensities of effort has limited value, particularly in diseased, middle-aged, and older individuals. An exercise intensity of 4 METs may be near-max-
Canadian guidelines also offer a menu of activity choices, emphasizing that the “time needed depends upon effort.” These recommendations have been effectively adopted and implemented by advanced health and fitness professionals (including CSEP-Certified Personal Trainers and CSEP-Certified Exercise Physiologists, http://www.csep.ca) across Canada. They also have provided a strong template upon which to develop international guidelines.

Inclusion of statements such as “Every little bit counts, but more is even better – everyone can do it!” reflects belief in a dose–response relationship between physical activity and health status; it is consistent with current international guidelines that acknowledge additional health benefits from greater energy expenditures. The accumulation of short bouts of exercise (10–15 min) throughout the day as a substitute for one prolonged exercise bout has found some recent advocates (American College of Sports Medicine 1998b; Gledhill 2001; Lee and Skerrett 2001). Literature supporting the minimal 10 min bout of exercise is lacking. Nonetheless, from the viewpoint of behavioural change, this paradigm shift may help previously sedentary individuals who would like to adopt a healthier lifestyle, but are unlikely to do so if it immediately involves prolonged vigorous exercise. The activities that adult Canadians elect during their leisure time follow this pattern (Table 4), and the new focus also seems attractive because recent evidence points to the greatest improvement in population health if sedentary individuals become physically active (Erikssen 2001). However, empirical evidence supporting this new approach is limited and this issue requires further investigation.

The guidelines of many agencies and countries (including Canada) have supported the inclusion of activities to tax the musculoskeletal system (e.g., resistance and flexibility exercises) on at least 2 d/week. Canadian guidelines also advocate flexibility exercises on at least 4 d/week. This policy is supported by increasing evidence of a relationship between musculoskeletal fitness and health outcomes (Katzmarzyk and Craig 2002; Mason et al. 2007; Payne et al. 2000a, 2000b; Warburton et al. 2001a, 2001b, 2006a).

**Descriptive epidemiology of physical inactivity**

The importance of being physically active for health and well-being is accepted by much of the general population. Nevertheless, the majority of people in developed countries fail to meet even minimal requirements (Canadian Fitness and Lifestyle Research Institute 1998; Craig et al. 1999; Katzmarzyk et al. 2000). In the European Union, at least two thirds of those over the age of 15 years engage in less than 30 min of moderate-intensity physical activity each day (World Health Organization 2006), and this is also true for 60% of the global population. In Canada, some 54% of women and 48% of men are physically inactive (defined as expending <6.2 kJ·kg\(^{-1}\)·d\(^{-1}\); <1.5 kcal·kg\(^{-1}\)·d\(^{-1}\)) (Fig. 2). Indeed, the prevalence of physical inactivity is higher than for all other modifiable cardiovascular disease risk factors (Fig. 3).

Various Canadian agencies have acknowledged the importance of increasing the physical activity of the population (Canadian Medical Association 2004; Federal–Provincial–...
Table 1. International physical activity guidelines for adults.

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Organization (reference)</th>
<th>Title</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>USA</td>
<td>ACSM (American College of Sports Medicine 1975)</td>
<td>Guidelines for graded exercise testing and prescription</td>
<td>3–5 d/week for 20–45 min/d at 70%–90% of heart rate range</td>
</tr>
<tr>
<td>1991</td>
<td>USA</td>
<td>ACSM (American College of Sports Medicine 1991)</td>
<td>Guidelines for graded exercise testing and prescription</td>
<td>3–5 d/week for 15–60 min/d at 60%–85% of heart rate range</td>
</tr>
<tr>
<td>1995</td>
<td>USA</td>
<td>CDC/ACSM (Pate et al. 1995)</td>
<td>Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine</td>
<td>Adults should accumulate 30 min or more of moderate-intensity physical activity on most, preferably all, days of the week.</td>
</tr>
<tr>
<td>1995</td>
<td>USA</td>
<td>NIH (National Institute of Health 1996)</td>
<td>NIH consensus development panel on physical activity and cardiovascular health</td>
<td>All individuals should engage in regular physical activity at a level appropriate to their capacity, needs, and interest. Children and adults should accumulate at least 30 min of moderate-intensity physical activity on most, and preferably all, days of the week. Individuals who currently meet these guidelines may achieve additional health benefits by becoming more physically active or including more vigorous activity. There should be greater utilization of cardiac rehabilitation programs that combine physical activity with other risk factor reduction. People of all ages should accumulate at least 30 min of moderate-intensity physical activity on most if not all days of the week. An increase in daily energy expenditure of approximately 150 kcal/d (or 1000 kcal/week) is associated with significant health benefits. Health benefits can be achieved through intermittent, moderate intensity physical activity. Additional health benefits can be gained through greater amounts of physical activity. 20–55-year-old adults should accumulate 60 min of daily physical activity, or 30 min of moderate or vigorous exercise on at least 4 days a week. Time needed depends on effort. “Every little bit counts, but more is even better – everyone can do it!” Specific guidelines include: Endurance exercises performed 4–7 d/week; Flexibility exercises performed 4–7 d/week including gentle reaching, bending and stretching; Strength exercises performed 2–4 d/week. Adults should accumulate at least 30 min of moderate-intensity physical activity on most, preferably all, days of the week and more vigorous activity will lead to greater health benefits. Adults should accumulate at least 30 min of moderate-intensity physical activity on most, preferably all, days of the week. More vigorous activity will lead to greater health benefits. For health, 20 min/d, at 40%–85% heart rate range on most days of the week.</td>
</tr>
<tr>
<td>1998</td>
<td>Canada</td>
<td>Health Canada and CSEP (Health Canada and the Canadian Society for Exercise Physiology 1998a)</td>
<td>Canada’s physical activity guide to healthy active living</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>USA</td>
<td>ACSM (American College of Sports Medicine 2000)</td>
<td>ACSM’s guidelines for exercise testing and prescription</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Country</td>
<td>Organization (reference)</td>
<td>Title</td>
<td>Guidelines</td>
</tr>
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<td>---------------</td>
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</tr>
<tr>
<td>2000</td>
<td>USA</td>
<td>Healthy People Consortium (US Department of Health and Human Services 2000)</td>
<td>Healthy people 2010</td>
<td>Adults should engage in vigorous-intensity physical activity 3 or more days per week for 20 or more minutes per occasion.</td>
</tr>
<tr>
<td>2000</td>
<td>Switzerland</td>
<td>Health-Enhancing Physical Activity (HEPA 2000)</td>
<td>Recommendations of the Swiss Federal Office of Sports, the Swiss Federal Office of Public Health and the Network HEPA Switzerland</td>
<td>At least 30 min of moderate-intensity physical activity on most days of the week. This can be accomplished through 10 min bouts of exercise. Equivalent to an additional energy expenditure of 1000 kcal/week. 10 min a time, 30 min/d, 5 d/week</td>
</tr>
<tr>
<td>2004</td>
<td>UK</td>
<td>Department of Health, Physical Activity, Health Improvement and Prevention (Department of Health Physical Activity Health Improvement and Prevention 2004)</td>
<td>At least five a week</td>
<td>For general health, at least 30 min of moderate-intensity exercise per day on 5 or more days of the week. These recommendations can be achieved by doing all of the activity in one session or through several shorter bouts of activity (10 min or more). For the prevention of obesity, 45–60 min of moderate-intensity exercise a day.</td>
</tr>
<tr>
<td>2006</td>
<td>European Union</td>
<td>WHO HEP A (World Health Organization 2006)</td>
<td>Physical activity: a basic requirement for health</td>
<td>At least 30 min of moderate-intensity physical activity on most days of the week (equivalent to expending 150 kcal/d). More activity may be required for weight control. It is recommended that activities to improve musculoskeletal fitness be performed twice weekly.</td>
</tr>
</tbody>
</table>

Note: ACSM, American College of Sports Medicine; CDC, Centers for Disease Control; NIH, National Institute of Health.
<table>
<thead>
<tr>
<th>Country</th>
<th>Consensus panel</th>
<th>Condition</th>
<th>Recommendation(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>American College of Sports Medicine (Pescatello et al. 2004)</td>
<td>Hypertension</td>
<td>Every US adult should accumulate 30 min or more of moderate-intensity physical activity on most, preferably all days of the week; training frequencies between 3 and 5 d/week are effective in reducing BP; for persons with high BP, an exercise program that is primarily aerobic-based is recommended; resistance training should serve as an adjunct to an aerobic-based program.</td>
</tr>
<tr>
<td>USA</td>
<td>American Heart Association (Fletcher 1997; Fletcher et al. 1996)</td>
<td>CVD</td>
<td>Persons of all ages should include physical activity in a comprehensive program of health promotion and disease prevention and should increase their habitual physical activity to a level appropriate to their capacities, needs, and interest; the greatest benefits can be seen at the lowest intensities, but there are additional benefits to physical activity of higher intensities; primary prevention must include a plan for a lifetime of appropriate physical activity. Ideally this activity should be done for at least 30 to 60 min four to six times weekly or 30 min on most days of the week. The frequency, duration, and intensity of the activity should be individualized to personal satisfaction as well as mood and progression.</td>
</tr>
<tr>
<td>USA</td>
<td>American Heart Association (Gordon et al. 2004)</td>
<td>Stroke</td>
<td>Large-muscle aerobic activities at 40%–70% heart rate reserve (RPE 11–14), 3–7 d/week, 20–60 min/session (or multiple 8–10 exercises); strength training consisting of 1–3 sets of 10–15 repetitions of 8–10 exercises using the major muscle groups, 2–3 d/week; flexibility training, 2–3 d/week (before or after aerobic or strength training), holding each stretch for 10–30 s; coordination and balance activities, 2–3 d/week.</td>
</tr>
<tr>
<td>Canada</td>
<td>Canadian Coalition for High Blood Pressure Prevention and Control, the Laboratory Centre for Disease Control at Health Canada, and the Heart and Stroke Foundation of Canada (Cleroux et al. 1999)</td>
<td>Hypertension</td>
<td>People with mild hypertension should engage in 50–60 min of dynamic exercise of the lower extremities 3–4 times/week to reduce blood pressure; exercise should be prescribed as an adjunct therapy for people who require pharmacologic therapy for hypertension; people who do not have hypertension should participate in regular exercise owing to the beneficial effects on blood pressure and the risk of CHD.</td>
</tr>
<tr>
<td>Canada</td>
<td>Canadian Hypertension Society (Khan et al. 2005)</td>
<td>Hypertension</td>
<td>Lifestyle modifications to prevent and (or) treat hypertension should include 30–60 min of aerobic exercise on 4–7 d/week.</td>
</tr>
<tr>
<td>Canada</td>
<td>Canadian Task Force on Preventive Health Care (Beaulieu 1994)</td>
<td>CHD</td>
<td>The preferred general primary prevention recommendation is moderate-level physical activity performed consistently to accumulate 30 min or more over the course of most days of the week; the form of physical activity that is best suited to a given individual depends on that individual’s needs, limitations, and goals.</td>
</tr>
<tr>
<td>Canada</td>
<td>Canadian Association of Cardiac Rehabilitation (Stone and Arthur 2005)</td>
<td>CHD</td>
<td>The regular practice of moderate-intensity physical activity is an independent risk factor associated with a reduction in: all-cause and CHD mortality, incidence of CHD, hypertension and T2DM, and the maintenance of a healthy body mass.</td>
</tr>
<tr>
<td>Canada</td>
<td>Cancer Care Ontario (Friedenreich 2000)</td>
<td>Cancer</td>
<td>Physical activity messages promoting at least 30–45 min of moderate to vigorous activity on most days of the week should be included in primary prevention interventions for cancer.</td>
</tr>
<tr>
<td>USA</td>
<td>Centers for Disease Control and ACSM (Pate et al. 1995)</td>
<td>Population health promotion</td>
<td>Every US adult should accumulate 30 min or more of moderate-intensity physical activity on most, preferably all, days of the week.</td>
</tr>
<tr>
<td>Country</td>
<td>Consensus panel</td>
<td>Condition</td>
<td>Recommendation(s)</td>
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</tr>
<tr>
<td>European Union</td>
<td>European Consensus (Shelley 2004; Shelley and Ryden 2004)</td>
<td>CVD</td>
<td>Every adult should accumulate at least 30 min of moderate-intensity physical activity most and preferably every day of the week; this should be seen as a meaningful target and not a maximum; all young people (5–18 years) should participate in physical activity of at least moderate intensity for one hour a day; higher levels of physical activity might be necessary for younger people to support optimal growth and development as well as reducing risk of CVD in later life.</td>
</tr>
<tr>
<td>Canada</td>
<td>Health Canada and the Canadian Society for Exercise Physiology (Health Canada and the Canadian Society for Exercise Physiology 1998a)</td>
<td>Population health promotion</td>
<td>Accumulate 60 min of physical activity every day to stay healthy or improve your health; the time needed for physical activity depends on effort. As you progress to moderate activity you can decrease the time needed to 30 min, 4 d/week.</td>
</tr>
<tr>
<td>Canada</td>
<td>Health Canada/United States Centers for Disease Control and Prevention Conference (Shephard 2002)</td>
<td>Population health promotion</td>
<td>The current guidelines of moderate-intensity physical activity on most days of the week (with the potential to use shorter bouts of exercise to accumulate the required dose) were sufficient to reduce the risk of premature mortality and multiple chronic diseases (including CVD and colon cancer); a larger volume of activity is likely needed to counter weight gain; exercises that tax the musculoskeletal system are required to attenuate age-related decreases in muscle mass and mobility; a greater volume of activity than advocated by these guidelines likely leads to greater benefits, but also increases the risk of injuries.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>The European Network for the Promotion of Health-Enhancing Physical Activity (HEPA) (Cavill et al. 2006)</td>
<td>Population health promotion</td>
<td>At least 30 min/d of moderate-intensity physical activity is recommended for women and men of all ages; activities that exceed the recommended amount of physical activity will bring about greater benefits.</td>
</tr>
<tr>
<td>Canada</td>
<td>Kino-Quebec (Thibaut 1999)</td>
<td>Population health promotion</td>
<td>The more active a person is, the better his or her health will be; there seems to be no level below which physical activity has no positive effect on health; any increase, however small, is beneficial; by increasing physical activity (even slightly), a sedentary person can obtain major health benefits; in absolute terms, a given increase in physical activity has a greater effect for a sedentary or slightly active person than for an active person.</td>
</tr>
<tr>
<td>Australia</td>
<td>National Heart Foundation of Australia (Bauman et al. 2001)</td>
<td>Population health promotion</td>
<td>At least 30 min of moderate-intensity activity on most or all days of the week; the total amount of physical activity seems to be more important than the intensity, so that lower intensity daily activity (such as walking) may confer similar benefits to higher intensity activity on fewer days of the week.</td>
</tr>
<tr>
<td>UK</td>
<td>National Institute for Health and Clinical Excellence (health education authority) (Department of Health Physical Activity Health Improvement and Prevention 2004) Report from the Chief Medical Officer for England</td>
<td>Population health promotion</td>
<td>At least 30 min of moderate physical activity 5 d/week (or more); it is likely that to prevent obesity, 45–60 min of moderate physical activity is needed every day of the week.</td>
</tr>
<tr>
<td>Country</td>
<td>Consensus panel</td>
<td>Condition</td>
<td>Recommendation(s)</td>
</tr>
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</tr>
<tr>
<td>USA</td>
<td>NIH (National Institute of Health 1996)</td>
<td>Cardiovascular health</td>
<td>All Americans should engage in regular physical activity at a level appropriate to their capacity, needs, and interest. Children and adults alike should set a goal of accumulating at least 30 min of moderate-intensity physical activity on most, and preferably, all days of the week; those who currently meet these standards may derive additional health and fitness benefits by becoming more physically active or including more vigorous activity; for those with known CVD, cardiac rehabilitation programs that combine physical activity with reduction in other risk factors should be more widely used.</td>
</tr>
<tr>
<td>USA</td>
<td>National High Blood Pressure Program (Whelton, P.K. et al. 2002)</td>
<td>Hypertension</td>
<td>For the primary prevention of hypertension it is recommended that people engage in regular aerobic activity 30 min/d on most days of the week.</td>
</tr>
<tr>
<td>International</td>
<td>Obesity Consensus Conference (Bouchard and Blair 1999)</td>
<td>Obesity</td>
<td>It is well established that regular physical activity has favorable effects on several of the comorbidities of obesity, particularly those pertaining to CVDs and type II diabetes.</td>
</tr>
<tr>
<td>USA</td>
<td>Report of the US Surgeon General on Physical Activity and Health (United States Department of Health and Human Services 1996)</td>
<td>Population health promotion</td>
<td>Significant health benefits can be obtained by including a moderate amount of physical activity (e.g., 30 min of brisk walking or raking leaves, 15 min of running, or 45 min of playing volleyball) on most, if not all, days of the week; through a modest increase in daily activity, most Americans can improve their health and quality of life; additional health benefits can be gained through greater amounts of physical activity. People who can maintain a regular regimen of activity that is of longer duration or of more vigorous intensity are likely to derive greater benefit; physical activity reduces the risk of premature mortality in general, and of CHD, hypertension, colon cancer, and diabetes mellitus in particular. Physical activity also improves mental health and is important for the health of muscles, bones, and joints.</td>
</tr>
<tr>
<td>USA</td>
<td>The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (Chobanian et al. 2003)</td>
<td>Hypertension</td>
<td>Lifestyle modifications that include engaging in regular aerobic physical activity such as brisk walking at least 30 min/d, most days of the week may result in an approximate systolic BP reduction of 4–9 mmHg.</td>
</tr>
<tr>
<td>International</td>
<td>World Health Organization—Global strategy on diet, physical activity and health. The 57th World Health Assembly (World Health Organization 2004)</td>
<td>Population health promotion</td>
<td>At least 30 min of regular, moderate-intensity physical activity on most days reduces the risk of CVD and diabetes, colon cancer and breast cancer. Muscle strengthening and balance training can reduce falls and increase functional status among older adults. More activity may be required for weight control.</td>
</tr>
</tbody>
</table>

**Note:** CVD, cardiovascular disease; CHD, coronary heart disease.
The Territorial Conference of Ministers Responsible for Sport (2003; Health Canada 2005) have advocated a 10% increase in physical activity levels in every jurisdiction by 2010 (Federal–Provincial–Territorial Conference of Ministers Responsible for Sport 2003), a policy also urged by the Canadian Medical Association (2004). The target of increasing physical activity levels is echoed in the Pan-Canadian Healthy Living Strategy, which calls for a 20% increase in the proportion of Canadians who are at least moderately active for at least 30 min/d (Health Canada 2005).

