

Physical activity: the health benefits outweigh the risks

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Purpose of review

This article will summarize the current findings on the effects of physical activity on human health and well-being.

Recent findings

Physical activity is associated with enhanced health and reduced risk of all-cause mortality such as cardiovascular disease, hypertension, type 2 diabetes, obesity, osteoporosis, sarcopenia, cognitive disorders, and some forms of cancer. Nevertheless, the effects of exercise with respect to potential health consequences are complex. When untrained or previously sedentary persons undertake vigorous exertion suddenly, the undesired side effects of injuries, dehydration or cardiac arrest are amplified.

Summary

It is reasonable to conclude that the risk exposure through physical activity is outweighed by its overall benefits, and health authorities strongly encourage participation in moderate intensity physical activity on a daily basis. In the future, the identification and characterization of particularly inactive subgroups of the population may facilitate and optimize the planning of public health interventions.

Keywords

cardiac arrest, cardiovascular disease, cognitive disorders, diabetes, dehydration, disease, exercise, health, injuries, obesity, osteoporosis, oxidative stress, physical activity, risk, sarcopenia

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Introduction

Physical activity is defined as ‘any bodily movement produced by skeletal muscles that results in energy expenditure beyond resting expenditure’ (p.126) (Table 1) [1–3]. Exercise is ‘a subset of physical activity that is planned, structured, repetitive, and purposeful in the sense that improvement or maintenance of physical fitness is the objective’ [1]. The hypothesis that physical activity and exercise promote health and longevity has been recognized for a long time. Nowadays, it is confirmed that physical activity is associated with as much as a 30% reduction in all-cause mortality rates [4]. As it is directly related to health, and produces a number of health benefits, engagement in such activity is recommended on a daily basis.

Nevertheless, the effects of physical activity with respect to potential health consequences are complex. The benefits do not come without some risk, particularly when vigorous exertion is undertaken suddenly by untrained or previously sedentary persons (Fig. 1) [5]. The purpose of this review is to summarize the current findings on the effects of physical activity on human health and well-being.

Benefits of physical activity

Increased physical activity is associated with a substantial reduction in the risk of chronic diseases in industrialized societies. Moreover, epidemiological data have established that sedentarism increases the incidence of at least 20 unhealthy conditions, almost all of which are chronic diseases or considered risk factors for chronic diseases [6].

Coronary heart disease

A lack of physical activity is a major, underlying risk factor for coronary heart disease [7]. Men who were initially unfit and became fit had a 52% lower age-adjusted risk of cardiovascular disease mortality than their peers who remained unfit [8]. Vigorous exercise (≥ 6 metabolic equivalent intensity levels) (Table 2) was found to be more effective for cardiorespiratory conditioning [9,10].

Regular activity has an impact on lowering blood pressure. In mildly hypertensive men, short-term activity decreased a mean arterial pressure for 12.7 h independent of the exercise intensity [11]. The average blood pressure was lower on exercise than on non-exercise days [11]. Hayashi *et al.* [12] found that for every 26.3 men who walk more than 20 min to work, one case of

Table 1. Definitions and descriptions associated with physical activity and exercise

Term	Definition/description
Physical activity	Any bodily movement produced by skeletal muscles that results in energy expenditure [2]
Leisure-time physical activity	A broad descriptor of the activities one participates in during free time, based on personal interests and needs [3]
Occupational physical activity	Physical activity associated with the performance of a job, usually within the time frame of an 8-h workday [3]
Exercise	A subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness [2]
Aerobic exercise	Exercise that involves large muscle groups in dynamic activities that result in substantial increases in heart rate and energy expenditure [3]
Anaerobic exercise	Exercise done at very high intensities such that a large portion of the energy is provided by glycolysis and stored phosphocreatine [3]
Resistance exercise	Exercise designed specifically to increase muscular strength, power, and endurance by varying the resistance, the number of times the resistance is moved in a single group (set) of exercise, the number of sets done, and the rest interval provided between sets [3]
Physical fitness	Set of attributes that are either health or skill-related The degree to which people have these attributes can be measured with specific tests [2]

