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The health benefits of physical activity and cardiorespiratory fitness

"Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it."
— Plato (427–347 BC)

ABSTRACT: The benefits of physical activity are plentiful and significant. High levels of physical activity and cardiorespiratory fitness (referred to simply as "fitness" in this article) are associated with lower all-cause and cardiovascular mortality. Furthermore, physical activity can reduce the development of chronic diseases such as hypertension, diabetes, stroke, and cancer. Additionally, physical activity can promote healthy cognitive and psychosocial function. An extensive effort to ascertain the benefits from the current Canadian physical activity guidelines on all-cause mortality and seven chronic diseases suggests that the current recommendation for at least 150 minutes of moderate-to-vigorous aerobic physical activity per week in sessions of 10 minutes or more is associated with a 20% to 30% lower risk for premature all-cause mortality and incidence of many chronic diseases. Because the health benefits of activity have been established and physical inactivity is a modifiable risk factor central to the development of many chronic diseases, it is imperative that we encourage regular physical exercise for optimal health. The benefits of physical activity exhibit a dose-response relationship; the higher the amount of physical activity, the greater the health benefits. However, the most unfit individuals have the potential for the greatest reduction in risk, even with small increases in physical activity. Given the significant health benefits afforded by physical activity, considerable efforts should be made to promote this vital agent of health.

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Ancient philosophers and physicians such as Plato and Hippocrates believed in the relationship between physical activity and health, and the lack of physical activity and disease. However, by the mid-20th century it was believed that physical activity might be harmful to health. Moreover, the recommended treatment of the time after myocardial infarction was complete bed rest. It was not until landmark epidemiological studies in the 1950s that physical inactivity was associated with increased risk of coronary heart disease (CHD). Dr Jeremy Morris examined the differences in CHD incidence between two groups of men working on London's double-decker buses: the drivers, who were sedentary (sitting for more than

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90% of their shifts), and the conductors, who were physically active (climbing roughly 500 to 750 steps a day). Despite coming from similar social classes, the physically active conductors had lower rates of CHD than the physically inactive drivers (overall annual incidence of 1.9/1000 for conductors versus 2.7/1000 for drivers). Furthermore, sudden cardiac death (SCD) occurred less often in conductors than drivers (0.5/1000 versus 1.1/1000), and the conductors' CHD were more likely to manifest as angina than SCD. Similarly, it was shown that physically active postal workers had lower rates of incident CHD and SCD than their less active co-workers.[1] Based on these findings, Morris and colleagues postulated that physically active work offered a protective effect, predominantly related to sudden cardiac death as a first manifestation of disease. These observations were the first formal studies to link physical inactivity and heart disease.

Physical activity and primary prevention of all-cause mortality

Contemporary studies have consistently demonstrated the inverse relationship between physical activity and rates for all-cause mortality and cardiovascular death (CVD).[2-4] Physical activity is an important determinant of cardiorespiratory fitness[4] and fitness is related to physical activity patterns.[5] While physical activity can be difficult to estimate, fitness can be assessed readily using the metabolic equivalent task (MET) to provide an objective measure of a subject's fitness.[4] (See **Box** for a definition of MET and other fitness-related terms used in this article.) Although determinants of cardiorespiratory fitness include age, sex, health status, and genetics, the principal determinant is habitual physical activity levels. Thus, cardiorespiratory fitness (referred to simply as "fitness" in this article) can be used as an objective surrogate measure of recent physical activity patterns.

The relationship of fitness to all-cause mortality was examined in the Aerobics Center Longitudinal Study[4] of 13 344 healthy people. The subjects included in the study had no personal history of MI, hypertension, diabetes, or stroke, and no resting or stress-induced electrocardiogram (ECG) changes. They were required to complete an exercise treadmill test (ETT) to establish their fitness level. After 8 years of follow-up, those subjects in the lowest quintile of fitness compared to those in the highest quintile had a relative risk (RR) all-cause mortality rate of 3.44 for men and 4.65 for women. Additionally, the RR for CVD in the least fit men and women compared with the most fit was 8.0. Even after adjusting for age, cholesterol level, blood pressure, smoking, fasting blood glucose, and family history of CHD, the findings were consistent for men and women.

