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Part G. Section 10: Adverse Events

Introduction

The benefits of regular physical activity outweigh the inherent risk of adverse events. Still, adverse events are common even if usually not severe and are an impediment to widespread participation in regular physical activity (1-4). Awareness of the types and causes of activity-associated adverse events can be helpful. Selection of low risk activities and prudent behavior while doing any activity can minimize the frequency and severity of adverse events and maximize the benefits of regular physical activity.

Physical activity-related adverse events are undesired health events that occur because a person is physically active. They may be mild or severe and include such diverse maladies as musculoskeletal injuries, cardiac arrhythmias, heat injuries, and infectious diseases. Musculoskeletal injuries are the most common type of physical-activity associated adverse event, have generated the most scientific study, and are the primary focus of this chapter. Musculoskeletal injuries may be sudden, such as a torn anterior cruciate ligament in the knee in a soccer player, or slow to develop, such as pain around the knee due to the iliotibial band syndrome in a runner or hiker. The current scientific literature does not routinely distinguish between these two types of injuries, sometimes referred to as traumatic and overuse, despite the value of doing so.

The chapter also considers in detail sudden adverse cardiac events because they may result in severe outcomes (e.g., death, myocardial infarction), fear of them likely reduces participation in activity, and their occurrence can be reduced. Other types of adverse events (e.g., heat-related illness, infections) are mentioned largely to provide examples and maintain awareness of the broad array of potential adverse events.

The factors that increase susceptibility to these adverse events also are diverse, and include the type of activity being performed (e.g., walking versus rugby), the dose of activity (the amount, as determined by the frequency, duration, and intensity), personal characteristics (e.g., age, physical activity habits), equipment or protective gear used (e.g., bike helmets), and environmental conditions (e.g., proximity to traffic, weather) (Table G10.1).

Table G10.1. Factors Associated With the Risk of Activity-Associated Adverse Events

1. Type of activity*
2. Dose of activity*
3. Personal characteristics
a. Demographic
b. Behavioral*
c. Health status
4. Protective gear and equipment
5. Environmental conditions

*Key factors under individual control

Whenever possible, the chapter draws from studies of the general population rather than research on elite or competitive athletes. Much of the research in this area has focused on competitive athletes. The frequency, duration, and intensity of the exposure and, sometimes, even the rules of the game differ markedly between competitive athletes and the general population, making extrapolation from the injury experiences of competitive athletes to the general population likely to be misleading.

While considering both the spectrum of adverse events and their causes, the chapter emphasizes the key factors of any physical activity program:

- The type (mode) of activity;
- The dose of activity as determined by the frequency, duration, and intensity of participation; and
- The rate of progression or change in the amount of activity (5).

These 3 factors are largely under individual control, and though the exact proportion of adverse events attributable to decisions in just these areas is not known, it is likely substantial. The risk of injury varies widely for different types of activities, with low-impact activities, such as walking or gardening, associated with the fewest musculoskeletal injuries. A higher dose of activity, especially among those who have previously not been active, is associated with more musculoskeletal injuries. Finally, modest and gradual increments in frequency and duration of activity are preferred at the beginning of any effort to increase aerobic activity. Augmentation of intensity, if desired, should come later (6). Attaining the desired level of activity may require a year, especially for elderly, obese, or habitually sedentary individuals (7).

Although the risk of activity-related injury is greater among persons who are more active, the risk of other types of injuries (e.g., motor vehicle, work-related) may be less, making the overall risk of injury for active people no greater than that for sedentary people. Only two population-based studies have examined this issue. One reported that people who ran or participated in sports activities were about 50% more likely to report an injury (activity-related or not) than people who reported walking for exercise or were sedentary (8). The other reported no significant differences in overall injury rates (activity-related or not) between inactive people, irregularly active people, and people who met current recommendations for physical activity (9). More studies of this type are needed, but it is possible that regular physical activity may cause some injuries and prevent others, and that physically active people may have no more injuries than sedentary individuals.

Review of the Science

Overview of the Questions Asked

The 5 major questions addressed in this chapter are:

1. What types of activities have the lowest risk of musculoskeletal injuries?
2. How does the dose of physical activity affect the risk of musculoskeletal injury?
3. Are individuals at increased risk of sudden adverse cardiac events when they are being physically active?
4. What general factors influence the risks of musculoskeletal injury and other adverse events related to physical activity?
5. Do the benefits of regular physical activity outweigh the risks?

Data Sources and Process Used To Answer Questions

The Adverse Events subcommittee used the *Physical Activity Guidelines for Americans* Scientific Database developed for the PAGAC process for this chapter (see ***Part F: Scientific Literature Search Methodology***, for a detailed description of the Database). The diversity of exposures, mediators, and outcomes plus the limited number of recently published papers on several important topics required an expanded search for pertinent work. The subcommittee therefore conducted special literature searches on upper respiratory infections and medical expenditures and added these publications to the Scientific Database. A literature search pertaining to air pollution and health was conducted but not added to the Database because physical activity was not a required component of the search. Additional citations were drawn from the Institute of Medicine's summary report of the Workshop on Adequacy of Evidence for Physical Activity Guidelines Development (10), review articles, consultants' recommendations, and other citations in pertinent articles.

Question 1. What Types of Activities Have the Lowest Risk of Musculoskeletal Injuries?