Figure 1. Benefits and risks of physical activity

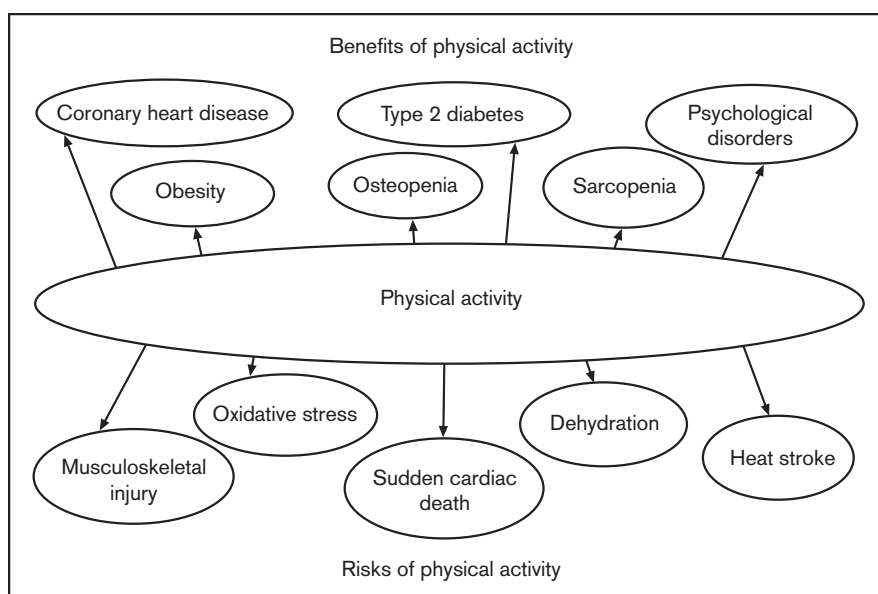


Table 2. Classification of energy costs of some physical activities as metabolic equivalent intensity levels (METs)*

Light physical activity (<3METs)		Moderate physical activity (3–6 METs)		Vigorous physical activity (>6 METs)	
Example	METs	Example	METs	Example	METs
Standing quietly	1.2	Frisbee playing, general	3.0	Bicycling, 150 W	7.0
Eating (sitting)	1.5	Walking, 5.1 km/h	3.5	Rowing, 100 W	7.0
Walking, <3.4 km/h	2.0	Rowing, stationary, 50 W	3.5	Jogging, general	7.0
Flying airplane	2.0	Gymnastics, general	4.0	Badminton, competitive	7.0
Washing dishes, standing	2.3	Stretching, hatha yoga	4.0	Tennis, general	7.0
Transportation (motorcycle)	2.5	Bicycling, <17 km/h	4.0	Running, 8.5 km/h	8.0
Billiards	2.5	Table tennis, ping pong	4.0	Hockey, ice	8.0
Music playing (piano)	2.5	Golf, general	4.5	Skiing, cross-country, 6.8–8.3 km/h	8.0
Pushing stroller with child	2.5	Badminton, general	4.5	Rugby	10.0
Fishing from boat, sitting	2.5	Skating, ice, ≤15.3 km/h	5.5	Swimming butterfly	11.0
		Bicycling, 100 W	5.5	Boxing, in ring, general	12.0
		Dancing, ballroom, fast	5.5		

*Source: Ainsworth *et al.* [10].

hypertension would be prevented. The acute effect of exercise on blood pressure is a low threshold phenomenon and requires exercise of only 40% maximal capacity [13].

Blood lipids play a major role in the pathogenesis of atherosclerosis, the underlying cause of coronary heart disease. Moderate to hard-intensity aerobic exercise training improves the blood lipid profile, with the data insufficient to establish the dose–response relationship [14]. The most commonly observed change with exercise was an increase in high-density lipoprotein cholesterol with reductions in total blood cholesterol, low-density lipoprotein-cholesterol and triglyceride [14]. Weight loss may be primarily responsible for the high-density lipoprotein and cardiovascular disease differences between active and sedentary men [15].

Type 2 diabetes

Physical activity is associated with a reduced risk of type 2 diabetes and improved insulin sensitivity and glucose homeostasis. Overweight subjects reduce their risk of getting type 2 diabetes by 58% while maintaining physical activity at 30 min/day [16]. Physical inactivity elevates the risk of type 2 diabetes in normal-weight individuals as well [17]. The acute effect of exercise on glucose metabolism appears to require exercise intensity reaching 70% of the $V_{O_{2max}}$, but this issue still requires thorough examination [13].