How much physical activity is enough?

The greatest reduction in all-cause mortality occurs between the least fit and the next-to-least fit group.[3-5] In a study assessing both fitness and physical activity and the relationship to all-cause mortality, age-adjusted mortality decreased per quartile, with a 41% reduction in death occurring between the least fit and the next-to-least fit quartiles.[5] These findings suggest that even small improvements in fitness can translate into significantly lower risk of all-cause mortality and CVD.[6] Efforts should be made to target the least fit (the physically inactive) because slight increases in activity can mean significant gains in health status. A theoretical relationship between physical activity and the risk for mortality and chronic disease is shown in **Figure 1**.[7]

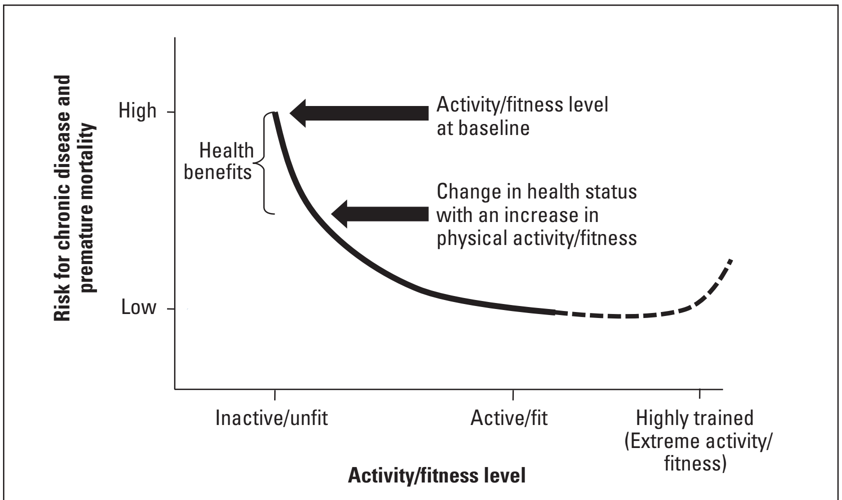

Figure 1. Dose-response relationship between physical activity/fitness and health status.

Estimates derived from prospective cohort studies are used here to show that a small change in physical activity/fitness in individuals who are physically inactive/unfit can lead to a significant improvement in health status, including a reduction in the risk for chronic disease and premature mortality. The dashed line represents the potential attenuation in health status seen in highly trained endurance athletes. Adapted from Bredin and colleagues[7] and used with permission.

What is the optimal amount of physical activity?

Data from many prospective population studies suggest there is a graded dose-response relationship between physical activity/fitness and mortality or disease state.[4,3,8] In other words, the greater the amount of physical activity, the greater the health benefits. A theoretical risk of excessive endurance exercise and the possibility of a U-shaped curve (Figure 1) is discussed by Warburton and colleagues in Part 2 of this theme issue. To examine whether low levels of physical activity (below the recommended weekly 150 minutes of moderate-intensity exercise) affect mortality, a large prospective study considered the mortality of 416 175 individuals in relation to five different activity volumes: inactive, low, medium, high, or very high activity.[9] Participants in the low-volume activity group who exercised for an average of 92 minutes per week, or approximately 15 minutes a day, experienced a 14% reduced risk of all-cause mortality and had a life expectancy 3 years longer than those in the inactive group. A graded benefit to exercise was also seen in this population: for every 15 minutes of exercise added to the minimum daily amount of 15 minutes, all-cause mortality was further reduced by 4% and all-cancer mortality was reduced by 1%.[9]