There are some encouraging indicators of success in promoting physical activity within Canada. There appears to have been an 11% increase in Canadian physical activity levels between the 1994–1995 National Population Health Survey and the 2002–2003 Canadian Community Health Survey (Health Canada 2005).

### Table 3. Relative intensities for aerobic exercise prescription (for activities lasting up to 60 min).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>%HRR</th>
<th>%HR&lt;sub&gt;max&lt;/sub&gt;</th>
<th>RPE&lt;sup&gt;a&lt;/sup&gt;</th>
<th>RPE&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Breathing rate</th>
<th>Body temperature</th>
<th>Example activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light effort</td>
<td>&lt;20</td>
<td>&lt;50</td>
<td>&lt;10</td>
<td>&lt;2</td>
<td>Normal</td>
<td>Normal</td>
<td>Dusting</td>
</tr>
<tr>
<td>Light effort</td>
<td>20–39</td>
<td>50–63</td>
<td>10–11</td>
<td>2–3</td>
<td>Slight increase</td>
<td>Start to feel warm</td>
<td>Light gardening</td>
</tr>
<tr>
<td>Moderate effort</td>
<td>40–59</td>
<td>64–76</td>
<td>12–13</td>
<td>4–6</td>
<td>Greater increase</td>
<td>Warmer</td>
<td>Brisk walking</td>
</tr>
<tr>
<td>Vigorous/hard effort</td>
<td>60–84</td>
<td>77–93</td>
<td>14–16</td>
<td>7–8</td>
<td>More out of breath</td>
<td>Quite warm</td>
<td>Jogging</td>
</tr>
<tr>
<td>Very hard effort</td>
<td>&gt;84</td>
<td>&gt;93</td>
<td>17–19</td>
<td>9</td>
<td>Greater increase</td>
<td>Hot</td>
<td>Running fast</td>
</tr>
<tr>
<td>Maximal effort</td>
<td>100</td>
<td>100</td>
<td>20</td>
<td>10</td>
<td>Completely out of breath</td>
<td>Very hot/perspiring heavily</td>
<td>Sprinting all-out</td>
</tr>
</tbody>
</table>

**Note:** The intensity required for health ranges from light to vigorous/hard effort. %HRR, percentage of heart rate reserve; %HR<sub>max</sub>, percentage of heart rate maximum; RPE, rating of perceived exertion. Adapted from Warburton et al. 2006 using information provided by the Handbook for Canada’s physical activity guide to healthy active living (Health Canada and the Canadian Society for Exercise Physiology 1998b) and Howley (2001).

<sup>a</sup>Fifteen-category RPE scale (6–20).

<sup>b</sup>Category–ratio RPE scale (0–10).

### Table 4. Top five physical recreation activities of Canadian adults (age 20+ years).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Activity</th>
<th>Percent of population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>Walking</td>
<td>69</td>
</tr>
<tr>
<td>2</td>
<td>Gardening, yard work</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>Home exercise</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Swimming</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Bicycling</td>
<td>24</td>
</tr>
</tbody>
</table>

**Note:** National Population Health Survey, 1998/99 (Statistics Canada 2001).

### Fig. 2. The prevalence of physical inactivity as a function of age in Canada. Source: 2004 Physical Activity Monitor (Canadian Fitness and Lifestyle Research Institute 2004). Inactivity was defined as a usual daily leisure-time energy expenditure of <1.5 kcal·kg<sup>-1</sup>·d<sup>-1</sup>.

### Fig. 3. Prevalence of traditional risk factors for cardiovascular disease in Canadian society according to gender. High cholesterol was defined as a plasma cholesterol level above 5.2 mmol·L<sup>-1</sup> (>200 mg·dL<sup>-1</sup>); diabetes was evaluated by self-report, diagnosed diabetes; hypertension was defined as a blood pressure of ≥140/90 mmHg; inactivity was defined as a usual daily leisure-time energy expenditure of <1.5 kcal·kg<sup>-1</sup>·d<sup>-1</sup>; smoking was defined as daily tobacco smoking; obesity was defined as a body mass index of >27; alcohol was defined as alcohol use in excess of 9 and 14 drinks/week for women and men, respectively. Source: National Population Health Survey 1996–1997 (Statistics Canada 1996), 2004 Physical Activity Monitor (Canadian Fitness and Lifestyle Research Institute 2004), and the The Changing Face of Heart Disease and Stroke in Canada (Heart and Stroke Foundation of Canada 2000).
Survey (Canadian Fitness and Lifestyle Research Institute 2004). An Australian report (Stephenson et al. 2000) suggested that Canada was “the best case scenario for feasible population change.” Although these reports are encouraging, they require confirmation because of several limitations to current physical activity monitoring systems (Katzmarzyk and Tremblay 2007).

Currently, 49% of adult Canadians are classed as at least moderately active, and 24% as active (Canadian Fitness and Lifestyle Research Institute 2004). At all ages, men tend to be more active than women (Fig. 2). A low socioeconomic status and (or) less education are correlates of physical inactivity. Older adults are also less likely to meet current recommendations. The preferred types of activity vary with sex (Table 4) and age (Canadian Fitness and Lifestyle Research Institute 2004).

The World Health Organization (2002) estimated that globally, physical inactivity causes 2 million premature deaths each year, including 10–16% of cases of breast cancer, colon cancer, rectal cancer, and T2DM, and 22% of cases of CHD (World Health Organization 2002). The Global Strategy on Diet, Physical Activity, and Health was created to address this concern (World Health Organization 2004). Canadian population-attributable risk data are comparable with figures from other developed countries (Table 5). In Australia and the US, physical inactivity (and diet) are second only to tobacco control as potential mechanisms for preventing chronic disease (Australian Institute of Health and Welfare 2006; McGinnis and Foege 1993; Mokdad et al. 2004). Physical inactivity imposes an enormous burden on Canadian society through related health care costs and human suffering (Katzmarzyk et al. 2000; Katzmarzyk and Janssen 2004; Warburton et al. 2006a).

### Methods

Our research team adopted several tactics to evaluate levels of evidence on physical activity and health. We relied heavily on major systematic reviews, meta-analyses, and consensus statements. Eight chronic conditions were identified as having the strongest supporting literature (and probably the greatest importance from the viewpoints of premature mortality, quality-adjusted life expectancy, and health-care costs). Our article is thus restricted to information on the prevention of CVD (including CHD and stroke), hypertension, T2DM, obesity, colon cancer, breast cancer, osteoporosis, as well as the promotion of psychological well-being. In view of their high prevalence and the substantial medical costs associated with CVD and obesity, the secondary treatment of these conditions is also evaluated briefly.

We reviewed the literature following a similar strategy to that adopted by the “Adequacy of Evidence for Physical Activity Guidelines Development: Workshop Summary” (West Suitor and Kraak 2007). Consideration was given to efficacy (does physical activity lead to a specific health benefit), effectiveness, the dosage required (minimal versus optimal), and mechanisms of action. As there appear to be multiple dose–response curves for various endpoints (see Gledhill and Jamnik's work in the Canadian physical activity and lifestyle approach (Canadian Society for Exercise Physiology 2003)), we have addressed each condition individually in the context of the Canadian physical activity guidelines. Our literature search used the terms physical activity, health, health status, fitness, exercise, chronic disease, and mortality, together with disease-specific terms (for example, CVD, stroke, obesity, hypertension, cancer, diabetes, and osteoporosis).

### Physical inactivity and chronic disease

Since the landmark work of Morris (Morris and Heady 1953; Morris et al. 1953) and Paffenbarger (Paffenbarger and Hale 1975; Paffenbarger et al. 1978), considerable epidemiological research has documented the health benefits of regular physical activity (Bouchard et al. 1994; US Department of Health and Human Services 1996). Although physical activity is a behaviour and physical fitness is an attained state, both are related to health status in a dose-dependent manner (Warburton et al. 2006a). Studies of both physical activity and physical fitness thus informed this report. Numerous reports document associations between physical inactivity or fitness and chronic disease, as well as between premature disease-specific and all-cause mortality (Blair and Brodney 1999; Katzmarzyk et al. 2000, 2004; Oguma et al. 2002; Warburton et al. 2006a). Regular physical activity is effective in the primary and secondary prevention of CVD, obesity, hypertension, T2DM, some forms of cancer (particularly of the colon and breast), osteoporosis, arthritis, and several psychologi-
Fig. 4. The importance of low physical fitness for the risk for all-cause mortality in comparison with other known risk factors. Relative risk was corrected for age and examination year. High systolic blood pressure (BP) was considered as ≥140 mmHg. High cholesterol was considered as ≥240 mg·dL⁻¹ (≥6.2 mmol·L⁻¹). Elevated body mass index (BMI) was ≥27. A relative risk of 1.0 was considered a normal risk. Data adapted from Blair et al. 1996.

Fig. 5. Early investigations examining the relative risks of all-cause mortality as a function of physical activity or fitness level. Top panel shows physical activity levels (kcal/week) in the Harvard Alumni Study (Paffenbarger et al. 1986b). Bottom panel shows quintiles of cardiorespiratory fitness in the Aerobics Center Longitudinal Study (Blair et al. 1989).

Physical inactivity and all-cause mortality

Assessments of all-cause mortality are complicated by the inclusion of deaths from suicides, homicide, and accidents (Katzmarzyk 2005). Nevertheless, in Canada, physical inactivity is a major cause of mortality from diseases of the circulatory system (33.3%), cancers (29.1%), and T2DM (3.49%) (Statistics Canada 2004). Numerous reviews (including several systematic and (or) meta-analytic reviews) have highlighted the relationship between physical inactivity or fitness and premature all-cause mortality (Appendix Table A1). The risk of all-cause mortality has been consistently lower in habitually active individuals, leading Powell and colleagues (1987) to assert that

...regular physical activity should be promoted as vigorously as blood pressure control, dietary modification to lower serum cholesterol, and smoking cessation.

An epidemiological study of 25 341 men and 7080 women demonstrated that low physical fitness was a more important risk factor for all-cause mortality than hypertension, high cholesterol, obesity, or cigarette smoking (Fig. 4) (Blair et al. 1996). Long-term prospective studies have consistently shown that physically active men and women have a 20%–35% lower all-cause and cardiovascular-related mortality than their sedentary peers (Macera et al. 2003; Macera and Powell 2001; Warburton et al. 2006a, 2006b). In 1989, an 8-year follow-up of healthy middle-aged men (n = 10 224) and women (n = 3120) revealed a progressively lower all-cause mortality rate across physical fitness quintiles, with individuals in the lowest quintile showing a risk of 3.4 (men) and 4.7 (women) relative to the top quintile. Individuals in the higher fitness categories also had the lowest mortality rates from CVD and cancer (Blair et al. 1989). This study and others (Fig. 5) suggest that the greatest differences in risk occur between the lowest and the next-lowest fitness category; if these inferences are correct, then sedentary individuals could substantially improve their health status with only a minor increment in habitual physical activity (Erikssen 2001; Paffenbarger et al. 1986b; Slentz et al. 2007; Warburton et al. 2006a).

Recent studies (Andersen et al. 2000; Katzmarzyk and Craig 2006; Myers et al. 2004; Trolle-Lagerros et al. 2005) have also revealed large reductions in the risk for all-cause mortality. Many of these studies have included women, with sub-analyses revealing similar reductions in the risk for all-cause mortality between sexes (Andersen et al. 2000; Katzmarzyk and Craig 2006; Trolle-Lagerros et al. 2005). A meta-analysis (Katzmarzyk et al. 2003) found an inverse
Fig. 6. The importance of physical fitness for all-cause mortality risk in patients with other known risk factors and the relative risk for death of any cause among participants with various risk factors including a history of hypertension, chronic obstructive pulmonary disease (COPD), diabetes, smoking, an elevated body mass index (BMI; ≥30), and high cholesterol (TC ≥ 220 mg·dL⁻¹). Data adapted from Myers et al. 2002.

Fig. 7. All-cause and cardiovascular disease mortality rates by cardiorespiratory fitness levels in healthy men and men with the metabolic syndrome. Note: All-cause and cardiovascular disease rates were adjusted for age and year of examination (n = 19,223 men aged 20–83 years). Data adapted from Katzmarzyk et al. 2004.

Fig. 8. The effects of physical fitness and obesity on the incidence of adverse cardiovascular events. Obesity was classified as a body mass index (BMI) ≥ 30. The “fit” classification was based on a Duke Activity Status Index score of ≥25 mL·kg⁻¹·min⁻¹ (≥7 METs). Major adverse events were defined as death, non-fatal myocardial infarction, or non-fatal stroke. All adverse events included all-cause death or hospitalization for nonfatal myocardial infarction, conges-
tive heart failure, stroke, unstable angina, or other vascular occurrences. Data adapted from Wessel et al. 2004.

Physical inactivity and co-morbidities

Physical activity or enhanced aerobic fitness appears to reduce the risk of premature mortality even in the presence of other chronic disease risk factors (Figs. 6–8). Myers et al. (2002) observed a markedly lower risk of death from any cause among fit participants, despite having such risk factors as hypertension, chronic obstructive pulmonary disease, T2DM, smoking, elevated body mass index (BMI ≥ 30 kg·m⁻²), and a high serum cholesterol (Fig. 6). The all-cause mortality was some two times greater in individuals with a peak exercise capacity of less than 5 METs than in individuals with a capacity of greater than 8 METs, irrespective of other risk factors (Myers et al. 2002). Two other investigations confirmed a better health status in physically active individuals, despite the presence of other cardiovas-
cular risk factors (Katzmarzyk et al. 2004; Wessel et al. 2004). Katzmarzyk et al. (2004) noted that cardiovascular fitness attenuated the risk of all-cause and CVD mortality in men with the metabolic syndrome (Fig. 7); their data showed a significant dose–response relationship.

All-cause and cardiovascular mortality are consistently
lower in fit individuals across the spectrum of adiposity (Haapanen-Niemi et al. 2000; Johansson and Sundquist 1999; Katzmarzyk et al. 2003; Lee and Paffenbarger 2000). Haapanen-Niemi et al. (2000) found that leisure-time physical activity was associated with a lower mortality risk in both obese and non-obese men and women, and in fit and unfit participants. Johansson and Sundquist (1999) reported that physical activity was associated with significantly lower mortality, irrespective of BMI or cigarette smoking. A systematic review by Katzmarzyk et al. (2003) revealed that physically active individuals had a lower risk of premature mortality irrespective of adiposity. Both physical inactivity and adiposity were important determinants of mortality, although the independent contribution of adiposity was difficult to assess because of the large number of covariates used in most analyses. Nevertheless, most recent studies suggest that physical inactivity and obesity are independent predictors of mortality (Hu et al. 2004; Katzmarzyk and Craig 2006). Katzmarzyk and Craig (2006) found that physical activity remained an independent predictor of 12-year mortality in Canadian women aged 20–69 years, even when waist circumference was included in the prediction model; physically active women had lower mortality rates at all levels of waist circumference.

Changes in physical activity

Longitudinal studies have demonstrated that improvements in either physical activity or fitness are associated with lower mortality, whereas decreases in activity or fitness are linked to a greater risk (Bijnen et al. 1999; Blair et al. 1995; Erikssen 2001; Erikssen et al. 1998; Gregg et al. 2003a; Johansson and Sundquist 1999; Kujala et al. 2002; Wannamethee et al. 1998; Warburton et al. 2006a). Blair et al. (1995) found a 44% lower 5-year mortality among individuals who improved from the unfit to the fit category; there was an 8% lower mortality risk for every 1 min increase in maximal treadmill time. The lowest risk (RR = 0.33) was seen in individuals who were fit at baseline and maintained or improved their fitness over the 5-year period. A growing body of evidence supports this view (Fig. 9).

Physical fitness appears to be a better predictor of cardiovascular and all-cause mortality than physical activity (Blair et al. 2001; Myers et al. 2004; Williams 2001). Risk reductions of greater than 50% are not uncommon in physically fit individuals (Myers et al. 2004; Williams 2001). A systematic review (Blair et al. 2001) revealed that health was more strongly related to physical fitness than to physical activity. This is not surprising, as the associations were not corrected for attenuation by measurement error; physical fitness is usually determined objectively, whereas most assessments of physical activity are based on self-reports of limited accuracy (Katzmarzyk 2005; Shephard 2003). Nevertheless, the relationship between physical activity and health status is incontrovertible. From the public health perspective, we should target increasing physical activity (Blair et al. 2001):

It would not make sense to encourage individuals to ‘become fit’, but instead we can, and should, recommend that individuals ‘increase activity’. We think it is likely that if sedentary persons do the latter, they will achieve the former.

Fig. 9. The relative risk of mortality as a function of changes in physical activity or fitness. Top panel includes studies that used the “Active/Fit to Active/Fit” group as the referent. Bottom panel includes investigations that used the “Inactive/Unfit to Inactive/Unfit” group as the referent (Bijnen et al. 1999; Blair et al. 1995; Gregg et al. 2003a; Johansson and Sundquist 1999; Kujala et al. 2002; Paffenbarger et al. 1993; Wannamethee et al. 1998).