Overweight and obesity

Physical activity appears to be an important contributor to weight stability in healthy persons [18]. When Kyle *et al.* [19] studied the effects of regular physical activity on body composition among 3853 healthy subjects between 15 and 64 years of age, it was concluded that physical activity is able to limit fat mass and weight gain in both, men and women.

Saris *et al.* [20**] reviewed 18 studies that investigated the effects of exercise on body weight reduction in obese patients, and concluded that in short-term interventions, lasting up to 26 weeks, the mean weight reduction was 0.24 kg/week. Blair [21] reviewed 11 studies on the influence of both exercise and diet on weight loss. The average weight loss of the diet-only group was 6.7 kg. When exercise was added to the diet program, the average weight loss was 8.5 kg. Weight loss is not only achieved but also maintained through physical activity. In 2001, the US National Weight Control Registry enrolled 3000 previously obese subjects, who reported an average weight loss of 30 kg, which was additionally maintained for an average 5.5 years [22]. In the registry report, women and men expended on average 2445 and 3298 kcal/week, respectively, in various sport activities. Only 9% of registry

subjects maintained their weight loss without regular physical activity.

Osteopenia

Physical activity as a contributor to bone development has been undervalued by researchers in the field of nutrition [23]. Nevertheless, everyday physical activity has a positive effect on skeletal mass. Electrical currents that are developed when bone is mechanically stressed stimulate the formation of new bone. For example, in tennis players, only the bones of the dominant arm show significant gains in bone mineral density [24]. Whole body, leg, and trunk body mineral density significantly increase in women who walk 7.5 miles/week compared with those who cover 1 mile per week or less [25]. Continuous 1-year psoas muscle training is associated with lumbar bone loss prevention in postmenopausal women [26]. During space flight, in contrast, alterations in bone metabolism are strongly correlated with the imposed weightlessness [27].

Sarcopenia

Decreased muscle fiber area during aging is characterized by a decline in the relative occurrence of type II to I fibers from approximately 60–45% between the third and seventh decade [28]. A considerable decline in creatinine excretion [29] with aging also reflects the body muscle mass loss.

Aerobic exercise training partly influences the rebuilding of body proteins and lean tissue mass [30]. Physically active subjects aged over 65 years have a significantly higher level of lean tissue mass than sedentary participants (C.A. Raguso *et al.*, in preparation). When 78 healthy, previously untrained men and women aged 19–87 years were studied before and after 4 months of bicycle training, it was concluded that the physical activity increased protein synthesis by 22% irrespective of age. Older people can safely tolerate higher intensity strength training with improvements comparable with those seen among younger persons [31,32].

Psychological disorders

Physical activity is associated with elevations in mood states and heightened psychological well-being [33]. Active persons are likely to perform better on tests of cognitive functioning and to report fewer symptoms of anxiety and depression compared with sedentary individuals. On the other hand, persons who become inactive are 1.5 times more likely to become depressed than those who maintain an active lifestyle [34]. Physical activity is protective against development of Alzheimer's disease [35] as it may increase blood flow, which in turn promotes nerve cell growth [36]. People who are intellectually and physically inactive have about a 250% increased risk of developing the disease [35].

Summary

The evidence summarized above thus highlights the importance of physical activity as a remedy for inactivity-related chronic health conditions. However, these chronic diseases are not the only ones on which physical activity has proved to have a positive effect to prevent or improve health. Other findings suggest that such activity is also associated with a reduction in certain other diseases (e.g. cancer, pulmonary diseases, gallstone formation) [6].

Risks of physical activity

Even if regarded as an important component of a healthy lifestyle, physical activity and exercise training are accompanied by certain risks that must be considered when recommending regular activity for the general population. Fortunately, available data indicate that, in the range recommended by recent public health guidelines [1], physical activity has quite an acceptable risk-to-benefit ratio [37••].