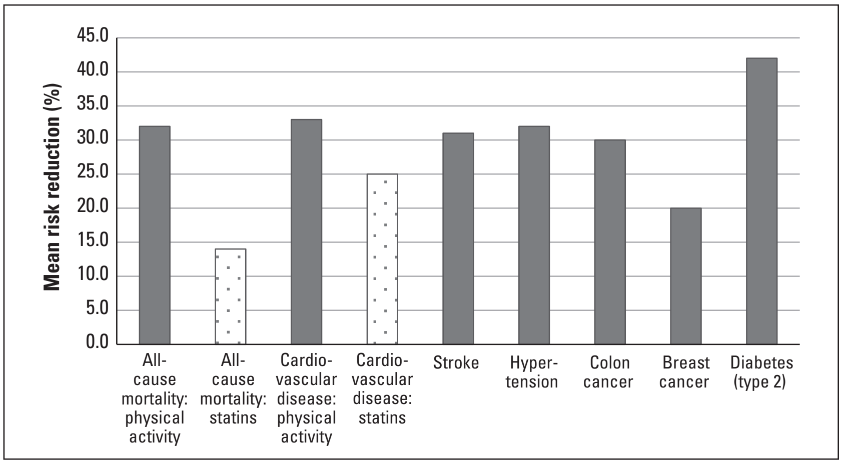

Figure 2. Risk reduction for all-cause mortality and chronic disease seen in physically active subjects.

Mean estimates of risk reduction for statins and all-cause mortality and cardiovascular disease from Taylor and colleagues,[10] cancer mortality risk estimates from Cholesterol Treatment Trialists' Collaboration,[11] and remaining mean risk reduction estimates from Warburton and colleagues.[8]

Physical activity and risk reduction

An extensive effort to ascertain the benefits from the current Canadian physical activity guidelines on all-cause mortality and seven chronic diseases was published recently.[8] The body of literature included in the study suggests that the current requirement for at least 150 minutes of moderate-to-vigorous aerobic physical activity per week in sessions of 10 minutes or longer (an energy expenditure of approximately 1000 kcal/week) is associated with a 20% to 30% lower risk for premature all-cause mortality and incidence of many chronic diseases, with greater health benefits for higher volumes and greater intensities

Box. Fitness-related terms

Cardiorespiratory fitness: The ability to transport and use oxygen during prolonged, strenuous exercise or work. Reflects the combined efficiency of the lungs, heart, vascular system, and muscles in the transport and use of oxygen.

Exercise: Structured and repetitive physical activity designed to maintain or improve physical fitness. Often incorporates aerobic activities that are rhythmic in nature and use large muscle groups at moderate intensities for 3 to 5 days per week for at least 10 minutes at a time (e.g., walking, bicycling, jogging).

Metabolic equivalent task (MET): A measure of energy expended during physical activity. One MET is defined as the amount of oxygen or calories consumed while sitting quietly—1 MET = 3.5 mL O_2 per kg per minute or 1 kcal (4.2 kJ) per kg per hour.

Physical activity: Any bodily movement produced by skeletal muscles that results in energy expenditure. By comparison, physical fitness depicts the capacity to achieve a certain performance standard or trait.

Physical inactivity (or sedentary activity): Involves no noticeable effort. Heart and breathing rates are not raised perceptibly above resting levels. Requires < 40.0% maximum heart rate. Measured as 1.0 to 1.6 METs.

Light-intensity physical activity: Has only minor effects on heart and breathing rates. Measured as 1.6 to < 3 METs.

Moderate-intensity physical activity: Increases heart and breathing rate to 50.0% to 70.0% of maximum. Energy requirement can usually be met by aerobic metabolism using the body's stores of glycogen and then fats. Measured as 3 to < 6 METs.

Vigorous-intensity physical activity: Increases heart and breathing rates to > 70.0% of their maximum. Anaerobic metabolism is needed to provide energy. Measured as ≥ 6 METs.

of activity (i.e., moderate or vigorous intensity rather than light intensity).[8] A summary of risk reduction in physically active subjects is shown in Figure 2.[8,10,11]

Efforts should be made to target the least fit (the physically inactive) because slight increases in activity can mean significant gains in health status.