Cardiovascular disease prevention

Systematic reviews and meta-analyses have examined the relationship between physical inactivity and development of CVD (Bauman 2004; Berlin and Colditz 1990; Kohl 2001; Williams 2001). Most reviews have dealt with CVDs as a whole and (or) CHD. Stroke has also gained increasing attention recently. The literature clearly supports the value of physical activity in the prevention of CVD and CHD (Appendix Table A1).

Morris and colleagues were the first to demonstrate that men in physically demanding occupations (bus conductors and postmen) had a significantly lower risk of CHD than individuals who selected less-demanding jobs (bus drivers and office workers) (Morris et al. 1953). Since then, several influential reports have asserted the role of physical activity in the prevention of CHD and CVD-related mortality. A meta-analysis by Berlin and Colditz (1990) found a greater risk of CHD both in individuals with low rather than high non-occupational physical activity (RR = 1.6; 95% CI = 1.3–1.8) and in sedentary versus physically active occupations (RR = 1.4; 95% CI = 1.0–1.8). A review by Kohl (2001) suggested that CHD incidence and mortality bore inverse dose-dependent relationships to physical activity. Wannamethee and Shaper (2001) noted that several large prospective investigations showed an independent association between regular physical activity and a 40%–50%
lower risk of CVD, in men and women of all ages, whether with or without established CVD (Wannamethee and Shaper 2001).

Emberson et al. (2005) explored the effects of within-person variation on relationships between physical activity and CVD. They argued that risk associations derived from baseline measurements did not identify the “true” relationship because of within-person variation; failure to consider this factor led to a substantial underestimation of the importance of physical activity to cardiovascular risk (Emberson et al. 2005). After correction for within-person variation (taking into account information provided across follow-up assessments), the risk of dying was 66% lower in moderately active than in inactive men (versus 46% in uncorrected data). Their conclusion is consistent with another report that made repeated measurements of physical activity; this data showed that women who walked at least 2 h/week experienced a 67% lower risk of CHD than their inactive peers (Lee et al. 2001).

As with all-cause mortality, physical activity confers health benefits independently of other known risk factors (Lee et al. 2001; Wessel et al. 2004). Wessel et al. (2004) observed that among women undergoing evaluation for suspected myocardial ischemia, those with higher scores on the self-reported Duke Physical Activity Status Index had fewer CAD risk factors, less angiographic CHD, and a lower risk of cardiovascular events (Fig. 8). Each 1 MET increase in the Duke Activity Status Index was associated with 8% fewer major cardiovascular events during a 4-year follow-up. These associations were similar in non-obese and obese groups.

As with the all-cause mortality data, the risk of CHD seems to bear a graded inverse relationship to physical activity. The difference in CVD-related mortality approximates 20%–50%, with greater gradients observed in trials using objective measures of physical fitness (Williams 2001). Williams (2001) noted that both physical activity and physical fitness showed an inverse dose-dependent relationship to the risk of CVD and (or) CHD. However, the risk advantage was twice as large for physical fitness as for increases in leisure-time physical activity (Fig. 10).

Men and women who maintain adequate physical activity or fitness, or who enhance their status, have a lower risk of CHD than individuals who remain unfit. The difference of CHD risk is similar for men and women, and the relationship seems to extend to non-white populations (Manson et al. 2002). Some evidence suggests that in both men and women, CVD-related mortality is lower in those taking relatively small amounts of physical activity (Oguma and Shinoda-Tagawa 2004; Wisloff et al. 2006).

Physical inactivity and stroke

Stroke affects a significant proportion of Canadians (some 50 000 new cases each year) (Heart and Stroke Foundation of Canada 2007). The relationship between habitual physical activity and the risk of stroke has had less extensive examination than CHD (Katzmarzyk 2005; Kohl 2001). However, there is growing evidence supporting the preventive value of physical activity (Hu et al. 2000; Lee and Blair 2002; Lee et al. 1999; Lee and Paffenbarger 1998). A review by Katzmarzyk and Janssen (2004) reported that lack of physical activity carried an RR of 1.60 (95% CI = 1.42–1.80) for stroke, similar to or higher than that for CHD (1.45), hypertension (1.30), colon cancer (1.41), breast cancer (1.31), T2DM (1.50), and osteoporosis (1.59).

In the Harvard Alumni study of 11 130 men, the risk of stroke was lower at a weekly energy expenditure of 4.2–8.4 MJ (1000–1999 kcal/week) (RR = 0.76 (95% CI, 0.59 to 0.98). With expenditures of 8.4–12.6 MJ/week (2000–2999 kcal/week) the RR dropped to 0.54 (0.38 to 0.76) (Lee and Paffenbarger 1998). Lee and Blair (2002) noted an inverse relationship between cardiorespiratory fitness and stroke mortality in 16 878 men from the Aerobics Center Longitudinal Study. The high-fitness group (estimated peak METs = 13.1) and the moderate fitness group (estimated peak METs 10.5) had significantly lower risks of stroke mortality (68% and 63%, respectively) than the least fit men (estimated peak METs 8.5).

It remains unclear whether there is a dose–response relationship between physical activity and the risk of stroke (Kohl 2001). It is also unclear whether physical activity is associated with protection against both ischemic and hemorrhagic stroke (Katzmarzyk 2005). In a study of 72 488 women aged 40–65 years, Hu and co-workers (2000) found that physical activity bore an inverse dose-dependent relationship to the risk of both total stroke and ischemic stroke. The highest physical activity quintile was associated with a 48% lower risk of ischemic stroke. Brisk walking was also associated with a lower risk of both total and ischemic stroke. However, there was no significant association between physical activity and subarachnoid haemorrhage or intracerebral haemorrhage (Hu et al. 2000). In contrast, Lee et al. (1999) found an inverse relationship between physical activity and total stroke incidence, with a stronger relationship for hemorrhagic than for ischemic stroke (Lee et al. 1999).

Secondary prevention of cardiovascular disease

There is mounting evidence that routine physical activity yields marked improvements in the health status of patients with established CVD (Appendix Table A1). Wannamethee
et al. (2000b) reported that men with established CHD who commenced at least light physical activity had a significantly lower all-cause mortality risk than those who remained sedentary. Habitual walking and (or) moderate or heavy gardening seemed sufficient to lead to health benefits (Wannamethee et al. 2000b). This is supported by several systematic reviews and meta-analyses (Iestra et al. 2005; Jolliffe et al. 2000; Karmisholt and Gotzsche 2005; Taylor et al. 2004, 2006). Taylor et al. (2004) conducted a systematic review and meta-analysis of 48 randomized controlled trials, finding significantly lower cardiac (20%) and all-cause (26%) mortality when cardiac rehabilitation was compared with usual care. A review of 19 “exercise-only” cardiac rehabilitation trials revealed an average 28% reduction in cardiac mortality (Taylor et al. 2006). Approximately half of this benefit was due to reductions in modifiable risk factors (such as smoking habits, cholesterol, and blood pressure). Jolliffe et al. (2000) noted that total cardiac mortality was reduced by 31% in “exercise-only” and by 26% in “comprehensive” cardiac rehabilitation programmes. A systematic review of the effects of lifestyle and dietary modification in patients with CHD indicated a 24% reduction in all-cause mortality (Iestra et al. 2005). Another systematic review by Karmisholt and Gotzsche (2005) reported a 27% reduction in all-cause and CHD mortality in response to increased physical activity.

The risks of cardiac rehabilitation in established CVD are quite low. One recent investigation cited event rates of 1 per 49 565 patient–hours of exercise training, and 1 per 8484 exercise stress tests, with a cardiac arrest rate of 1.3 per 1 000 000 patient–hours of supervised exercise training (Pavy et al. 2006).

In summary, there is compelling evidence that habitual physical activity is an effective form of secondary prevention in CVD, reducing all-cause mortality by 25%–30%. Further research is needed to examine effects of age, sex, ethnicity, and socio-economic status.

Dose–response considerations for all-cause mortality and for cardiovascular-related morbidity and mortality

There is compelling evidence that 30 min of moderate-intensity (~40%–59% of heart rate reserve) exercise on most days of the week (equivalent to 4.2 MJ/week or 1000 kcal/week) reaches a threshold associated with significant reductions in all-cause and cardiovascular-related mortality (Myers et al. 2004; Paffenbarger et al. 1986b). An even smaller volume of exercise may be cardio-protective (Wisloff et al. 2006).

Paffenbarger et al. (1986b) established that physical activity of >8.4 MJ/week (>2000 kcal/week) was associated with a 1–2-year increase in the life expectancy of middle-aged men. Further, there was a gradient of all-cause mortality with levels of physical activity (Fig. 5). Subsequent work has demonstrated that an energy expenditure of ≥4.2 MJ/week (≥1000 kcal/week) is linked to a lower incidence of CVD and (or) premature mortality (Lee and Skerrett 2001; Sesso et al. 2000). All-cause mortality not uncommonly being 20%–30% less with this level of physical activity (Lee and Skerrett 2001; Paffenbarger et al. 1986b, 1993; Warburton et al. 2006a). Manson et al. (2002) reported that women who walked or exercised vigorously for at least 2.5 h/week had a 30% lower risk of CVD. They found similar differences in risk with an increase in MET score. The RR of CVD in the highest MET quintile was 0.48 (95% CI = 0.25–0.93) for black women and 0.55 (95% CI = 0.47–0.65) in white women. Moreover, there was a significant gradient with increasing habitual speeds of walking (risks relative to inactive women of 0.86, 0.76, and 0.58 for walking speeds of 3.2–4.8, 4.8–6.4, and >6.4 km/h, respectively).

Schnohr et al. (2007) examined the effects of intensity versus duration of walking in 7308 initially healthy women and men, aged 20–93. Over a 12-year follow-up, there were 1391 deaths; these were more strongly associated with walking intensity than with duration. They noted a graded inverse relationship between walking intensity and the risk of death, concluding that brisk walking was preferable to a slower pace (Schnohr et al. 2007).

Taken as a whole, at least a 20% lower risk is seen if individuals meet current guidelines (approximately 4.2 MJ/week, 1000 kcal/week), although further health benefits are observed with higher volumes and (or) intensities of physical activity (Lee and Skerrett 2001; Warburton et al. 2006a). The form of the curvilinear dose–response relationship seems such as to predict a steep decline in risk with relatively low levels of physical activity and (or) fitness, but diminishing returns at the upper end of the physical activity and fitness distributions (Blair et al. 2001).

Weekly volumes of even less than 4.2 MJ (1000 kcal) may have some cardio-protective effect (Kushi et al. 1997; Lee et al. 2001; Lee and Skerrett 2001; Leon et al. 1987; Paffenbarger et al. 1993), especially for the extremely deconditioned and the frail elderly (Warburton et al. 2006a). Lee et al. (2001) found that as little as 1 h/week of walking was associated with a 50% lower CVD mortality in one sample of women (RR = 0.49, 95% CI = 0.28–0.86). Wisloff et al. (2006) examined the association between the amount and intensity of exercise and CVD-related mortality in 27 143 men and 28 929 women over a 16-year period. Individuals were classified into categories based on the frequency, intensity (low- (no sweating) or high-intensity (sweating and exhausted)), and duration of physical activity (less than or greater than 30 min/d). A single weekly bout of self-reported high intensity exercise was associated with a lower risk of cardiovascular death relative to those reporting no activity in both men (RR = 0.61, 95% CI = 0.49–0.75) and women (RR = 0.49, 95% CI = 0.27–0.89) (Fig. 11). Moreover, no additional benefit was seen with higher durations or frequency of exercise sessions. The authors concluded that this evidence challenges current recommendations that require at least 1000 kcal/week of caloric expenditure to achieve exercise-induced protection against premature cardiovascular death. However, many current guidelines, including Canada’s physical activity guidelines, have recognized there is some potential health benefit from low volumes of physical activity, as reflected by such statements as “Every little bit counts, but more is even better – everyone can do it!” Lee and Skerrett (2001) recently postulated that a half of the currently recommended volume of
Fig. 11. Relative risk of cardiovascular disease-related death among Norwegian men and women (grouped into categories of frequency, duration, and intensity of physical activity) (Wisloff et al. 2006).

This is important to ascertain because recommending an even lower volume of physical activity for health surely will be more palatable to the many sedentary individuals in the world.

Nevertheless, the search for a minimum dose should not undermine the fact that progressive increments in health status are associated with larger doses of physical activity.

In the secondary prevention of CVD, a weekly energy expenditure of approximately 6.7 MJ (1600 kcal) seems effective in halting disease progression, and an expenditure of approximately 9.2 MJ (2200 kcal) reduces the size of atherosclerotic plaques (Franklin et al. 2003; Hambrecht et al. 1993). Even modest levels of exercise such as training at less than 45% of maximal aerobic power carry significant health benefits for individuals who are already suffering from CVD (Blumenthal et al. 1988). However, training at >45% of heart rate reserve is generally recommended for patients with heart disease, and additional health benefits are likely at higher exercise intensities (Meyer et al. 1997; Warburton et al. 2005).

Obesity prevention and treatment

Most existing physical activity guidelines were conceived to maintain or promote good health, with recommendations based on epidemiological studies of the relationship between physical activity or fitness and chronic disease or mortality outcomes (Health Canada and the Canadian Society for Exercise Physiology 1998; Pate et al. 1995; United States Department of Health and Human Services 1996). Although Canada’s physical activity guide to healthy active living lists maintenance of body mass as one of the health benefits associated with physical activity, no specific recommendations are made for either the prevention of weight gain or the treatment of obesity.

Obesity is one of a myriad of adverse health consequences of our current sedentary lifestyle (Avenell et al. 2004; Kay and Fiatarone Singh 2006; Shaw et al. 2006). The 2005 Canadian Community Health Survey found that 51% of adults were physically inactive (defined as a gross energy expenditure on active leisure pursuits of less than 6.3 kJ·kg⁻¹·d⁻¹ (Statistics Canada 2006). Further, approximately 59% of Canadian adults were overweight or obese, with 2% underweight, and 39% having a weight in the desired range (Statistics Canada 2006). Thus, in contemporary Canadian society, it is more “normal” to be overweight or obese than to have a healthy weight. Any discussion of physical activity guidelines must be made within the context of this reality.

Obesity and dose–response considerations

Routine physical activity plays an important role in body mass management (Avenell et al. 2004; Kay and Fiatarone Singh 2006; Shaw et al. 2006). Specific recommendations for the prevention of weight gain or the maintenance of weight loss have appeared in the US (Jakicic et al. 2001; Saris et al. 2003; US Department of Health and Human Services and US Department of Agriculture 2005), informed largely by the experience of weight loss and obesity trials that focused on changes in body mass without regard for other health outcomes. Current recommendations are 45–60 min/d of physical activity to prevent weight gain, and 60–90 min/d to sustain long-term weight loss (Jakicic et al. 2001; Saris et al. 2003; US Department of Health and Human Services and US Department of Agriculture 2005). Specific physical activity recommendations for “weight loss” are rare. The total required volume of physical activity depends on the desired weight loss. In most short-term trials, the loss is proportional to what might be expected from the amount of physical activity undertaken (Ross and Janssen 2001). Recommendations for the maintenance of body mass have not been widely disseminated, and have not been integrated with other public health recommendations.

The Institute of Medicine (IOM) of the US National Academies of Science has based population physical activity recommendations on a Dietary Reference Intake approach, drawing upon cross-sectional doubly labelled water determi-
nations of energy expenditure in a large sample of normal weight, overweight, and obese adults (Institute of Medicine of the National Academies of Science 2002). Based on this information, the IOM has recommended 60 min/d of physical activity; this corresponds to a physical activity level (PAL; total daily energy expenditure / basal energy expenditure) of >1.6. Because an average of 60 min/d of moderate-intensity physical activity provides a PAL associated with a normal BMI range, this amount of activity is recommended for normal weight adults. The report states explicitly that because

the Dietary Reference Intakes are provided for the apparently healthy population … levels of physical activity that would result in weight loss of overweight or obese individuals are not provided.

The logic behind the IOM recommendations has been questioned, as the mean PAL values were quite similar for normal weight and overweight/obese individuals (Blair et al. 2004); nevertheless, obesity probably results from the accumulation of small errors in energy balance. Further, given that two thirds of the US (and Canadian) population is currently overweight or obese (Ogden et al. 2006), recommendations targeted at people of “healthy” weight are applicable to only one third of the population.

The most recent iteration of Dietary guidelines for Americans (US Department of Health and Human Services and US Department of Agriculture 2005) includes physical activity recommendations for both the maintenance of general health and the management of body mass. Although the two sets of messages are not fully integrated, they appear together in the document, representing an attempt to address the issue of obesity within broader public health recommendations. The basic message here is 30 min/d of moderate-intensity physical activity, but higher levels of physical activity are recommended for the prevention of weight gain and maintenance of weight loss.

Given that the majority of the Canadian adult population is currently overweight or obese, it seems appropriate to consider integrating information on the maintenance of a healthy body mass into physical activity recommendations for general health. It is difficult to envision contemporary guidelines that do not target overweight and obese populations. Current evidence suggests that energy expenditures for the prevention of weight gain and the maintenance of weight loss must be larger than for the prevention of chronic disease. Thus, current public health recommendations targeted at the sedentary population and call for a minimal amount of physical activity may be a prescription for obesity.

The primary prevention of cancer

Considerable research has linked physical inactivity to site-specific cancers (Lee 2003; Monninkhof et al. 2007; Rockhill et al. 1999; Sesso et al. 1998; Shephard and Futcher 1997; Thune and Furberg 2001). Habitual physical activity is inversely related to the development of colon and breast cancer (see Appendix Table A2). In a systematic review, Lee (2003) reported that physically active men and women had a 30%–40% lower risk of colon cancer, and physically active women had a 20%–30% lower risk of breast cancer compared with their inactive counterparts. Another systematic review provided strong evidence for a 20%–80% lower risk of breast cancer in active post-menopausal women (Monninkhof et al. 2007); in comparison, there was only a weak association between breast cancer risk and physical activity in pre-menopausal women. Combining pre- and post-menopausal samples, physically active individuals had a 15%–20% lower risk of breast cancer. These effects did not appear to be confounded by inter-individual differences in BMI.