Musculoskeletal injury

The most prevalent complications are musculoskeletal in nature. During a 12-year longitudinal study examining 6313 community adults aged 20–85 years [38], 25% of all participants reported a musculoskeletal injury while 82 and 84% of the total all-cause musculoskeletal injuries among men and women, respectively, were attributed to physical activity. The lower extremity accounted for the majority of activity-related injuries (68% for men and 65% for women) (Table 3). Due to the injuries, approximately 30% of all participants reported permanently stopping their exercise program.

A risk of injury is determined by a history of previous injury [39], as well as intensity, duration and frequency of exercise [40]. Sedentary persons have lower levels of

neuromuscular fitness than fit people [38]. During the infrequent times they participate in activity, the lack of neuromuscular strength and coordination may increase the injury risk. The general principle that the volume of physical activity should be increased gradually over time is widely regarded as critical for reducing injury risk [37••]. Risk of walking injury among young (<45 years) and older men (>45 years) is significantly lower than the risk of running injuries [40]. A greater amount of walking does not increase the injury risk.

Dehydration and heat stroke

During prolonged performance, a significant amount of body water is lost via sweating [41]. The fluid loss results in decreased circulatory blood volume, blood pressure and sweat production [42]. This can be accompanied by weakness, fatigue, headache, vomiting, diarrhea, and muscle cramps [41]. Even moderate levels of dehydration, leading to 1–2% loss of body mass, leads to a reduction in the subjective perception of alertness and ability to concentrate, and to an increase in self-reported tiredness and headache [43]. For every 1% bodyweight loss due to dehydration during exercise, the core body temperature rises an additional 0.15–0.2°C [42], the heart rate rises by an additional 3–5 beats/min [42]. Muscle tissue changes associated with dehydration include increased glycogen degradation, elevated temperature and increased lactate levels [44]. The fluid losses also result in increased vascular resistance leading to decreased skin blood flow, which impairs heat dissipation and thus directly induces hyperthermia [41]. The dehydration predisposes physically active persons to heat exhaustion or to even more dangerous heat stroke [45].

Exercise performance is optimal when athletes maintain fluid balance during exercise [46]. Nevertheless, fluid balance is not always possible because maximal sweat rates exceed maximal gastric emptying rates [46]. While endurance athletes can lose up to 1.5 L/h or more during their performance, the maximal gastric emptying rate reaches only about 1.0 L/h [41]. It is recommended that athletes should drink 400–600 mL of fluid 1–2 h before exercise, 150–350 mL every 15–20 min during exercise, and 450–675 mL for every 0.5 kg of body weight lost after the exercise [46]. On the other hand, the advice to drink before being thirsty and the availability of drinking stations every mile in endurance sports events introduces the potentially deadly risk of overhydration and hyponatremia [41].

Sudden cardiac death

Sport activity is not in itself the cause of enhanced mortality [47], but it triggers cardiac arrest in those physically active persons who already have inherited cardiovascular abnormalities [48]. Out of 158 sudden deaths that occurred in trained athletes throughout the

Table 3. Distribution and percentage by body site of activity-related sport injuries*

Site of injury	Men, n = 1052 (%)	Women, n = 260 (%)
Eye	12.9	0.8
Shoulder	7.4	5.4
Hand	1.6	2.9
Wrist	1.1	2.1
Elbow	4.9	5.4
Hip	6.2	6.6
Back	10.6	10.3
Ham	5.6	5.4
Knee	23.2	22.3
Shin	2.6	3.3
Quad	1.9	2.9
Calf	5.7	2.1
Ankle	7.5	8.7
Foot	12.9	15.7
Achilles	5.7	0.4

Data from Hootman *et al.* [38].

United States from 1985 through 1995, 85% were explained by cardiovascular causes [49]. Ninety percent of the incidents occurred during or shortly after vigorous exertion, mainly among male athletes (90%). The most common cardiovascular disease identified at autopsy as the primary cause of death was hypertrophic cardiomyopathy and malformations involving an anomalous coronary artery origin.

Even though intense exertion can be one of the factors that can influence the occurrence of sudden cardiac death, habitual participation in the activity is associated with an overall reduction in the risk of the event [50]. However, further research directed at the mechanisms underlying sudden death during vigorous physical activity may lead to new forms of preventive therapy.