Hypertension

Hypertension is the most common risk factor for heart disease, stroke, and renal disease and has been identified as a leading cause of mortality.[12] In a recent meta-analysis of 13 prospective cohort studies, high-level recreational physical activity was associated with decreased risk of developing hypertension when subjects were compared to a reference group with low-level physical activity (RR 0.81).[13] In another meta-analysis that included 30 studies involving patients with existing hypertension, aerobic endurance training was shown to reduce blood pressure by 6.9/4.9 mm Hg.[14]

Diabetes

Type 2 diabetes is a worldwide problem with significant health, social, and economic implications. Diabetes results from a complex interplay of environmental and genetic components. There is strong evidence that such modifiable risk factors as obesity and physical inactivity are the main nongenetic determinants of the disease.[15] Current diabetes treatments can help control hyperglycemia and slightly reduce diabetic complications, but cannot eliminate all the adverse consequences and have had limited success at reducing macrovascular complications.[16] Since current methods for treating diabetes remain inadequate, prevention of the disease is preferable.[16]

A randomized controlled trial sought to determine whether lifestyle intervention or treatment with metformin would prevent or delay the onset of diabetes in patients with impaired fasting glucose levels. Participants assigned to the intensive lifestyle intervention were able to achieve and maintain a reduction of at least 7% of initial body weight through a healthy low-calorie, low-fat diet and to engage in moderate-intensity physical activity such as brisk walking for at least 150 minutes per week. When compared with placebo, the lifestyle intervention reduced the incidence of diabetes by 58% and the metformin intervention reduced the incidence by 31%.[16] This translates into a number needed to treat (NTT) of 7 for the lifestyle intervention and 14 for the metformin when attempting to prevent one case of diabetes over a 3-year period. Thus, physical activity represents a major public health opportunity to reduce the cost of a major source of morbidity.

Stroke

Stroke is the third leading cause of death in Canada, where 5.5% of all deaths are due to cerebrovascular diseases.[17] Physically inactive people have a significantly elevated stroke risk (RR 1.60).[18] In a systematic review, high levels of physical activity were associated with a 31% risk reduction. The reduced risk of stroke is seen in both men and women, and it appears that this benefit may be present for both ischemic and hemorrhagic stroke.[19]

Cancer

Cancer is now the leading cause of death among Canadians, accounting for 29.9% of all deaths (more than MI and stroke combined).[17] Population studies from the 1980s have identified an increased risk of developing cancer among physically inactive people.[4,20] In the NHANES I survey, physical inactivity was associated with a relative risk of 1.8 for men and 1.3 for women compared with their physically active counterparts.[20] Multiple studies provide compelling evidence that high physical fitness levels are associated with a reduced risk of developing and dying from cancer. A recent meta-analysis confirmed that fitness is inversely related to cancer mortality: individuals with high cardiorespiratory fitness levels had a 45% reduced risk of total cancer mortality (RR 0.55) when compared with their unfit peers, independent of adiposity.[21]

Cancer, like CHD, is also preventable to some extent and shares several common risk factors such as poor nutrition, obesity, inflammation, and physical inactivity. Improvements in some of these risk factors with regular exercise might explain the cancer mortality benefits seen in meta-analyses.[8] Physical activity appears to affect all the stages of carcinogenesis (initiation, promotion, and progression), and it is likely that multiple mechanisms act synergistically to reduce overall cancer risk.[22] Some protective mechanisms that may attenuate cancer risk or promote survival are shown in Figure 3.[22]