A growing body of evidence supports the protective effects of habitual physical activity against other forms of cancer, Cust et al. (2007) reviewed epidemiological reports for endometrial cancer, finding a 30% lower RR for active individuals; many studies exhibited a dose–response relationship. Further, there was evidence that light, moderate, and vigorous activity might all be linked to a lower risk (Cust et al. 2007).

In summary, there is clear evidence that habitual physical activity is associated with lower risks of colon cancer (approximately 30%) and breast cancer (approximately 20%); it may be also have value against other forms of cancer.

Cancer and dose–response considerations

Lee (2003) concluded that there is likely a dose–response relationship for cancers of the colon and breast; 30–60 min/d of moderate-to-vigorous physical activity was associated with a lower risk of both colon and breast cancer. The International Agency for Research on Cancer (2002) recommended 45–60 min/d of moderate-to-vigorous exercise to reduce the risk of colorectal cancer (International Agency for Research on Cancer 2002). Thune and Furberg (2001) reported that both occupation- and leisure-related physical activity showed an inverse graded dose–response relationship to the risk of colon and breast cancer. Their review of the literature suggested that moderate physical activity (>4.5 METs, equivalent to mowing the lawn) had greater protective effects than lighter-intensity activities. Monninkhof et al. (2007) found a 6% lower risk of breast cancer for each additional hour of physical activity per week. However, it was not clear whether the relationship was linear.

Other researchers have shown a linear relationship between physical activity and breast cancer. Rockhill et al. (1999) reported significantly lower risks (12% or more) of breast cancer in women who accumulated at least 1 h of moderate or vigorous physical activity each week. Similarly, Sesso et al. (1998) observed an 8% lower risk with a weekly energy expenditure of 2.1–4.2 MJ (500–999 kcal), and yet lower risk (51% reduction) at expenditures ≥4.2 MJ (≥1000 kcal). The general recommendations for physical activity thus seem appropriate to prevent colon and breast cancer, although further research is required to determine if light-intensity exercise also protects against cancer.

Diabetes prevention

fitness is also inversely associated with the risk of T2DM (Lynch et al. 1996; Wei et al. 1999). Both aerobic- and resistance-type activities appear to reduce the risk for T2DM (Eriksson et al. 1998; Katzmarzyk et al. 2007). Exercise training is also an effective strategy for secondary prevention (Eriksson et al. 1997; Gregg et al. 2003b; Honkola et al. 1997; Ishii et al. 1998; McGavock et al. 2004). Several reviews of this topic have been completed (Appendix Table A3).

Hsia et al. (2005) conducted a prospective 5-year study of 87,907 post-menopausal women, finding a strong, graded, inverse relationship between physical activity and T2DM. The relationship was stronger in “Caucasian” than in minority (African-American, Hispanic or Asian) women; the authors postulated this finding might reflect less precise risk assessments in minority women (Hsia et al. 2005).

Investigators have shown a reduced incidence of T2DM in high-risk (e.g., overweight) individuals after lifestyle interventions (Williamson et al. 2004). Tuomilehto et al. (2001) conducted a randomized controlled trial with middle-aged, overweight subjects with impaired glucose tolerance (172 males and 350 females). Each participant received detailed advice about moderate-intensity physical activity (30 min/d) and detailed dietary control. The authors found that lifestyle changes reduced the risk of T2DM by approximately 54% in women and 63% in men (Tuomilehto et al. 2001). In the US Diabetes Prevention Program, 3234 high-risk participants were randomly assigned to one of three groups: (i) a placebo control, (ii) metformin drug therapy (850 mg twice daily), and (iii) a lifestyle intervention. The lifestyle intervention (which included physical activity for at least 150 min/week) was more effective than metformin alone (respective reductions in incidence: 58% and 31%). To prevent a single case of diabetes over a 3-year period, approximately 7 persons would need to participate in the lifestyle intervention, versus prescription of metformin for 14 persons (Knowler et al. 2002). A review by Williamson and co-workers (2004) concluded that over a 3–4-year period, modest weight loss via diet and physical activity reduced the incidence of T2DM in high-risk individuals by 40%–60% (Williamson et al. 2004).

In summary, there is compelling evidence that habitual physical activity is effective in preventing T2DM. Further research is needed to uncover the ideal modalities (e.g., resistance versus aerobic exercise), possible effects of race and ethnicity, and the impact of socio-economic status on the observed relationships.

**Diabetes and dose–response considerations**

Several investigators have shown a dose-dependent relationship between T2DM and levels of physical activity or fitness. This relationship seems relatively linear across the physical activity and fitness spectrum, and risks are much lower in those engaging in moderate-intensity exercise. Small changes in activity levels can yield a significant reduction in the risk of T2DM (particularly in high-risk individuals). Hu and co-workers (2003a) recently reported on a 6-year follow up of 68,497 nurses; those who engaged in 1 h/d of brisk walking had 24% less obesity and 34% less T2DM. In contrast, the risks of obesity and T2DM were significantly greater with sedentary behaviour (TV watching) (Hu et al. 2003a). Similarly, over a 5-year period, male physicians who exercised vigorously at least once weekly had a 29% lower incidence of T2DM than individuals who did not exercise on a weekly basis (Manson et al. 1992). Manson and co-workers (1992) noted that physical activity sufficient to cause a sweat was associated (in graded fashion) with a lower incidence of T2DM.

Moderately intense physical activity (≥5.5 METs for at least 40 min/week) and (or) cardiovascular fitness >31 mL·kg−1·min−1 have also been associated with a lower risk of T2DM in middle-aged men (Lynch et al. 1996), the effect being greatest in high-risk individuals. Also, moderate occupational, commuting, and leisure-time physical activities all have a significant inverse relationship with risk in middle-aged men and women (Hu et al. 2003b).

**Prevention and treatment of hypertension**

In Canada, one fifth of adults report a diagnosis of hypertension (Joffres et al. 1997; McAlister et al. 2005). A 55-year-old normotensive Canadian also has a greater than 90% chance of developing hypertension before reaching the age of 80 years (McAlister et al. 2005). Available evidence supports the notion that physical activity is effective in the primary and secondary treatment of hypertension in both normotensive and hypertensive individuals. Prospective trials have evaluated the relationship between physical activity and hypertension (Folsom et al. 1990; Haapanen et al. 1997; Paffenbarger et al. 1983; Pereira et al. 1999). Folsom et al. (1990) concluded that women with low physical activity levels were 43% more likely to develop hypertension over a 2-year period than women with high activity levels. Similarly, Paffenbarger and associates (1983) found that individuals expending less than 8.4 MJ/week (2000 kcal/week) had a 30% greater risk of developing hypertension over a 6–10-year period. Katzmarzyk and Janssen (2004) calculated that physically inactive individuals had an RR of 1.30 (95% CI = 1.16–1.46) for hypertension, the population-attributable risk being 13.8%.

Several reviews (Appendix Table A4) have evaluated the relationship between physical activity and blood pressure (Cornelissen and Fagard 2005a, 2005b; Dickinson et al. 2006; Fagard 1999, 2001, 2005, 2006; Fagard and Cornelissen 2007; Hamer et al. 2006; Kelley 1999; Whelton, S.P. et al. 2002), with available evidence supporting an inverse relationship between physical activity or fitness and the incidence of hypertension (Fagard 1999).

Several randomized controlled trials show that habitual physical activity can lead to clinically relevant reductions in resting blood pressure. A meta-analysis of 44 randomized interventions (68 groups) revealed that exercise led to net reductions of both systolic (−3.4 mmHg; 95% CI = −4.5 to −2.3) and diastolic (−2.4 mmHg; 95% CI = −3.2 to −1.6) blood pressure (Fagard 2001). This assessment has been supported by more recent meta-analyses (Fagard and Cornelissen 2007; Whelton, S.P. et al. 2002). The effect appears to be greatest in those with hypertension, but also extends to the prevention and treatment of hypertension in the overweight and obese (Fagard 1999; Fagard and Cornelissen 2007; Whelton, S.P. et al. 2002). Benefit is also seen in...
women. In a meta-analysis of 10 randomized aerobic exercise trials (in 732 adult women), Kelley (1999) found decreases in systolic and diastolic blood pressure of approximately 2% and 1%, respectively. Moderate-intensity resistance training can also reduce resting blood pressure (Cornelissen and Fagard 2005a; Fagard and Cornelissen 2007).

A recent position stand (Pescatello et al. 2004) asserted that habitual activity (primarily aerobic) is integral to the prevention of hypertension and the lowering of blood pressure in both normotensive and hypertensive individuals. In the latter, blood pressure reductions of 5–7 mmHg have important clinical implications; a 2 mmHg reduction in SBP is associated with respective reductions of 14% and 9% in the risks of stroke and CHD (Pescatello et al. 2004).

**Dose–response issues for the prevention and treatment of hypertension**

Physical activity is effective in both primary and secondary treatment of hypertension. However, the optimal dose remains unclear. Moderate-intensity aerobic exercise seems sufficient to lower blood pressure, with the greatest effect in hypertensive individuals (Fagard 2001; Haennel and Lemire 2002). The American College of Sports Medicine (Pescatello et al. 2004) recently advocated that to prevent hypertension, individuals should exercise on most, and preferably all, days of the week at a moderate intensity, for 30 min/d or more (continuous or accumulated). They also recommended supplementing endurance-type activities with resistance exercise. This is supported by research indicating that moderate-intensity resistance training can reduce blood pressure (Cornelissen and Fagard 2005a). Further research is needed to refine these guidelines for women, older adults, and various ethnic groups (Pescatello et al. 2004).

Exercise also induces beneficial acute changes in blood pressure (Hamer et al. 2006). It is not uncommon to see a reduction in pressures for 12–22 h after a single exercise session (with the largest decrements in individuals with hypertension) (Pescatello et al. 2004; Thompson et al. 2001). These acute changes highlight the ability of a single exercise session to affect blood pressure positively. When considering these benefits, the recommendation of daily exercise for the control or prevention of hypertension is likely warranted.

**Primary prevention of osteoporosis**

Relationships between bone mineral density or bone mineral content and physical activity have been evaluated extensively (Appendix Table A5). Analyzing observational trials, Katzmarzyk and Janssen (2004) estimated the RR of inactivity was 1.59 (95% CI = 1.40–1.80), and that the population-attributable risk in Canada was 24%. Weight-bearing exercise (especially resistance exercise) appears to have positive effects on bone mineral density (Warburton et al. 2001a, 2001b). Several cross-sectional investigations have reported that resistance-trained individuals have greater bone mineral density than their non-trained counterparts (Warburton et al. 2001a). Furthermore, athletes that participate in high-impact sports have a greater bone mineral density than athletes from low-impact sports (Warburton et al. 2001a).

Intervention trials have evaluated the effects of both aerobic and resistance training on bone mineral density across the lifespan (from children to the elderly). There is compelling evidence that weight-bearing and impact exercise benefits bone health across the lifespan (Warburton et al. 2006a). Systematic and (or) meta-analytic reviews (Berard et al. 1997; Bonaiti et al. 2002; Kelley 1998a, 1998b; Kelley and Kelsey 2004; Wolff et al. 1999) and consensus statements (Brown and Josse 2002) have dealt predominantly with bone health in pre- and post-menopausal women. Wolff et al. (1999) estimated that exercise interventions prevented or reversed 1% of bone loss per year in the lumbar spine and the femoral neck of pre- and post-menopausal women. Bonaiti et al. (2002) undertook a meta-analysis of 18 randomized controlled trials on post-menopausal women from the Cochrane database and found that aerobic, resistance, and weight-bearing exercise were all effective in increasing bone mineral density in the spine, and that walking benefited bone mineral density in the hip. Another meta-analysis (Wallace and Cumming 2000) revealed that impact exercise improved bone mineral density in the lumbar spine and the femoral neck (preventing respective bone losses of 1.6% and 1.0% in post-menopausal women). Non-impact exercise (e.g., weight lifting) also resulted in improvements in the lumbar spine (1.0%). Similar results were found in pre-menopausal women (Wallace and Cumming 2000).

**Prevention of falls and fractures**

Several studies have shown that exercise reduces the risk and (or) the number of falls in comparison with inactive controls (Carter et al. 2001b; Liu-Ambrose et al. 2004; Shaw and Snow 1998; Tinetti et al. 1994; Wolf et al. 1996). Furthermore, the fracture risk and (or) incidence is lower in active individuals (Carter et al. 2001a; Gregg et al. 2000; Stevens et al. 1997). Case-control studies of older persons who suffered a hip fracture revealed that these individuals undertook significantly less physical activity throughout adulthood (Boyce and Vessey 1988; Brown and Josse 2002). Prospective studies have also shown an inverse relationship between the incidence of fractures and physical activity (Feskanich et al. 2002; Joakimsen et al. 1998; Kujala et al. 2000). In a 21-year cohort study, Kujala et al. (2000) demonstrated that intense physical activity (at baseline) was associated with a lower incidence of hip fracture (hazard ratio = 0.38, 95% CI = 0.16–0.91). This supports earlier reports of lower fracture rates in individuals who perform more weight-bearing activities (Joakimsen et al. 1998). Feskanich et al. (2002) noted a linear association between moderate physical activity and a lower risk of hip fracture in postmenopausal women who were not receiving hormone replacement therapy.

Individually tailored programs (involving resistance, aerobic and balance training) are thought to be effective in reducing falls and injuries (Brown and Josse 2002). The Canadian Medical Association (Brown and Josse 2002) reached a consensus that a “higher level of activity throughout middle life is associated with a reduced risk of hip fracture in old age.” These benefits clearly outweigh potential risks, and highlight the importance of physical activity for
bone health, especially for older individuals (Warburton et al. 2007).

The lower risk of falling and (or) fractures in physically active individuals is not solely the result of changes in bone mineral density. Changes in balance control, muscular strength, mobility, and flexibility also likely contribute to the reduced risk associated with routine physical activity (Warburton et al. 2001a, 2001b).

In summary, habitual physical activity appears to be important in the attenuation and (or) reversal of bone mineral density losses and the overall prevention of osteoporosis (particularly in post-menopausal women).

**Osteoporosis and dose–response considerations**

There is limited information on minimal and optimal doses of physical activity for the prevention of osteoporosis. Current evidence indicates that adaptations are load dependent and site specific (Kerr et al. 1996; Warburton et al. 2001a, 2001b; Warburton et al. 2006a). Physical activities that involve significant loading or impact are thus advocated for the prevention of osteoporosis. A literature review showed that running 22–30 km/week was associated with bone mineral accrual or maintenance. Bone mineral density was sometimes lower in those running longer distances (Brown and Josse 2002).

Some evidence suggests that current physical activity guidelines may be sufficient to maintain and (or) improve bone health. Feskanich et al. (2002) found that the risk of hip fracture was 6% lower for each 3 MET·h higher activity per week or 1 h/week of walking at an average pace. The risk of hip fracture also showed an inverse linear gradient with higher levels of physical activity. Walking for at least 4 h/week was associated with a 41% lower risk of hip fracture compared to individuals exercising less than 1 h/week (Feskanich et al. 2002).

In summary, preliminary evidence suggests that current physical activity guidelines may be sufficient to maintain and (or) improve bone health. However, further research is required, particularly to examine the relationships between physical activity and bone health in groups from different ethnic and (or) racial backgrounds.

**Musculoskeletal fitness and health**

Significant enhancements in health status can occur with increased physical activity in the absence of marked changes in aerobic fitness (Warburton et al. 2001a, 2001b, 2006a). Thus, regular physical activity can reduce the prevalence of risk factors for chronic disease and disability (American College of Sports Medicine 1998a; Warburton et al. 2001a, 2001b) without necessarily changing traditional determinants of cardiovascular fitness such as maximal cardiac output and oxidative potential, particularly in older individuals and (or) those who are extremely deconditioned (Warburton et al. 2006a). This observation has led to a greater focus on the health benefits of musculoskeletal fitness (Payne et al. 2000a, 2000b; Warburton et al. 2006a), especially as one ages (see Paterson et al. (2007))

Two systematic reviews (Warburton et al. 2001a, 2001b) reported that positive associations between musculoskeletal fitness and glucose homeostasis, bone health, functional independence, mobility, psychological well-being, and overall quality of life; there were also negative associations with fall risk, morbidity, and premature mortality. Interventions that increased musculoskeletal fitness had a significant positive effect on health status, particularly in individuals with a low musculoskeletal reserve. Grip strength is inversely related to premature mortality and (or) morbidity (Fujita et al. 1995; Katzmarzyk and Craig 2002; Metter et al. 2002; Rantanen et al. 1998). Rantanen et al. (1998) noted that individuals with the lowest grip strength had an earlier mortality over a 27-year follow-up. Furthermore, those with a faster rate of decline in muscular strength (>1.5%/year) or a very low grip strength (<210 N) had a greater incidence of chronic diseases such as diabetes, stroke, arthritis, CHD, and pulmonary disorders. Those in the lowest third of the grip strength distribution had an 8-fold higher risk of disability. Individuals with a high muscular strength also developed fewer functional limitations over a 5-year period (Fig. 12) (Brill et al. 2000).