Oxidative stress

Increased energy demand during physical activity, especially of the aerobic type, imposes an increase in oxygen supply to active tissues. The rate of oxygen uptake by the body during exercise may increase by 10 to 15-fold and that of active peripheral skeletal muscle tissue by approximately 100-fold [51]. Vigorous physical activity may thus induce a state in which the antioxidant defenses of several tissues are overwhelmed by excessive production of reactive oxygen species.

Body tissues with the highest oxygen consumption, such as liver, brain and kidney, have the greatest antioxidant enzyme capacities compared with those muscles with lower oxidative potential [52]. High-intensity exercise training enhances the antioxidant defense system and superoxide dismutase, glutathione peroxidase, catalase and glutathione work together to reduce the harmful effects of oxidants in the cell [52]. However, this enhanced protection may not be sufficient to completely protect highly fit individuals from exhaustive exercise-induced oxidative stress [51]. Regular physical activity in association with dietary habits that ensure an adequate supply of appropriate antioxidants may be expected to yield desirable results.

Health benefits to health risk relationship

The major contributor to exercise-induced medical complications is the intensity of the exercise. Once the intensity and amount of exercise performed is increased, the risk for injury will indisputably be elevated. Thus, when attempting to establish the optimal dose of exercise for health outcomes, the risk profile for that dose should be taken into account [53]. It is suggested that for the general population, walking is a safe form of moderate physical activity with a low risk of injury [40]. Higher exercise intensity, like running, may provide greater benefit for a specific biological outcome, but it also has a higher risk profile [53]. This information is

important for public health recommendations regarding participation in physical activity [40].

How much physical activity is needed in adults in order to promote health?

After considering positive and negative aspects of physical activity, there is a great deal of agreement that regular participation in physical activity and exercise results in positive health related outcomes. Thus, the most important question when considering physically active lifestyle as the basis of successful public health programs is how much physical activity is needed in adults in order to promote health [54].

The US Centers for Disease Control and Prevention and the American College of Sports Medicine formulated the recommendation that 'every US adult should accumulate 30 min or more of moderate-intensity physical activity on most, preferably all, days of the week' (p. 404) [1]. However, the US Institute of Medicine concluded that 30 min/day of regular physical activity is insufficient to maintain body weight in adults within the recommended body mass index range from 18.5 up to 25 kg/m², and achieve all the identified health benefits fully [55]. On the basis of doubly labeled water data and the results of epidemiologic studies, the physical activity recommendation for adults was judged to be 60 min/day (e.g. walking/jogging at 4–5 mph), that is, physical activity levels above 1.6. The International Association for the Study of Obesity [20**] confirmed that a physical activity level of 1.7 is required to prevent the transition to overweight or obesity.

Prevalence of physical activity in the general population

Although health authorities strongly encourage the general population to engage in moderate physical activity on a daily basis, the percentage of those who are physically active is low. Among US adults, only 38.5% meet the national guidelines [1] for physical activity [56]. Even among a self-conscious and well-educated US sample across a broad age range, national recommendations have made modest progress in increasing physical activity rates [56]. The prevalence of sedentarism (<150 kcal/day spent in moderate intensity activity) among adults in Geneva, Switzerland is staggering at 79.5% in men and 87.2% in women. The total amount of time spent engaging in physical activity declines with age among Swedish men aged 45–79 years [57]. All in all, the decrease in physical activity is greatest among obese men, current smokers, low-educated men and those with poor health [57].

Conclusion

Physical activity is associated with enhanced health and reduced risk of all-cause mortality such as cardiovascular

disease, hypertension, type 2 diabetes, obesity, osteoporosis, sarcopenia, cognitive disorders, and some forms of cancer. Even so, if the volume of activity is not increased gradually over time, undesired side effects, such as injuries, dehydration or cardiac arrest, are amplified. Given the substantial and compelling data from the studies mentioned above, it is nevertheless reasonable to conclude that the risk exposure through physical activity is outweighed by its overall benefits. Therefore, different health authorities strongly encourage participation in moderate intensity activity from 30–60 min on a daily basis. In the future, the identification and characterization of particularly inactive subgroups of the population may prove beneficial for the understanding of worldwide trends towards decreased physical activity and may thus facilitate and optimize the planning of public health interventions.

Acknowledgements

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