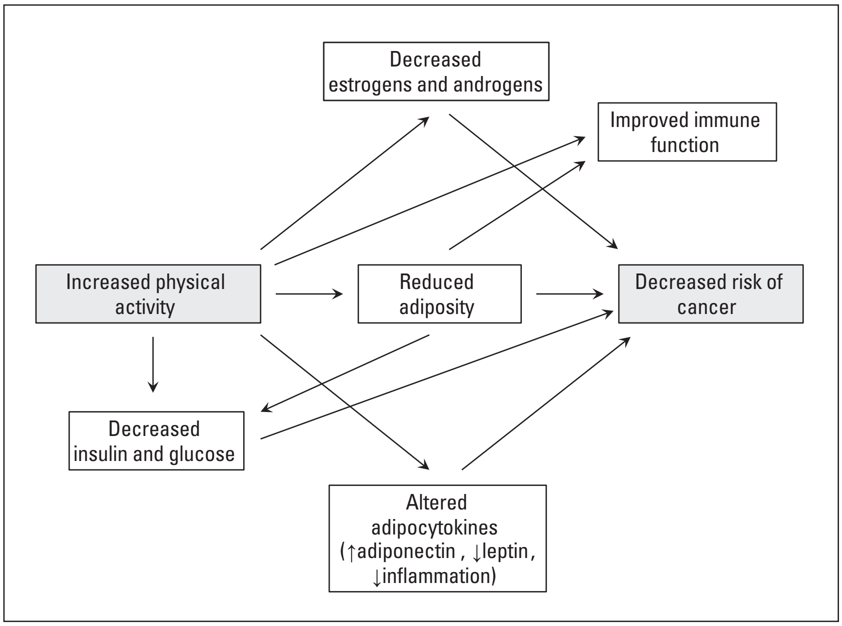

Figure 3. Protective mechanisms of physical activity that may reduce cancer risk.

Adapted from McTiernan.[22]

Depression

Depression is associated with poorer adherence to medical treatments and reduced health-related quality of life, as well as increased disability and health care utilization.[23] Furthermore, depression is independently associated with increased cardiovascular morbidity and mortality, and is commonly seen in patients with CHD.[24]

In a meta-analysis examining the effect of exercise in patients with chronic disease, exercise significantly reduced depressive symptoms by 30%. The greatest reduction in depressive symptoms occurred in patients with higher baseline depressive symptoms and exercise-improved physical function.[23] A recent Cochrane review found exercise to be effective at reducing depression symptoms when compared with psychological and pharmacological therapies.[25]

Cognitive function

The benefits of physical activity in maintaining cognitive function in older age and promoting healthy aging have been well documented. In the third decade of life the human brain starts to show a loss of gray matter that is disproportionately large in the frontal, parietal, and temporal lobes of the brain.[26]

In a meta-analysis of 33 816 nondemented subjects from 15 prospective cohorts, physical activity was found to protect against cognitive decline. The most fit subjects had a reduced risk of cognitive decline of 38%. Even low-to-moderate-level exercise showed a significant reduction in risk (35%).[27] In addition to reducing risk factors associated with the incidence of vascular dementia, physical activity appears to increase the production of neurotrophic factors in the brain[28] and can potentially mitigate against the loss of gray matter.[29] High levels of physical fitness (as measured objectively by maximal oxygen consumption) are associated with greater gray matter volume in frontal and temporal lobes independent of age.[30] There is a consistent association between higher levels of fitness and greater gray matter, and between physical activity and a reduction in accelerated brain aging or neuron loss.

Physical activity may also reduce the risk for developing Alzhiemer disease. In a 21-year longitudinal study that assessed individuals age 65 to 79, twice-weekly leisure-time physical activity was associated with a reduced risk of dementia and Alzheimer disease. This risk reduction was more pronounced in individuals with a specific *APOE* e4 allele, the strongest known genetic risk factor for Alzheimer disease.[31]

An exciting aspect of the positive relationship between physical activity and gray matter volume is that aerobic exercise interventions over a 6- to 12-month period appear to be sufficient for increasing volume.[32] Furthermore, in an intention-to-treat study of older adults with memory impairment who did not meet diagnostic critieria for dementia, a short 24-week home-based exercise program demonstrated a modest improvement in cognition. Those subjects who did not receive the exercise program had a decline in cogntive function over the study period.[33]

Physical inactivity—a modifiable risk factor

Physical inactivity is the fourth leading cause of death worldwide.[34] It is estimated that over a third of cancers and about 80.0% of heart disease, stroke, and type 2 diabetes could be

Table 1. Health outcomes and conditions improved by physical activity.