Three recent Canadian epidemiological investigations (Katzmarzyk and Craig 2002; Katzmarzyk et al. 2007; Mason et al. 2007) have related musculoskeletal fitness to health status. Katzmarzyk and Craig (2002) found a significantly greater risk of premature mortality in those with the lowest quartile of sit-up scores in both men (RR = 2.72) and women (RR = 2.26). Grip strength also predicted mortality in men (RR = 1.49), but not in women. Mason et al. (2007) reported that musculoskeletal fitness was a significant predictor of weight gain over a 20-year period. Individuals with low musculoskeletal fitness, as indicated by the CSEP’s Canadian physical activity, fitness and lifestyle approach (Canadian Society for Exercise Physiology 2003), had 78% greater odds of significant weight gain (≥10 kg) compared with those with high musculoskeletal fitness. These studies provide empirical support for the inclusion of resistance and flexibility training in general physical activity

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**Fig. 12. Importance of muscular strength in reducing the incidence of functional limitations in men and women (age = 30–82 years) over a 5-year period. In this investigation, the odds ratios of reporting functional limitations at follow-up in men and women (with high levels of strength) were 0.56 and 0.54, respectively. Data adapted from Brill et al. 2000.**

![Graph showing the relationship between muscular strength and functional limitations](image)
Physical activity and mental health

Maintenance of positive mental health and the prevention of mental disorders through regular physical activity has been a focus of considerable research. In general, the focus has been on basic associations with physical activity and not on dose–response or meeting specific guideline recommendations. Below, we discuss and overview the evidence for the effect of physical activity on central mental health outcomes that have received research attention: depressive symptoms, anxiety, perceived health-related quality of life, well-being, and global self-esteem.

Depressive symptoms

Over 100 original studies and 10 meta-analyses or narrative reviews report on the association between depressive symptoms and physical activity (Appendix Table A6). The majority are large-scale epidemiological surveys suggesting that lower scores for depressive symptoms are associated with higher levels of physical activity (medium effect size). The most rigorous work on depressive symptoms and physical activity has focused on clinical depression, which affects approximately 5% of the Canadian population (Patten et al. 2005). Still, one of the most comprehensive meta-analyses has provided evidence that non-clinical and clinical populations may reap rather similar benefits (North et al. 1990). Dunn et al. (2001) reviewed studies featuring participants who had been diagnosed with Diagnostic and statistical manual of mental disorders IV (DSM-IV) depressive and anxiety disorders: 9 cross-sectional epidemiological studies, 9 prospective epidemiological studies, and 19 quasi-experimental studies. Overall, the results suggested that physical activity at all intensities, across different time periods, and with all modalities, was related to lower scores for depressive symptoms, but no definitive conclusions could be drawn in terms of dose owing to a lack of controlled studies (Dunn et al. 2001). A meta-analysis of 14 randomized controlled trials with participants reporting clinical depression (Lawlor and Hopker 2001) paralleled these results (effect size (ES) \( d = -1.1 \) (Cohen 1992)), and the most rigorously controlled study to date found similar effects (Dunn et al. 2005). Most importantly, the study showed that depressive symptoms were lower with standard moderate physical activity guidelines (64 kJ·kg\(^{-1}\)·week\(^{-1}\), 15.5 kcal·kg\(^{-1}\)·week\(^{-1}\)), but that individuals engaging in a lower dose (29kJ·kg\(^{-1}\)·week\(^{-1}\), 7.0 kcal·kg\(^{-1}\)·week\(^{-1}\)) could not be distinguished from controls. Thus, regular moderate physical activity appears an effective intervention to alleviate depressive symptoms for those with clinical depression, but Health Canada’s mild activity guidelines may not be sufficient for this purpose. The impact of adequate physical activity on clinical depression seems as great as pharmacological treatment (Blumenthal et al. 1999) and may even have better sustainability (Babyak et al. 2000). Firm conclusions cannot be drawn about the effectiveness of regular physical activity in alleviating depressive symptoms among non-clinical populations owing to a lack of methodological rigour; nevertheless, prospective correlational evidence is supportive of a preventive relationship (North et al. 1990).

Anxiety

Over 100 studies and several reviews (Appendix Table A6) have evaluated the effect of physical activity on anxiety (state and trait). Like depressive symptoms, most studies link physical activity to lower anxiety, the magnitude of effect being comparable with other anxiety-reduction methods such as relaxation (O’Connor et al. 2000) and pharmacological treatments (Brooks et al. 1998). The effect size has ranged from \( d = -0.24 \) to \( d = -0.56 \), depending on the anxiety measures used and the initial levels of participant anxiety (O’Connor et al. 2000; Petruzzello et al. 1991). Almost all of these studies have been conducted with non-clinical populations, the majority using undergraduate convenience samples. Assessment of a dose–response relationship for the anxiolytic effect has proven difficult, with current evidence mixed as to what intensity, duration, and frequency provide the best anxiolytic response; 20 min post-exercise moderate aerobic exercise seems superior to high-intensity resistance training (O’Connor et al. 2000; Petruzzello et al. 1991). In conclusion, physical activity consistently reduces anxiety symptoms among asymptomatic adults, the effect size ranging from small to borderline-medium. Dose–response relationships have not been established, but warrant sustained research.

Health-related quality of life and generalized well-being

Perceived health-related quality of life (i.e., perceived health status) and generalized well-being (e.g., perceived general happiness, social functioning, psychological function) are difficult to disentangle in existing research because of mixed and unstandardized methods of measurement (Rejeski et al. 1996). Furthermore, most studies relating health-related quality of life and well-being to physical activity have focused on clinical populations, older adults, or populations with chronic illness. In the general adult population, eight quality of life or well-being studies have focused on a relationship with physical activity (Blacklock et al. 2007; Brown et al. 2004; Gauvin 1989; Laforge et al. 1999; McTeer and Curtis 1990; Smale and Dupuis 1993; Vullilain et al. 2005; Wendel-Vos et al. 2004). All are correlational surveys using self-reports of physical activity and various measures for quality of life/well-being (covaried for sociodemographic factors). Almost all studies show small but positive relationships between quality of life and physical activity (construed as meeting moderate or vigorous guidelines). However, a longitudinal study using change in physical activity to predict quality of life/well-being, found trivial effects in all domains but social functioning (Wendel-Vos et al. 2004). In the single study to evaluate effects of frequency and duration, no marked dose-related differences were seen (Brown et al. 2004). Nonetheless, mild-intensity activity does not appear to be associated with quality of life or well-being outcomes (Blacklock et al. 2007). Correlational studies with modest sample sizes also failed to show associations with life satisfaction, arguably the central and fundamental construct of overall well-being (Blacklock et al. 2007; Gauvin 1989). Overall, meeting at least moderate-intensity physical activity guidelines may be associated with most health-related quality of life domains (e.g., mental, social, and physical), but the effect is small and it may not generalize to overall life satisfaction. Since
research to date is limited to correlational designs, no definitive conclusions are yet possible.

**Global self-esteem**

The self is probably one of the most-studied psychological constructs and its relationship to mental health is well-established (Keyes and Waterman 2003). Global self-esteem sits at the top of the hierarchy in multi-faceted self-esteem models (Shavelson et al. 1976), and thus is the most applicable to overall mental health. Several reviews have been focused on physical activity and global self-esteem (Appendix Table A6). Spence et al. (2005) conducted a meta-analysis of 113 experimental studies on the effect of physical activity on global self-esteem among adults. The overall effect size was small ($d = +0.23$), but change in fitness moderated this relationship; specifically, the greater the change in fitness, the greater the increase in self-esteem. Mode of activity, frequency, duration, intensity, length of programme, type of participants, sex, and age did not influence the effect (Spence et al. 2005). These results suggest that physical activity may have a small overall effect on global self-esteem, but dose-related differences are negligible.

In summary, the effect of physical activity on depressive symptoms and anxiety is well-established, although dose-response issues still need experimental research with a prevention-based focus. There is a small positive relationship between general physical activity meeting moderate activity guidelines and measures of mental health-related quality of life and well-being, but the evidence to date is only correlational. Generalized indicators of well-being and self-esteem may have a very small relationship with physical activity in asymptomatic adults regardless of dose; this is probably due to the myriad factors that can affect these global executive perceptions.

**Physical inactivity and sedentary behaviour**

Many agencies are now recognizing the need to address the issue of sedentary behaviour as well as physical activity. A growing body of research has evaluated the impact of the time spent in sedentary behaviour (e.g., sitting, watching television) upon the risk of chronic disease (Hu et al. 2003a; Manson et al. 2002). Manson et al. (2002) reported that in 73,743 women aged 50–79 years, the risk of CVD was associated with the number of hours spent sitting each day. The RR was 1.38 (95% CI = 1.01–1.87) in women that sat for 12–15 h/d, and 1.68 (95% CI = 1.07–2.64) in those who sat at least 16 h/d in comparison with those who spent less than 4 h/d lying down or sleeping. Hu et al. (2003a) noted that the time spent watching TV was also directly related to the risk of obesity and T2DM. For each 2 h/d decrease in TV watching there was a 23% lower risk of obesity and a 14% lower risk of T2DM. Further, each 2 h/d increase in sitting at work was associated with a 5% higher risk of obesity and a 7% higher risk of T2DM. In contrast, brisk walking was associated with a significantly lower risk of both obesity and T2DM. The authors concluded that 30% and 43%, respectively, of incident obesity and T2DM could be prevented by adopting an active lifestyle (including less than 10 h/week of TV watching and 30 min/d or more of brisk walking).

**The healthy lifespan approach**

The average life expectancy continues to increase in Canada (Statistics Canada 2007), although it has recently been suggested that physical inactivity may have a negative impact on life expectancy (Katzmarzyk and Craig 2006). Nevertheless, life expectancy in itself does not take into account the years a person may live in a dependent or diseased state. The overall quality of life is of utmost importance (especially as one ages). Thus, health agencies are now adopting new criteria reflecting the number of years a person might live in a healthy state. The WHO has recently introduced the health-adjusted life expectancy (HALE) scale that takes into account anticipated years of ill-health to provide an estimate of years of healthy living.

Regular physical activity not only prolongs one’s life expectancy (Lee et al. 1997), it also delays the onset of chronic disease and (or) disability. Therefore, physical activity is an effective means of increasing the number of years that a person lives in a healthy state. If disability does develop in an active person, it is generally only briefly, at the end of life (Powell and Blair 1994). Accordingly, when promoting the health benefits of physical activity it is important to acknowledge its capacity to improve quality of life across the lifespan. This is covered in greater detail in the companion article by Paterson and colleagues (2007).

**Mechanisms of action**

Several biological mechanisms may explain directly or indirectly the vast capacity of physical activity to affect multiple disease states. Indirect adaptations include improvements in body composition (e.g., reduced abdominal obesity and improved weight control). Direct adaptations include reduced systemic inflammation (Nicklas et al. 2005), improved glucose homeostasis and insulin sensitivity (American College of Sports Medicine 1998a; Kelley and Goodpaster 1999; Wallberg-Henriksson et al. 1998; Warburton et al. 2001a, 2001b; Young 1995), decreased blood coagulation (Rauramaa et al. 1986), enhanced lipid lipoprotein profiles (Berg et al. 1997; Brenes et al. 1986; DuRant et al. 1993; Halle et al. 1996; O’Connor et al. 1995; Taimela et al. 1994; Tell and Vellan 1988; Warburton et al. 2001a, 2001b), improved autonomic tone (Adamopoulos et al. 1992; Tiukinhoy et al. 2003), reduced resting blood pressure (American College of Sports Medicine 1993; Paffenbarger et al. 1991, 1983), improved coronary blood flow (Hambrecht et al. 2000b), enhanced cardiac function (Warburton et al. 1999, 2004a, 2004b) and improved endothelial function (Gokee et al. 2002; Hambrecht et al. 2000a; Kobayashi et al. 2003; McGavock et al. 2004). Collectively, these adaptations are of particular importance for diseases of the cardiovascular system, but also have significant implications for the prevention and (or) treatment of various other chronic diseases including T2DM, osteoporosis, hypertension, obesity, cancer, and psychological well-being.

Physical activity may also result in adaptations that are of particular benefit for individual disease states (Warburton et al. 2006a, 2006b). For example, a series of adaptations have particular benefit for the prevention and (or) treatment of T2DM, including increased GLUT-4 protein and mRNA ex-
pression (Christ-Roberts et al. 2004; Dela et al. 1994), improved muscle capillary density (resulting in improved glucose delivery to the muscle) (Mandroukas et al. 1984), and increased glycogen synthase (Christ-Roberts et al. 2004) and hexokinase activity (Mandroukas et al. 1984). Habitual activity may affect cancer rates via an increased energy expenditure that offsets a high-fat diet (Shephard and Futcher 1997), changes in fat stores (Shephard and Futcher 1997), activity-related alterations in sex hormones, insulin and insulin-like growth factors, enhanced immune function, reduced free-radical generation (Westerdinck 2003), and direct effects on the tumour (Westerlind 2003).

Evidence-informed recommendations for physical activity in adult Canadians

Most international physical activity guidelines support the incorporation of moderate-intensity physical activity on most (preferably all) days of the week. The current Canadian physical activity guidelines for adults are consistent with international guidelines, expert opinion, and literature supporting marked reductions in the risk for varied chronic conditions and premature mortality. If the entire Canadian population (Katzmarzyk et al. 2000; Katzmarzyk and Janssen 2004) followed the current physical activity guidelines, approximately one third of deaths related to CHD could be prevented, approximately one quarter of deaths related to stroke could be prevented, approximately 20% of deaths related to colon cancer and T2DM could be prevented, up to 14% of deaths related to breast cancer could be prevented, up to 20% of deaths related to hypertension could be prevented, and approximately one quarter of deaths related to osteoporosis could be prevented. The prevention of weight gain and the maintenance of weight loss require greater physical activity levels than the general physical activity recommendations. The minimal amount of physical activity currently advocated may be a prescription for obesity.

Areas requiring further investigation

Further investigation is required to establish clearly whether a volume of exercise lower than that currently recommended by most health and fitness agencies is associated with a lower risk for varied chronic conditions, or whether such a level helps in initiating a more active lifestyle. Further examination of the minimal and optimal level of physical activity needed to address the current epidemic of obesity is warranted, and additional research is required to examine the relationships between physical activity and certain specific sub-populations (including females, various racial and ethnic groups, and those of low socio-economic status).

Summary

There is overwhelming evidence that regular physical activity is an effective strategy for preventing premature mortality, CHD, stroke, hypertension, obesity, T2DM, depression, breast cancer, colon cancer, and osteoporosis. Physical activity may also have a small overall effect on global self-esteem. In many instances, the dose–response relationship is linear, with further health benefits accruing from increasing levels of activity. The current Canadian physical activity guidelines for adults seem sufficient to reduce the risk of many chronic diseases simultaneously. However, further refinement is likely required to tackle the current epidemic of obesity. Further investigation of responses is also warranted in specific sub-populations such as recent immigrants and those of low socio-economic status.

Acknowledgements

This project was supported by the Public Health Agency of Canada. The leadership and administrative assistance was provided by the Canadian Society for Exercise Physiology. Dr. Warburton and Dr. Rhodes were supported by a Canadian Institutes of Health Research (CIHR) New Investigator award and a Michael Smith Foundation for Health Research Scholar award. We are indebted to the work conducted by Lindsay Nettlefold in the review of the literature and the development of tables for this manuscript.

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Appendix A
Appendix A appears on the following pages.
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<th>Author</th>
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<th>Purpose of review</th>
<th>All-cause mortality results</th>
<th>Cardiovascular mortality/morbidity results</th>
<th>Main findings/conclusions</th>
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<tbody>
<tr>
<td>Berlin and Colditz 1990</td>
<td>Performed a meta-analysis on data extracted in a previous review (Powell 1987). Eight additional articles published since the study of Powell et al. were identified by a MEDLINE search and by checking reference lists. Studies were separated into work-related activity and leisure-time related activity (studies that used both were grouped with the leisure-time studies)</td>
<td>To examine (via meta-analytic procedures) the relationship between PA and CHD</td>
<td>Pooled RR (95% CI) for CHD death. Occupational activity. High vs. moderate PA in studies that reported moderate and sedentary comparison groups (5 studies); RR = 1.4 (1.2–1.8). High vs. low PA in studies that did not separate moderate and sedentary comparison groups (6 studies); RR = 1.5 (1.1–2.0). High PA vs. sedentary from studies that reported both moderate and sedentary comparison groups (5 studies); RR = 1.9 (1.6–2.2). Non-occupational activity. High vs. moderate PA in studies that reported moderate and sedentary comparison groups (1 study); RR = 1.3 (1.0–1.7). High vs. low PA in studies that did not separate moderate and sedentary comparison groups (2 studies; RR = 1.9 (1.0–3.4). High PA vs. sedentary from studies that reported both moderate and sedentary comparison groups (1 study); RR = 1.6 (1.2–2.2). Non-occupational activity (including the studies that were not included in Powell’s article); High vs. moderate PA in studies that reported moderate and sedentary comparison groups (3 studies); RR = 1.6 (1.1–2.4). High PA vs. sedentary in studies that reported moderate and sedentary comparison groups (4 studies); RR = 1.7 (1.2–2.3)</td>
<td>Convincing evidence that PA is protective against CHD; pattern of association noted in this study is supportive of a dose–response relationship</td>
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<tr>
<td>Eaton 1992</td>
<td>A search of MEDLINE was supplemented by a manual search of the literature. 7 articles examined the relationship between physical fitness and CHD</td>
<td>To examine the relationship between PA and physical fitness with CHD</td>
<td>All 7 studies demonstrated a reduction in CHD with increased physical fitness; RR for least vs. most fit ranged from 1.2 to 4.8</td>
<td>Evidence supports a causal relationship between physical fitness and CHD; further research is needed to discover clinical and public health implications</td>
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<tr>
<td>Thompson 1994</td>
<td>Not described</td>
<td>To describe the physiological aspects of exercise and its effect on risk for CVD, cancer and all-cause mortality</td>
<td>Strong evidence for a reduction in all-cause mortality with exercise</td>
<td>Strong evidence for a reduction in risk of CVD with exercise</td>
<td>Literature suggests that exercise is effective in reducing the risk for CVD and all-cause mortality, with some disagreement</td>
</tr>
<tr>
<td>Author</td>
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<td>Pate 1995</td>
<td>Not described</td>
<td>To examine the literature concerning the dose–response relationship between PA and health</td>
<td>PA or fitness is inversely related to all cause mortality. In studies examining the change in PA, increases in PA or fitness were associated with lower mortality risks than staying at the same level of PA</td>
<td></td>
<td>Graded response between most health parameters and PA levels</td>
</tr>
<tr>
<td>Blair and Connelly</td>
<td>Reviewed selected recent representative studies supplemented by classical studies in the area</td>
<td>To review and summarize the evidence regarding the type and amount of exercise necessary for health and function</td>
<td></td>
<td>Evidence shows an inverse relationship between the risk of disease and levels of PA or fitness</td>
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<tr>
<td>Bauman and Owen</td>
<td>Not described</td>
<td>To review the recent epidemiological evidence for the association between PA and health</td>
<td>Strong and consistent evidence for a reduction in risk</td>
<td>Maximum benefit seen when moving from sedentary or low fitness group to moderate fitness group. The RR between the most and least active groups suggests that those individuals in the least active group have about double the risk as those in the most active group</td>
<td>Research since 1995 (following the US Surgeon General’s report) has similar results to the US Surgeon General’s report; individuals in the low fitness group are at twice the risk of cardiovascular events or mortality than those in higher fitness groups; there is evidence for a dose–response relationship</td>
</tr>
<tr>
<td>Ketola et al. 2000</td>
<td>A search of MEDLINE (1966–December 1998), DARE, EMBASE and the Cochrane Library (Issue 3, 1999). 57 articles met the inclusion criteria</td>
<td>To examine the effectiveness of different lifestyle interventions in the primary and secondary prevention of CVD in adults</td>
<td>1 study revealed a positive effect on total mortality</td>
<td>10/16 studies that included changes in exercise had positive outcomes. The outcome measures were varied between studies and could not be combined; CVD Mortality; 8/16 studies used CVD mortality as an endpoint; 2 of these showed an effect of exercise</td>
<td>More research should be performed examining the use of exercise as primary prevention; future studies should adhere to a standard of outcome measurement to facilitate evaluations of effectiveness</td>
</tr>
<tr>
<td>Blair et al. 2001</td>
<td>PubMed search from 1990 to August 25, 2000. Included articles that had 3 or more categories of activity or fitness and a health outcome. A total of 67 articles were included (All Evidence Category C)</td>
<td>To assess whether there is a dose–response relationship between PA and (or) physical fitness and health</td>
<td>Across fitness groups (9 studies), all studies included showed a reduction in mortality with increasing fitness. Most studies showed at least a 50% lower mortality rate in the highest fitness group compared to the lowest fitness group</td>
<td>It was not possible to quantify a dose–response relationship because of a wide range of health outcomes (i.e., not just CVD) and assessment of PA (49 studies). However, most studies show an inverse graded response for health outcomes across PA categories</td>
<td>Most studies show an inverse graded response between activity levels and reduced risk of CHD, CVD, and stroke; relationship is commonly curvilinear with a steeper response in the lower fitness groups and a more shallow response (i.e., an asymptote) in the higher fitness groups</td>
</tr>
<tr>
<td>Jolliffe et al. 2001</td>
<td>Cochrane database systematic review to December 1998; N = 8440 CHD patients</td>
<td>To examine the effectiveness of exercise only or exercise as part of a comprehensive cardiac rehabilitation program on mortality, morbidity and health-related quality of life.</td>
<td>Pooled effects estimate, odds ratio (95% CI); 0.73 (0.54 – 0.98) = exercise only; 0.87 (0.71 – 1.05) = comprehensive program</td>
<td>Pooled effects estimate, odds ratio (95% CI); 0.69 (0.51 – 0.94) = exercise only; 0.74 (0.57 – 0.96) = comprehensive program</td>
<td>Exercise rehabilitation is effective in reducing cardiac-related and all-cause mortality in men and women with CHD</td>
</tr>
<tr>
<td>Author</td>
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<td>Kohl 2001</td>
<td>MEDLINE search of the literature up to August 2000. Findings were supplemented by consensus reports and other published literature</td>
<td>To summarize the existing literature regarding the dose–response relationship between PA and CVD endpoints</td>
<td>Major observational studies indicate a dose–response relationship between PA and CVD incidence/mortality. There is disagreement in the literature concerning the effect of PA on the risk for stroke with some studies showing a dose–response relationship, others showing no relationship and still others showing “U” shaped relationships</td>
<td>PA is inversely associated, in a dose–response manner, with the risk of CVD; evidence for a dose–response relationship between PA and stroke is equivocal</td>
<td></td>
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<tr>
<td>Lee and Skerrett 2001</td>
<td>Review of papers published between 1966 and July 2000; 44 papers identified with ≥2 levels of PA</td>
<td>To examine the dose–response relationship between PA and all-cause mortality</td>
<td>Clear evidence of an inverse linear dose–response relationship</td>
<td>Clear evidence of an inverse linear dose–response relationship between volume of PA and all-cause mortality rates in men and women; evidence suggests that the relationship is linear rather than L-shaped or with a threshold and that PA eliciting an energy expenditure of ~1000 kcal/week reduces all-cause mortality ~20%–30%; several studies have suggested that benefits may occur with energy expenditure below this level</td>
<td></td>
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<tr>
<td>Oja 2001</td>
<td>A search of MEDLINE, Sport, Ebsco, Academic Search Elite, Cochrane Systematic Reviews and Dare databases yielded 19 observational and 15 RCT</td>
<td>To examine the characteristics of the dose–response relationship between volume of PA and fitness and health outcomes</td>
<td>Cross-sectional and follow-up observational studies suggest a graded positive dose response between total volume of PA and all-cause mortality</td>
<td>Observational studies demonstrate a dose–response relationship between the volume of PA and health measures: non-randomized, uncontrolled randomized and RCTs did not show a dose–response relationship between PA volume and health and fitness</td>
<td></td>
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<tr>
<td>Shephard 2001</td>
<td>MEDLINE search from 1991 – December 1999. Findings were supplemented by previous review articles and previously collected published literature</td>
<td>To examine relative vs. absolute intensity of PA in health outcomes</td>
<td>The literature included for analysis in this review suggests an absolute intensity of about 6 METs was required for reductions in all-cause mortality. Some studies have shown health benefits to occur at light and moderate intensities as well</td>
<td>One study suggested an energy expenditure of 8.4MJ/week was needed to reduce the size of atherosclerotic lesions</td>
<td>A number of reports suggest that the threshold for all-cause or CVD benefit is an absolute intensity of about 6 METs; unknown how this relates to relative intensities or to the volume of activity</td>
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<tr>
<td>Author and Year</td>
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<td>Wannamethee and Sharp 2001</td>
<td>Review of epidemiological studies regarding PA and CVD</td>
<td>To examine the epidemiological evidence for a relationship between PA and CVD</td>
<td>Not discussed</td>
<td>The literature generally supports the theory that there is an association between the amount of PA and reductions in CVD mortality in both men and women</td>
<td>Large prospective studies have shown that PA is independently associated with a 40%–50% reduction in the risk of stroke and CHD in men and women, whether young or old, with or without pre-existing CVD; regular PA at a moderate intensity appears to be sufficient to obtain significant benefits for CHD, stroke and CVD; the literature suggests a linear dose–response relationship between PA and CVD up until certain amount of PA.</td>
</tr>
<tr>
<td>Williams 2001</td>
<td>Meta-analysis of 16 cohorts (1,012,809 person–years) included in the Surgeon General’s Report</td>
<td>To compare the dose–response relationships between CVD endpoints and LTPA/fitness</td>
<td>Each percentile of PA ≥25th percentile has significantly lower risk of CHD or CVD in comparison to the referent (least active) group</td>
<td>Comparison demonstrates that LTPA and fitness have significantly different relationships to CVD/CHD risk; increasing either fitness or LTPA was associated with a reduction in risk, but the reductions in RR with increasing fitness are almost twice as large as the reductions in RR with increasing LTPA.</td>
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<tr>
<td>Haennel and Lemire 2002</td>
<td>A MEDLINE search from Jan 1991 – Dec 2000 yielded 39 articles. This was supplemented by consensus documents and by checking the reference lists</td>
<td>To examine the role of PA in the prevention of CVD-related mortality with an emphasis on the intensity and amount of PA needed for health benefits</td>
<td>Moderate levels of PA are associated with lower mortality rates in older and younger men and women. The literature supports an inverse linear relationship between all-cause mortality and the amount of PA</td>
<td>The literature suggests an inverse relationship between the weekly amount of PA and the incidence of CVD-related mortality</td>
<td>Clear evidence of an inverse linear relationship between the amount of PA and all-cause and CVD-related mortality; energy expenditures of ~4200 kJ·week⁻¹ are associated with substantial health benefits, although the minimal effective dose remains unknown; significant reductions in the incidence and mortality of CVD are noted with 30–60 min moderate activity (i.e., brisk walking) on most days of the week.</td>
</tr>
<tr>
<td>Houde and Melillo 2002</td>
<td>MEDLINE and CINAHL search from 1990 to August 2000. A total of 44 articles were reviewed that examined PA and cardiovascular health in older adults</td>
<td>To evaluate the current status of the literature concerning PA and CVD risk factors in older adults</td>
<td>Study outcomes overwhelmingly support the contention that the risk of mortality is reduced in more active individuals</td>
<td>An active lifestyle decreases mortality and can reduce risk factors for CVD.</td>
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</tr>
<tr>
<td>Oguma et al. 2002</td>
<td>Review of papers published between January 1966 – December 2000; women only</td>
<td>To examine the association of PA or fitness with all-cause mortality in women</td>
<td>Median RR (CI not reported) = 0.66. Types of PA: RR (CI’s not reported); 0.75 = total PA; 0.66 = LTPA; 0.54 = OPA; 0.55 = physical fitness</td>
<td>Adherence to current PA guidelines (4200 kJ of energy expenditure per week) can postpone mortality in women</td>
<td></td>
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<tr>
<td>Author</td>
<td>Design</td>
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<tr>
<td>Brown 2003</td>
<td>A systematic review and meta analysis of the literature using the same methods as the Cochrane systematic review whenever possible. This was performed to update the evidence found in the 1998 Cochrane systematic review; The search yielded 10 new trials that have been published since the Cochrane review; This brought the total number of articles to 46. Studies were categorized as exercise cardiac rehabilitation (19 studies, 2984 patients) or comprehensive cardiac rehabilitation (27 studies, 5693 patients)</td>
<td>To review cardiac rehabilitation programs with exercise components for secondary prevention of CVD in terms of clinical and cost effectiveness. This was performed to update the evidence found in the 1998 Cochrane systematic review</td>
<td>All cause mortality: RR (95%CI); Exercise cardiac rehabilitation: 0.76 (0.59 – 0.98); Comprehensive cardiac rehabilitation: 0.87 (0.74 – 1.02)</td>
<td>CVD Mortality: RR (95%CI) Exercise cardiac rehabilitation: 0.73 (0.56 – 0.96); Comprehensive cardiac rehabilitation: 0.80 (0.65 – 0.99)</td>
<td>Cardiac rehabilitation programs including exercise appear to be beneficial in the reduction of cardiac and total mortality; comprehensive cardiac rehabilitation programs may have a somewhat greater effect than exercise only programs on risk factors</td>
</tr>
<tr>
<td>Katzmarzyk et al. 2003</td>
<td>A variance-based method of meta analysis was used to summarize 55 analyses (31 studies) for physical inactivity</td>
<td>To identify the independent effects of physical inactivity and excess adiposity on premature mortality</td>
<td>All cause mortality (summary relative risk (95% CI)); With adiposity as covariate: 0.80 (0.78 – 0.82); Without adiposity as covariate: 0.82 (0.80 – 0.84)</td>
<td></td>
<td>Physical activity and mortality are inversely related independent of adiposity</td>
</tr>
<tr>
<td>Mosca et al. 2004</td>
<td>MEDLINE (1966-July 3, 2003), CINAHL (1982 – 3 July 2003) and PsycInfo (1872 – 3 July 2003) searches identified 399 articles</td>
<td>To develop a set of evidence-based guidelines for the prevention of CVD in adult women</td>
<td></td>
<td></td>
<td>Women should be encouraged to accumulate at least 30 min of moderate intensity PA on most, if not all, days of the week; evidence supporting this recommendation is considered class I (i.e., useful and effective), category B (i.e., evidence comes from limited RCT and non-randomized studies) and it is very likely that the results can be generalized to women</td>
</tr>
<tr>
<td>Oguma and Shinoda-Tagawa 2004</td>
<td>Systematic review and meta-analysis of 30 papers published between January 1966 – March 2003; women only</td>
<td>To examine the dose-response relationship between PA and CVD-related morbidity and (or) mortality in women</td>
<td>CVD-related morbidity and (or) mortality RR (95% CI); 1.00 = least active level, referent; 0.84 (0.75-0.94) = second least active; 0.77 (0.69-0.87) = third most active; 0.69 (0.57-0.83) = second most active; 0.67 (0.52-0.85) = most active</td>
<td></td>
<td>There is a graded reduction in the risk for CVD in women with increasing levels of PA; as little as 1 h/week of walking is associated with a reduced risk for CVD</td>
</tr>
<tr>
<td>Taylor et al. 2004</td>
<td>Systematic review &amp; meta-analysis of RCTs, up to March 2003; 48 trials, 8940 patients with CHD</td>
<td>To compare cardiac rehabilitation vs. usual care</td>
<td>Reduced all-cause mortality, odds ratio (95% CI) = 0.80(0.68 – 0.93)</td>
<td>Reduced cardiac mortality, odds ratio (95% CI) = 0.74 (0.61 – 0.96)</td>
<td>Exercise-based cardiac rehabilitation is of benefit for reducing cardiac and all-cause mortality in patients with CHD</td>
</tr>
<tr>
<td>Author</td>
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<td>Clark et al. 2005</td>
<td>A search of MEDLINE (1966–2004), Cochrane Central Register of Controlled Trials (Issue 4, 2004), EMBASE (1980–2004), CINAHL (1982–2004), SIGLE (1980–2004) and PubMed (Jan 2004 – Dec 2004) for RCTs. This was supplemented by manual searches of reference lists and references provided by the Centers for Medicare &amp; Medicaid Services. 63 unique randomized clinical trials met all of the inclusion criteria. This comprised 21,295 patients with coronary disease. Three categories of interventions were described: Program without exercise, program with exercise, exercise only.</td>
<td>To evaluate (via meta-analytic procedures) secondary prevention programs for cardiovascular disease both with and without exercise components</td>
<td>All Cause Mortality: Exercise only vs. control (Risk ratio (95% CI)) - 0.72 (0.54 – 0.95); All Cause Mortality: Program with exercise or exercise only vs. control (Risk ratio (95% CI)) - 0.83 (0.72 – 0.96); All Cause Mortality: Program with no exercise (Risk ratio (95% CI)) - 0.87 (0.76 – 0.99)</td>
<td>Secondary prevention programs with and without exercise are effective in improving health in patients with CHD</td>
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<tr>
<td>Warburton et al. 2006</td>
<td>Narrative review of the literature</td>
<td>To examine the evidence for PA in the primary and secondary prevention of varied chronic conditions</td>
<td>There is compelling evidence that moderate PA levels are associated with risk reductions of at least 20%-35% for premature mortality</td>
<td>Regular PA is an effective primary and secondary preventive strategy for CVD (and multiple other chronic conditions)</td>
<td>There is irrefutable evidence of the effectiveness of regular PA in the primary and secondary prevention of several chronic diseases (e.g., CVD, T2DM, cancer, hypertension, obesity, depression and osteoporosis) and premature death; current Canadian PA guidelines are sufficient to elicit health benefits, especially in previously sedentary people; there is a dose–response relationship between PA and health status</td>
</tr>
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</table>