- All-cause mortality
- Cardiovascular disease mortality
- Cancer incidence (convincing data for breast and colon cancer)
- Cancer mortality
- Type 2 diabetes
- Hypertension (through primary prevention and by lowering blood pressure in patients with established hypertension)
- Stroke
- Osteoporosis
- Sarcopenia
- Depression
- Anxiety
- Cognitive function
- Fear of falling

Table 2. How physical activity improves health outcomes: Proposed mechanisms.

- Improves fitness as measured by metabolic equivalent task values
- Decreases systemic vascular resistance
- Decreases sympathetic activity
- Decreases plasma renin activity
- Helps maintain body weight
- Decreases waist circumference
- Reduces percentage of body fat
- Improves insulin resistance
- Raises HDL cholesterol levels
- Lowers LDL cholesterol levels
- Reduces systemic inflammation
- Improves heart rate variability
- Improves endothelial function
- Improves immune function
- Protects against gray matter loss

prevented by eliminating behavioral risk factors such as physical inactivity, unhealthy diet, tobacco smoking, and alcohol use.[35] In a study designed to examine the population attributable risk of physical inactivity on death from diseases such as CHD, cancer, and diabetes, 6.0% to 10.0% of all deaths from noncommunicable disease worldwide were attributed to physical inactivity.[36] Specifically, in Canada 5.6% of CHD, 7.0% of diabetes, 9.2% of breast cancer, 10.0% of colon cancer, and 9.1% of all-cause mortality were attributed to physical inactivity.[36] These results suggest that 6.0% of the burden of noncommunicable disease worldwide could be eliminated if all inactive people become active. Furthermore, the public health burden of physical inactivity is similar in magnitude to that of obesity and even smoking. In 2008, it was estimated that physical inactivity contributed to 9.0% of premature mortality or more than 5.3 million of the 57.0 million deaths worldwide.[36] In Canada nearly half the population (47.8%) is physically inactive and only one-quarter (25.1%) of Canadians are moderately active.[37] The physical inactivity of Canadians has a significant economic impact, and in 2001 was estimated to be $5.3 billion or 2.6% of total health care costs.[18] Among Canadians physical inactivity is the most prevalent modifiable risk factor,[38] and improvements in fitness over time have been demonstrated to improve prognosis and longevity.[2] Health outcomes and conditions that are improved by physical activity and the proposed mechanisms they are improved by are shown in **Table 1** and **Table 2**.

Conclusions

Physical inactivity is central to the development of many chronic diseases that pose a major threat to our health and survival. The physically inactive have increased rates of cardiovascular disease and all-cause mortality. Not only can a physically active lifestyle reduce mortality and prevent many chronic diseases such as hypertension, diabetes, stroke, and cancer, it can promote healthy cognitive and psychosocial function. Physical inactivity should be recognized and treated like other modifiable risk factors.

Extensive evidence shows an inverse relationship between physical activity and mortality and the development of chronic disease: the greater the amount of physical activity, the greater the benefits. As well, evidence confirms there is a graded dose-response relationship. The unfit or the physically inactive can achieve the largest health gains with slight increases in activity levels. Even patients with established disease or cardiovascular risk factors can reduce their risk of premature mortality by becoming physically active. The recommended weekly 150 minutes of moderate-intensity aerobic activity has been shown to prevent and positively moderate disease. The benefits of physical activity cannot be overstated, and encouraging physical activity should remain an important health care policy objective.

Competing interests

None declared.

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