Note: PA, physical activity; CVD, cardiovascular disease; RCT, randomized control trials; CHD, coronary heart disease; HRR, hazard rate ratio; kJ/week, kilojoules/week; RR, relative risk ratio; LTPA, leisure-time physical activity; OPA, occupational physical activity; CI, confidence interval; T2DM, type 2 diabetes mellitus.
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<tr>
<th>Author</th>
<th>Objective</th>
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<th>Primary results</th>
<th>Main findings/conclusion</th>
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<tr>
<td>Monninkhof et al. 2007</td>
<td>To examine the epidemiologic evidence for an association between PA and risk of breast cancer. To evaluate whether PA is more or less effective in reducing risk at different points in life (for example pre and post-menopause). To examine how study quality affects the outcome</td>
<td>Systematic search of PubMed up to February 2006. This was supplemented by a manual search of reference lists. Developed a quality assessment tool and split the studies about the median score into lower and higher quality groups. Used RR&lt;0.8 as reduced risk; 0.8&lt;RR&lt;1.25 as no association and RR&gt;1.25 as increased risk</td>
<td>19 cohort studies and 29 case-control studies met the inclusion criteria for the review</td>
<td>Cohort studies (total activity, n = 3) Inconsistent results: one decreased risk, one no association, one increased risk; Cohort studies (LTPA, n = 17); 8/17 studies showed a reduction in risk; 9/17 showed no association; * PA in general, lower quality studies showed greater reductions in risk; * 6/7 studies reporting &gt;2 levels of PA showed an inverse dose-response relationship; Case-control (total activity, n = 6); 46 studies showed a reduction in risk; Of these, 2 appeared to show a dose-response relationship but presented no P values for trend and 1 reported a significant test for trend however the graph did not appear to show a dose-response effect; Case-control (LTPA, n = 28); 14/28 showed a reduction in risk ranging from 23%–65%; Of these, 9 appeared to show a dose-response relationship</td>
<td>The studies reviewed show strong evidence of an inverse relationship between PA and post-menopausal breast cancer (20%–80% risk reduction). The authors suggest that the evidence for a relationship between PA and pre-menopausal breast cancer is weak and indecisive. Overall, PA elicits a reduction in risk of 15%–20%. A dose-response relationship was observed in half of the high quality studies that showed a reduction in risk with PA. The risk reduction was ~6% with each additional hour of PA/week. &quot;Being physically active as an adult appears to reduce breast cancer risk irrespective of the amounts of activity before age 20.&quot;</td>
</tr>
<tr>
<td>Samad et al. 2005</td>
<td>To review the evidence regarding an association between PA and large bowel cancer</td>
<td>A search of Medline, Embase and the Cochrane Library database up to January 2002. This was supplemented by a manual search of reference lists</td>
<td>19 cohort studies and 28 case-control studies met the inclusion criteria for the review</td>
<td>Colon and colorectal cancer. 40 studies showed a reduction in risk in men. 18 studies showed a reduction in risk in women. Cohort Studies: Physically active men RR (95% CI): Occupational PA: 0.79 (0.72–0.87); Recreational PA: 0.78 (0.68–0.91); Physically active women RR (95% CI): Occupational PA: not significant: 1.11 (0.84–1.46); Recreational PA: 0.71 (0.57–0.88) No association between; PA and rectal cancer in either men (1.00, 95% CI = 0.78–1.29) or women (1.00, 95% CI = 0.53–1.88); Case-Control Studies: Physically active men RR (95% CI): Occupational PA: 0.70 (0.64–0.77); Recreational PA: 0.58 (0.47–0.72); Physically active women RR (95% CI): Occupational PA: 0.49 (0.37–0.65); Recreational PA: 0.61 (0.45–0.83); No association between PA and rectal cancer in either men (0.94, 95% CI = 0.83–1.07) or women (0.87, 95% CI = 0.51–1.47)</td>
<td>PA appears to be protective against colon cancer but not against rectal cancer. Men and women experience similar reductions in risk except for cohort studies of occupational PA</td>
</tr>
<tr>
<td>Author</td>
<td>Objective</td>
<td>Method</td>
<td>Participants</td>
<td>Primary results</td>
<td>Main findings/conclusion</td>
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<tr>
<td>Thune and Furberg 2001</td>
<td>To examine the evidence for a dose–response relationship between the volume of PA and cancer risk</td>
<td>A systematic search of Medline and PubMed until August 2000. This was supplemented by a manual search of reference lists</td>
<td>48 studies involving colorectal, colon and rectal cancer were identified (23 cohort studies, 25 case-control studies)</td>
<td>35/48 studies observed 10%–70% reductions in colon/colorectal cancer risk with LTPA, OPA or total PA; 21/33 studies showed a significant, inverse, crude dose–response relationship between LTPA and colon cancer; There was no relationship between PA and rectal cancer in 80% of 24 studies; 26/41 studies showed a dose–response relationship between PA and risk for breast cancer</td>
<td>The authors state that despite methodological limitations, the combined evidence confirms that PA is protective in a dose–response manner against breast and colon cancer, but not against rectal cancer</td>
</tr>
<tr>
<td>Quadrilatero and Hoffman-Goetz 2003</td>
<td>To review the proposed mechanisms linking physical activity and colorectal cancer</td>
<td>A 3-stage systematic search of Medline from 1970 to 2002</td>
<td>23 review articles were identified to generate hypotheses. 12 original research articles were identified (6 prospective cohort, 6 case-control)</td>
<td>Occupational PA and colon cancer multivariate adjusted RR (95% CI); Non-worker: 0.61 (0.39–0.98); Sedentary: 1.00 (referent); Light: 0.60 (0.34–1.04); Moderate/heavy: 0.45 (0.26–0.78); LTPA and colon cancer RR (95%CI); Sedentary: 1.00 (referent) Active: 0.82 (0.59–1.13)</td>
<td>Research generally supports the hypothesis that increased levels of PA are associated with reduced risks for colon cancer. However, research systematically examining the mechanisms for the relationship between PA and colon cancer is limited. At the moment the indirect evidence most strongly supports a link between PA and insulin-like growth factors</td>
</tr>
<tr>
<td>Kruk and Aboul-Enein 2006</td>
<td>To examine the relationship between physical activity and cancer risk, and the potential mechanisms of cancer prevention</td>
<td>A narrative review of recent systematic reviews, meta-analyses and articles published in the area</td>
<td>The number of studies evaluated was not provided</td>
<td>Recent evidence supports the fact that 30–60 min of daily moderate-to-vigorous physical activity is required to protect against breast and colon cancer. Potential biological mechanisms include alterations in hormones levels, improved body composition, enhanced immune function, and alterations in free radical damage</td>
<td>Regular PA is associated with reduced risks for colon and breast cancer. Additional research is required to understand the biological mechanisms responsible and the specific exercise prescription for various cancer sites</td>
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Note: PA, physical activity; LTPA, leisure time physical activity; OPA, occupational physical activity.
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<tr>
<th>Author</th>
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<th>Participants</th>
<th>Methods</th>
<th>Primary Results</th>
<th>Main Findings/Conclusion</th>
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<tr>
<td>Abuissa et al.</td>
<td>To assess different strategies in the prevention of type 2 diabetes</td>
<td>14 RCTs (377 participants) comparing exercise against no exercise met the inclusion criteria.</td>
<td>A systematic search of MEDLINE and The Cochrane Database of Systematic Reviews from 1996–2004 was supplemented by hand searches and consultation</td>
<td>Exercise vs. control 95% CI; HbA1c reduced (13 studies): –0.6% HbA1c (–0.9 to –0.3), P&lt;0.0001; Visceral adipose tissue reduced (2 studies): –45.5 cm² (–63.8 to –27.3), P&lt;0.0001</td>
<td>Exercise significantly improved glycemic control, reduced visceral fat mass, and increased insulin sensitivity in people with type 2 diabetes, despite no change in body mass. The results need to be confirmed in higher quality trials.</td>
</tr>
<tr>
<td>Thomas et al.</td>
<td>To assess the effects of exercise in type 2 diabetes</td>
<td>17 systematic reviews met the inclusion criteria.</td>
<td>A search of MEDLINE and The Cochrane Database of Systematic Reviews from 1998–2004 was supplemented by hand searches and consultation</td>
<td>The effect of exercise is comparable to metformin and appears to be independent of changes in body mass. The trials were generally of low quality and the results need to be confirmed in higher quality trials.</td>
<td>The authors note that the exercise trials were generally of low quality and the results need to be confirmed in higher quality trials.</td>
</tr>
<tr>
<td>Karmisholt and</td>
<td>To conduct a meta-analysis of systematic reviews of PA for secondary</td>
<td>17 systematic reviews met the inclusion criteria.</td>
<td>A search of MEDLINE and The Cochrane Database of Systematic Reviews from 1998–2004 was supplemented by hand searches and consultation</td>
<td>Exercise significantly improved glycemic control, reduced visceral fat mass, and increased insulin sensitivity in people with type 2 diabetes, despite no change in body mass. The results need to be confirmed in higher quality trials.</td>
<td>Exercise significantly improved glycemic control, reduced visceral fat mass, and increased insulin sensitivity in people with type 2 diabetes, despite no change in body mass. The results need to be confirmed in higher quality trials.</td>
</tr>
<tr>
<td>Norris et al.</td>
<td>To conduct a systematic review of physical activity and behavioral weight</td>
<td>9 studies (5,668 participants) meeting the inclusion criteria.</td>
<td>A search of MEDLINE, Embase, Cochrane Library, and the Cochrane Central Register of Controlled Trials.</td>
<td>3/9 studies reported incidence of diabetes as an outcome. 2/9 studies met the inclusion criteria. 3/9 studies found a reduction in the incidence of diabetes.</td>
<td>The authors note that the exercise trials were generally of low quality and the results need to be confirmed in higher quality trials.</td>
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</table>

The effects of exercise on glycemic control, visceral fat mass, and insulin sensitivity in people with type 2 diabetes, despite no change in body mass. The results need to be confirmed in higher quality trials.
Table A3 (continued).

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<th>Participants</th>
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<th>Main Findings/Conclusion</th>
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<tr>
<td>Norris et al. 2004</td>
<td>To assess dietary, physical activity, and behavioral weight loss/weight control interventions for adults with type 2 diabetes</td>
<td>A search of MEDLINE, EMBASE, CINAHL, ERIC, PsychINFO, Web of Science, Biosis, and Nutrition Abstracts and Review, The Cochrane Library (2004, Issue 2) and the Cochrane Central Register of Controlled Trials (CENTRAL) (2004, Issue 2); this was supplemented by hand searches of selected journals, the National Heart, Lung, and Blood Institute 1998 Review and the University of York, National Health Centre for Reviews and Dissemination review (1997); experts in obesity research were also contacted for additional citations; the last search was conducted in May 2004</td>
<td>22 studies (4,659 participants) met the inclusion criteria. Follow up ranged from 1–5 y</td>
<td>3 studies incorporating diet and physical activity observed reductions in HbA1c in the intervention vs. control group; most between group changes in this outcome variable were related to changes in weight and were not significant; there was considerable heterogeneity among studies</td>
<td>Future research should examine optimal strategies for implementing dietary, physical activity and behavioural interventions in individuals with type 2 diabetes</td>
</tr>
<tr>
<td>Boule et al. 2003</td>
<td>The objective was to compare the effect of structured aerobic exercise with no exercise on the cardiopulmonary fitness of adults with type 2 diabetes</td>
<td>A search of MEDLINE, EMBASE, SPORTDiscus, HealthSTAR, Dissertation Abstracts and the Cochrane Controlled Trials Register was performed up to March 2002; this was supplemented by hand searches of reference lists, major textbooks, reviews and consultation with experts in the area; studies published in any language were eligible.</td>
<td>7 RCTs met the inclusion criteria (266 patients)</td>
<td>HbA1c was reduced post-intervention in the exercise groups, weighted mean difference = 0.71 (95% CI: –1.10 to –0.32, ( p = 0.0004 ))</td>
<td>Post-intervention standardized mean difference for ( VO_2_{max} ) was significantly associated with the weighted mean difference for HbA1c ( (r = -0.72, p = 0.04) ), suggesting greater glycaemic control with increasing ( VO_2_{max} )</td>
</tr>
<tr>
<td>Boule et al. 2001</td>
<td>To conduct a systematic review and quantification of the effect of exercise on HbA1c and body mass in patients with type 2 diabetes</td>
<td>Searched MEDLINE, EMBASE, Sport Discuss, Health Star, Dissertation Abstracts, and the Cochrane Controlled Trials Register up to Dec 2000; this was supplemented by searching reference lists from textbooks and identified articles</td>
<td>Meta-analysis of 14 controlled clinical trials in type 2 diabetics &amp; glycemic control; no studies that included drug co-interventions</td>
<td>HbA1c lower in exercise vs. control groups (0.66%, ( p &lt; 0.001 ))</td>
<td>Exercise training reduces HbA1c to an extent that is of clinical benefit to persons with type 2 diabetes</td>
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Table A3 (concluded).

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<tr>
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<tr>
<td>Blair and Brodney 1999</td>
<td>The review addressed 3 questions: Do higher levels of physical activity attenuate the increased health risk normally observed in overweight or obese individuals? Do obese but active individuals actually have a lower morbidity and mortality risk than normal weight persons who are sedentary? Which is a more important predictor of mortality, overweight or inactivity?</td>
<td>Searched for papers identified in the 1996 publication, “Physical Activity and Health: A Report of the Surgeon General” in combination with searches of databases, personal files and reference lists in identified published articles; more than 700 potentially relevant articles were identified with 24 meeting all inclusion criteria.</td>
<td>24 articles met the inclusion criteria</td>
<td>Active individuals (both M and F) had a lower incidence of type 2 diabetes than sedentary participants. Fit men with a BMI of ( \geq 27.0 ) had a slightly lower incidence of type 2 diabetes than unfit men in the BMI&lt;27.0 group. Adjusted odds ratio for the development of type 2 diabetes in men - Low fitness vs. high fitness = 3.2. Adjusted for age, history of parental diabetes, length of follow-up, BMI, high blood pressure, high density lipoprotein cholesterol, total cholesterol, triglycerides, cigarette smoking status, alcohol intake, and change in fitness</td>
<td>PA and fitness appear to confer some protection against the development of type 2 diabetes</td>
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Note: F, female; M, male; RCT, randomized controlled trial; HbA1c, glycosylated hemoglobin; CI, confidence interval.
<table>
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<tr>
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<th>Main findings/conclusion</th>
</tr>
</thead>
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<tr>
<td>Fagard 1999</td>
<td>To examine the role of physical activity in the prevention and treatment of hypertension with particular attention to interactions with body mass</td>
<td>An analysis of epidemiological studies and 44 RCTs (68 study groups).</td>
<td>68 study groups (52 with normotensive and 16 with hypertensive individuals). 2674 participants (65% were men).</td>
<td>Epidemiological findings: There is an inverse relationship between physical activity or fitness and the incidence of hypertension; this effect was either independent of body mass or more pronounced in the overweight. Randomized Controlled Trials: Overall: systolic −3.4 (95% CI, −4.5 to −2.3 mmHg); diastolic −2.4 (95% CI, −3.2 to −1.6 mmHg); normotensive: systolic −2.6 (95% CI, −3.7 to −1.5 mmHg); diastolic −1.8 (95% CI, −2.6 to −1.1 mmHg); hypertensive: systolic −7.4 (95% CI, −10.5 to −4.3 mmHg); diastolic −5.8 (95% CI, −8.0 to −3.5 mmHg)</td>
<td>Physical activity contributes to blood pressure control in overweight and lean individuals.</td>
</tr>
<tr>
<td>Kelley 1999</td>
<td>To examine the effects of aerobic exercise training on resting blood pressure in women</td>
<td>A meta-analysis of 10 RCTs retrieved through a search of MEDLINE, SPORTdiscus, and Current Contents (articles published between January 1966 and January 1998) complemented with hand searches of reference lists</td>
<td>732 adult women</td>
<td>Systolic −2 (95% CI, −3 to −1) mmHg, Diastolic −1 (95% CI, −2 to −1 mmHg)</td>
<td>Aerobic exercise training results in small reductions in resting blood pressure in women.</td>
</tr>
<tr>
<td>Fagard 2001</td>
<td>To examine the effects of various characteristics of the exercise training program (in particular exercise intensity) on blood pressure in normotensive and hypertensive individuals.</td>
<td>44 RCTs published prior to August 1998</td>
<td>68 study groups. 2674 participants (65% were men)</td>
<td>Overall: systolic −3.4 (95% CI, −4.5 to −2.3 mmHg), diastolic −2.4 (95% CI, −3.2 to −1.6 mmHg)</td>
<td>Training 3–5 d/week, 30–60 min/d, at moderate to vigorous intensity, appears to be effective for blood pressure reduction</td>
</tr>
<tr>
<td>Whelton, S.P. et al. 2002</td>
<td>To evaluate the effect of aerobic exercise on blood pressure</td>
<td>A systematic review and meta-analysis of articles retrieved through a search of MEDLINE and SPORTdiscus up to September 2001 complemented with hand searches of reference lists</td>
<td>54 trials (34 reports including 2419 participants) met the inclusion criteria</td>
<td>Systolic −3.84 (95% CI, −2.72 to −4.97 mmHg), diastolic −2.58 (95% CI, −1.81 to −3.35 mmHg)</td>
<td>Aerobic exercise lowers blood pressure in hypertensive and normotensive participants, regardless of weight loss during the trial; exercise appears to be more effective in persons of African and Asian descent</td>
</tr>
<tr>
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<tr>
<td>Cornelissen and Fagard 2005a</td>
<td>To review the literature for the effect of resistance training on resting blood pressure in sedentary adults</td>
<td>A systematic review and meta-analysis of articles (up to December 2003) retrieved through a MEDLINE search complemented with hand searches of reference lists</td>
<td>Nine RCTs (341 participants; average age 20–72 years) met the inclusion criteria</td>
<td>The weighted (by number of participants) changes for systolic and diastolic blood pressure were −3.2 (95% CI, −7.1 to +0.7 mmHg) and −3.5 (95% CI, −6.1 to −0.9 mmHg), respectively; the change for systolic blood pressure was not significant; when weighted by the reciprocal of the variance of the blood pressure change, both systolic and diastolic blood pressure were significantly reduced by −6.0 (95% CI, −10.4 to −1.6 mmHg) and −4.7 (95% CI, −8.1 to −1.4 mmHg), respectively</td>
<td>Moderate-intensity resistance training is not contraindicated; however, more studies are needed to confirm the benefit, particularly in the hypertensive population</td>
</tr>
<tr>
<td>Cornelissen and Fagard 2005b</td>
<td>To review the effect of aerobic endurance exercise on resting and ambulatory blood pressure</td>
<td>Studies were identified through a database of RCTs examining the effect of exercise on blood pressure; this was supplemented by a MEDLINE search up to December 2003 and a search of reference lists from published articles and review articles</td>
<td>72 trials (3936 participants; average age 21–83 years) met the inclusion criteria</td>
<td>Resting blood pressure was significantly reduced: Systolic: 3.0 (95% CI, 2.0 to 4.0 mmHg); diastolic: 2.4 (95% CI, 1.7 to 3.1 mmHg); ambulatory blood pressure was significantly reduced: systolic: 3.3 (95% CI, 0.9 to 5.8 mmHg); diastolic: 3.5 (95% CI, 1.9 to 5.2 mmHg)</td>
<td>There is a positive effect of exercise on blood pressure; this appears to occur through a reduction in vascular resistance and favourably affects cardiovascular risk factors</td>
</tr>
<tr>
<td>Dickinson et al. 2006</td>
<td>To evaluate the effectiveness of lifestyle interventions in the hypertensive population</td>
<td>A systematic review and meta-analysis of articles retrieved through a search of MEDLINE, EMBASE and CENTRAL (1998 to May 2003) and from previous guidelines and reviews (published prior to 1998)</td>
<td>105 trials (6805 participants) met the inclusion criteria</td>
<td>Statistically significant reductions in systolic blood pressure were observed for interventions targeting: diet (−3.0; 95% CI, −3.1 to −2.9 mmHg); aerobic exercise (−4.6; 95% CI, −7.1 mmHg); alcohol restriction (−3.8; 95% CI −1.4 to −6.1 mmHg); sodium restriction (−3.6; 95% CI, −2.5 to −4.6 mmHg); fish oil supplements (−2.3; 95% CI, −0.2 to −4.3 mmHg)</td>
<td>Hypertensive individuals should regulate their diet and participate in aerobic exercise. The evidence does not suggest a therapeutic effect of relaxation therapies, calcium, magnesium or potassium supplements.</td>
</tr>
<tr>
<td>Fagard 2006</td>
<td>To describe the results of previous meta-analyses examining the effect of aerobic and resistance training on resting and ambulatory blood pressure</td>
<td>Not described</td>
<td>Aerobic exercise: 72 trials (3936 participants; average age 21–83 years). Resistance exercise: 9 trials (341 participants; average age 20–72 years)</td>
<td>Aerobic exercise: resting blood pressure was reduced 3.0/2.4 mmHg on average; ambulatory blood pressure was reduced 3.3/1.5 mmHg on average; no significant effect on night time blood pressure; resistance training: systolic blood pressure was reduced 3.2 mmHg but was not significant; diastolic blood pressure was reduced 3.5 mmHg</td>
<td>The evidence suggests that aerobic endurance exercise reduces blood pressure; there is fewer data available for resistance training but it also suggests a reduction in blood pressure with exercise</td>
</tr>
<tr>
<td>Author</td>
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<tr>
<td>Hamer 2006</td>
<td>To review the literature for the effect of acute aerobic exercise on stress-related blood pressure</td>
<td>A systematic review and meta-analysis of articles retrieved through a MEDLINE search, complemented with hand searches of reference lists</td>
<td>A total of 15 studies met the inclusion criteria (496 participants; 17–60 years)</td>
<td>10/15 studies demonstrated significant reductions in post-exercise stress-related BP responses in comparison with control; average reduction in post-exercise stress-related diastolic blood pressure of 3.0±2.7 mmHg; absolute reduction in post-exercise stress-related systolic blood pressure of 3.7±3.9 mmHg; greater effects were observed with increasing dose of exercise; a significant effect was shown at a minimum dosage of 30 min at 50% $\text{VO}_2\text{max}$.</td>
<td>Most evidence suggests that there is a significant effect of an acute bout of aerobic exercise on stress-related blood pressure</td>
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Note: RCT, randomized controlled trial; CI, confidence interval.
Table A5. Selected reviews evaluating bone mineral density or bone mineral content and physical activity.

<table>
<thead>
<tr>
<th>Author</th>
<th>Participants</th>
<th>Activity</th>
<th>Results</th>
<th>Main findings/conclusion</th>
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<tbody>
<tr>
<td>Berard et al. 1997</td>
<td>Meta-analysis of 18 prospective intervention trials evaluating healthy post-menopausal women between 1966 – 1996</td>
<td>Moderate intensity programs of primarily walking, running, physical conditioning and aerobics</td>
<td>Vertebral column (L2–4) BMD = large ES (0.8745, p&lt;0.05); no effect seen on forearm and femoral bone mass</td>
<td>Exercise programs in post-menopausal women (&gt;50 year) are effective for preventing BMD loss of the vertebral column</td>
</tr>
<tr>
<td>Kelley 1998a</td>
<td>Meta-analysis of 11 RCTs, 719 post-menopausal women (370 exercise, 349 non-exercise); January 1975 – December 1995</td>
<td>Exercise vs. non-exercise group, aerobic and (or) strength training</td>
<td>Aerobic training = +1.62% (95% CI, 1.12–2.12) regional BMD; strength training = +0.65% (95% CI, 0.48 – 0.83) regional BMD</td>
<td>Exercise may slow the rate of bone loss in post-menopausal women</td>
</tr>
<tr>
<td>Kelley 1998b</td>
<td>Meta-analysis of 10 prospective investigations, 330 post-menopausal women (192 exercise, 138 non-exercise); January 1975 – December 1994</td>
<td>Aerobic activity vs. non-exercise group; change in lumbar spine BMD</td>
<td>2.83±0.77% (95% CI, 1.33 – 4.35%) difference in lumbar spine BMD between group; exercise = +0.32±2.46% (95% CI, –0.94 to –1.58), non-exercise = –2.5±2.69% (95% CI –4.60 to –0.96).</td>
<td>Exercise helps maintain lumbar BMD in post-menopausal women</td>
</tr>
<tr>
<td>Wolff et al. 1999</td>
<td>Meta-analyses of 25 RCTs and controlled trials; pre- and postmenopausal women; 2 or more interventions compared with each other; 1966 – December 1996</td>
<td>Endurance and (or) strength training; change in BMD or BMC of lumbar spine &amp; femoral neck</td>
<td>Overall treatment effect (inverse variance weighting) at lumbar spine for RCTs: Pre-menopausal: endurance + strength training = 0.91 (95% CI 0.44 – 1.37)(p&lt;0.05); Post-menopausal: endurance = 0.96 (95% CI 0.43 – 1.49)(p&lt;0.05); strength only = 0.44 (95% CI –0.32 to 1.21); combined exercise = 0.79 (95% CI 0.35 – 1.22)(p&lt;0.05); overall treatment effect (inverse variance weighting) at femoral neck RCTs: Pre-menopausal: endurance = 0.90 (95% CI 0.29 – 1.50) (p&lt;0.05); Post-menopausal: endurance = 0.90 (95% CI 0.29 – 1.51) (p&lt;0.05); strength only = 0.86 (95% CI –0.18 – 1.91); combined exercise = 0.89 (95% CI 0.36 – 1.42)</td>
<td>RCTs reveal consistently that exercise training prevents or reverses the approximate 1% bone loss per year in both the lumbar spine and femoral neck for both pre- and post-menopausal women</td>
</tr>
<tr>
<td>Wallace and Cumming 2000</td>
<td>Meta-analysis of 35 RCTs of impact (aerobic) and non-impact (resistance) training on lumbar spine and femoral neck in pre- and postmenopausal women</td>
<td>Aerobic and strength training effects on bone mineral density</td>
<td>In the lumbar spine, impact and non-impact exercise programs appeared to prevent bone loss of 1.6% (95% CI = 1.0%–2.2%) and 1.0% (95% CI = 0.4%–1.6%), respectively, in post-menopausal women; similar findings in the lumbar spine in pre-menopausal women; impact and non-impact exercise prevented bone loss of 1.5% (95% CI = 0.6%–2.4%) and 1.2% (95% CI = 0.7%–1.7%), respectively; impact exercise prevented bone loss at the femoral neck in post-menopausal women (1.0% (95% CI = 0.4%–1.6%), and possibly in pre-menopausal women</td>
<td>Both impact and non-impact exercise appear to have a positive effect on bone health at the lumbar spine in pre- and post-menopausal women; impact exercise also appears to have a positive effect at the femoral neck</td>
</tr>
<tr>
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<tr>
<td>Bonaiuti et al. 2002</td>
<td>Cochrane database of systematic reviews of 18 RCTs; 289 healthy post-menopausal women</td>
<td>Aerobic, weight bearing, and resistance exercise efficacy on BMD of the spine (13 studies) or hip (8 studies) vs. usual activity or placebo with or without drug consumption; 9 aerobic studies, 4 resistance studies, 3 walking studies, 1 repetitive back extension study, 1 weighted leg flexion study</td>
<td>WMD: combined aerobic &amp; weight bearing = +1.79% (95% CI, 0.58 – 3.01); walking effective on BMD of spine = +1.31% (95% CI, -0.03 – 2.65) &amp; hip = +0.92% (95% CI, 0.21 – 1.64); only aerobic exercise increased BMD of wrist = 1.22% (95% CI, 0.71 – 1.74).</td>
<td>Aerobic, resistance, and weight-bearing exercise are all effective for increasing BMD in the spine of post-menopausal women; walking is also of benefit for BMD in the hip</td>
</tr>
<tr>
<td>Kelley and Kelley 2004</td>
<td>Meta-analyses of individual patient data; 143 pre-menopausal women (74 exercise, 69 control)</td>
<td>Resistance exercise on lumbar spine and femoral neck BMD vs. control group</td>
<td>Lumbar spine BMD: exercise = 0.64±2.99% &amp; control = 0.74±7.58%; femoral neck BMD: exercise = 0.46±3.10% &amp; control = 0.31±2.97%; no statistically significant difference in either BMD found within or between groups (p&gt;0.05).</td>
<td>Results do not support the effectiveness of resistance training for increasing or maintaining lumbar spine and femoral neck BMD in pre-menopausal women</td>
</tr>
</tbody>
</table>

Note: BMC, bone mineral content; BMD, bone mineral density; L, lumbar; RCT, randomized controlled trial; ES, effect size; WMD, weighted mean difference.
Table A6. Selected reviews examining the relationship between physical activity and psychological well-being.

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Review method</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depression</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martinsen 1990</td>
<td>Symptomatic</td>
<td>Narrative review</td>
<td>Exercise association with anti-depressive effects in clinical patients; Non-aerobic &amp; aerobic exercise equally effective ( d = -0.59 ); acute &amp; chronic exercise effectively reduce clinical depression; aerobic &amp; non-aerobic exercise are both effective</td>
</tr>
<tr>
<td>North et al. 1990</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Meta-analysis</td>
<td>( d = -1.22 ); sig. decrease in depression with aerobic exercise; ( d = -0.83 ) (Normals) &amp; ( d = -1.17 ) (Depressed); aerobic exercise was more effective in those subjects who were clinically depressed</td>
</tr>
<tr>
<td>McDonald and Hodgdon 1991</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Meta-analysis</td>
<td></td>
</tr>
<tr>
<td>Byrne and Byrne 1993</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Investigations are supportive of anti-depressant effects of exercise programs; many methodological problems need to be addressed</td>
</tr>
<tr>
<td>Weyerer and Kupfer 1994</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Evidence is + for relations between PA &amp; depression; more specific research is necessary</td>
</tr>
<tr>
<td>Scully et al. 1998</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>PA – associated with depression; most notable affects on clinical populations ( d = -0.72 )</td>
</tr>
<tr>
<td>Craft and Landers 1998</td>
<td>Symptomatic</td>
<td>Meta-analysis</td>
<td>Sufficient evidence exists for the effectiveness of exercise in the treatment of clinical depression</td>
</tr>
<tr>
<td>Fox 1999</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>PA associated with a decreased risk of developing clinical depression; aerobic &amp; resistance exercise are effective in treating depression</td>
</tr>
<tr>
<td>Mutrie 2000</td>
<td>Symptomatic</td>
<td>Narrative review</td>
<td>Studies suggest PA is –associated with depression; more randomized controlled trials needed to demonstrate efficacy in clinical populations ( d = -1.1 ) when exercise compared with no treatment; short term exercise is – associated with depressive symptoms; effectiveness of exercise on clinical populations unknown due to poor quality research</td>
</tr>
<tr>
<td>O’Neal et al. 2000</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td></td>
</tr>
<tr>
<td>Lawlor and Hopker 2001</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Systematic review</td>
<td>PA – associated with depressive symptoms; little evidence exists for PA dose response effects on depressive symptoms due to lack of studies</td>
</tr>
<tr>
<td>Dunn et al. 2001</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Systematic review</td>
<td>Exercise reduces depression in both asymptomatic and symptomatic populations</td>
</tr>
<tr>
<td>Callaghan 2004</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Systematic review</td>
<td>PA improves depressive symptoms; PA – associated with clinical depression; consistent PA may prevent onset of depression</td>
</tr>
<tr>
<td>Penedo and Dahn 2005</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td></td>
</tr>
<tr>
<td><strong>Anxiety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gleser and Mendelberg 1990</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Moderate to vigorous exercise is successful in reducing state anxiety ( d = -0.25 ); anxiety reducing effects only apparent for young/middle-aged male participants performing various types of exercise</td>
</tr>
<tr>
<td>McDonald and Hodgson 1991</td>
<td>N.C.</td>
<td>Meta-analysis</td>
<td>( d = -0.25 ); high intensity aerobic exercise more than 20 min duration associated with reductions in anxiety ( d = 0.45 ) within group &amp; ( d = 0.36 ) contrast group; exercise effective in reducing anxiety, particularly in high-stress individuals</td>
</tr>
<tr>
<td>Petruzzello et al. 1991</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Meta-analysis</td>
<td>PA + affects anxiety; short bursts of PA are efficient; most + affects are among those who adhere to exercise regimes over several months</td>
</tr>
<tr>
<td>Long and Stavel 1995</td>
<td>Asymptomatic</td>
<td>Meta-analysis</td>
<td>Exercise has a moderate reducing effect on anxiety</td>
</tr>
<tr>
<td>Scully et al. 1998</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Acute &amp; chronic exercise decrease anxiety in normal &amp; clinical populations</td>
</tr>
<tr>
<td>Fox 1999</td>
<td>Asymptomatic</td>
<td>Narrative review</td>
<td></td>
</tr>
<tr>
<td>O’Connor et al. 2000</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td></td>
</tr>
</tbody>
</table>

**Global Self-Esteem (GSE)** | | | |
| Sonstroem 1984 | Asymptomatic & symptomatic | Narrative review | Exercise associated with increased SE; mechanisms are not known |
| Gleser and Mendelberg 1990 | Asymptomatic & symptomatic | Narrative review | PA has steadily been found to increase SE in diverse populations |
Table A6 (concluded).

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Review method</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>McDonald and Hodgdon 1991</td>
<td>N.C.</td>
<td>Meta-analysis</td>
<td>Aerobic exercise leads to moderate changes in GSE</td>
</tr>
<tr>
<td>Spence and Poon 1997</td>
<td>N.C.</td>
<td>Meta-analysis</td>
<td>Inconsistent &amp; weak relationship between PA &amp; SE</td>
</tr>
<tr>
<td>Fox 1999</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Exercise can increase GSE particularly with initial low GSE individuals</td>
</tr>
<tr>
<td>Fox 2000a</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>Weak relationship between PA &amp; SE</td>
</tr>
<tr>
<td>Fox 2000b</td>
<td>N.C.</td>
<td>Narrative review</td>
<td>Inconsistent &amp; weak relationship between PA &amp; GSE</td>
</tr>
<tr>
<td>Spence et al. 2005</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Meta-analysis</td>
<td>d = 0.23; exercise leads to small, but significant increases in GSE; change in fitness necessary for increase in GSE to occur</td>
</tr>
</tbody>
</table>

**Generalized well-being**

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Review method</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rejeski et al. 1996</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Narrative review</td>
<td>PA is associated with improvements with various aspects of HRQoL, regardless of age, activity status, or health of the participants</td>
</tr>
<tr>
<td>Fox 1999</td>
<td>Asymptomatic</td>
<td>Narrative review</td>
<td>Research provides support for a + relationship between exercise &amp; subjective well-being</td>
</tr>
<tr>
<td>Laforge et al. 1999</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Correlational survey</td>
<td>Exercise stage is associated with self-perceived quality of life; variables most strongly associated were physical functioning, general health perceptions &amp; vitality</td>
</tr>
<tr>
<td>Biddle 2000</td>
<td>N.C.</td>
<td>Narrative review</td>
<td>Moderate association between PA &amp; subjective well-being</td>
</tr>
<tr>
<td>Brown et al. 2003</td>
<td>Asymptomatic</td>
<td>Correlational survey</td>
<td>Individuals attaining recommended PA guidelines had higher overall HRQoL</td>
</tr>
<tr>
<td>Macera et al. 2003</td>
<td>Symptomatic</td>
<td>Narrative review</td>
<td>Review of studies supports the association between PA and health in diseased populations</td>
</tr>
<tr>
<td>Wendel-Vos et al. 2004</td>
<td>Asymptomatic</td>
<td>Correlational survey</td>
<td>Cross-sectional association between moderate PA and general health perceptions; Cross-sectional associations were found for physical components of QoL</td>
</tr>
<tr>
<td>Brown et al. 2004</td>
<td>Asymptomatic &amp; symptomatic</td>
<td>Correlational survey</td>
<td>Moderate or vigorous PA is independently associated with higher levels of HRQoL; participation in daily moderate or vigorous PA for very short or extended periods of time is associated with poorer HRQoL</td>
</tr>
<tr>
<td>Lustyk et al. 2004</td>
<td>Asymptomatic</td>
<td>Correlational survey</td>
<td>High frequency PA of mild intensity performed to improve health &amp; fitness has the strongest influence on QoL</td>
</tr>
<tr>
<td>Penedo and Dahn 2005</td>
<td>Asymptomatic</td>
<td>Narrative review</td>
<td>Exercise &amp; PA associated with better HRQoL; further research is needed</td>
</tr>
<tr>
<td>Vuillemin et al. 2005</td>
<td>Asymptomatic</td>
<td>Correlational survey</td>
<td>Higher leisure time PA and meeting public health guidelines for PA was associated with higher HRQoL</td>
</tr>
<tr>
<td>Blacklock et al. 2007</td>
<td>Asymptomatic</td>
<td>Correlational survey</td>
<td>HRQoL is related to walking interventions and annual income; weak relations between PA and overall happiness</td>
</tr>
</tbody>
</table>

**Note:** N.C., description of participant characteristics is not clear.
References


Hamer, M. 2006. The anti-hypertensive effects of exercise: inte-