Conclusions

Activities with fewer and less forceful contact with other people or objects have appreciably lower injury rates than do collision or contact sports. Walking for exercise, gardening or yard work, bicycling or exercise cycling, dancing, swimming, and golf, already popular in the United States, are activities with the lowest injury rates.

Rationale

Risk of musculoskeletal injury varies substantially across different activities and is determined to a large extent by the frequency and force of collisions or contact with other people, the ground, or other inanimate objects. Categorization of activities by risk is difficult because style and rules of play vary by age, location, and other factors. However, the Committee on Sports Medicine and Fitness has proposed general categories that provide a guide to the injurious forces associated with specific activities (11). In collision sports (e.g., football, ice hockey, wrestling) participants purposefully hit or collide with each other or inanimate objects. In contact sports (e.g., basketball, soccer) participants make contact with each other but usually with less force. In limited-contact sports (e.g., baseball, ultimate Frisbee) participants' contact with other players or objects is infrequent or unintentional. In non-contact sports (e.g., running, swimming, tennis) contact between participants is uncommon. In general, the risk of injury is higher for collision or contact sports than for limited- or non-contact activities.

What Types of Activities Are Associated With the Lowest Risk of Injury in the General Population?

Most of the published information about the number of injuries incurred during different types of activities does not take into account either the number of people participating in various activities or the length of time they spend doing so. As a result, tabulations of injuries seen in emergency departments or other health care settings usefully describe the load on medical care services but do not allow risk estimates for different activities at the individual level. Very few studies have provided injury rates based upon the amount of time spent doing the activities.

A survey of injury risk in the general population in Finland reported a wide range of injury risk for different types of physical activities (Table G10.2[1]) (12).

Table G10.2. Injuries per 1,000 Hours of Participation and Per 1,000 Participants by Activity, Finland (12)

Commuting Activities

Activity*	Injuries per 1,000 Hours of Participation	Estimated† Injuries per 10^6 MET-Min of Participation Value (METs)	Injuries per 1,000 Persons Reporting the Activity
Walking	0.2	0.8 (4)	23.2
Cycling	0.5	1.4 (6)	21.2

Lifestyle Activities

Activity*	Injuries per 1,000 Hours of Participation	Estimated† Injuries per 10^6 MET-Min of Participation Value (METs)	Injuries per 1,000 Persons Reporting the Activity
Hunting, fishing, berry picking	0.3	1.3 (4)	20.6
Home repair	0.5	2.1 (4)	78.2
Gardening	1.0	4.2 (4)	92.0

*Not all activities in category are shown
†MET values estimated from reference 13
‡Categories from reference 11

[1] The amount of physical activity has been measured and reported in various formats, including minutes of exposure as in this study, miles or kilometers of running per week, or kilocalories of energy expenditure. MET-minutes are being used with increasing frequency. In this chapter, whenever feasible, an estimate of exposure expressed in MET-minutes is provided. The estimate is less precise than the original measures reported in this study but may be helpful when comparing the findings from different studies. For this study, the categories used by Parkkari and colleagues (12) did not correspond exactly with the categories in the Compendium of Physical Activities (13), and approximations were made.

Table G10.2. Injuries per 1,000 Hours of Participation and Per 1,000 Participants by Activity, Finland (12) (continued)

Sports, Noncontact‡

Activity*	Injuries per 1,000 Hours of Participation	Estimated† Injuries per 10^6 MET-Min of Participation Value (METs)	Injuries per 1,000 Persons Reporting the Activity
Golf	0.3	1.1 (4.5)	35.1
Dancing	0.7	2.3 (5)	23.5
Swimming	1.0	2.4 (7)	23.6
Walking	1.2	5.0 (4)	89.7
Rowing	1.5	3.6 (7)	51.9
Pole walking	1.7	5.7 (5)	54.9
Cross-country skiing	1.7	3.5 (8)	67.2
Running	3.6	6.0 (10)	123.2
Track and field sports	3.8	7.9 (8)	318.2
Tennis	4.7	13.1 (6)	188.2

Sports, Limited Contact‡

Activity*	Injuries per 1,000 Hours of Participation	Estimated† Injuries per 10^6 MET-Min of Participation Value (METs)	Injuries per 1,000 Persons Reporting the Activity
Cycling	2.0	4.2 (8)	62.4
Aerobics, gymnastics	3.1	7.9 (6.5)	120.6
Horse riding	3.7	15.4 (4)	546.9
Downhill skiing	4.1	11.4 (6)	192.5
In-line skating	5.0	6.7 (12.5)	190.8
Volleyball	7.0	29.2 (4)	447.2
Squash	18.3	25.4 (12)	629.6

*Not all activities in category are shown
†MET values estimated from reference 13
‡Categories from reference 11

Table G10.2. Injuries per 1,000 Hours of Participation and Per 1,000 Participants by Activity, Finland (12) (continued)

Sports, Collision and Contact‡

Activity*	Injuries per 1,000 Hours of Participation	Estimated† Injuries per 10^6 MET-Min of Participation Value (METs)	Injuries per 1,000 Persons Reporting the Activity
Karate	6.7	11.2 (10)	611.1
Ice hockey	7.5	15.6 (8)	670.7
Soccer	7.8	18.6 (7)	445.0
Basketball	9.1	25.3 (6)	508.5
Wrestling	9.1	25.3 (6)	625.0
Judo	16.3	27.2 (10)	1363.6

*Not all activities in category are shown
†MET values estimated from reference 13
‡Categories from reference 11

Reported activity-related injuries per 1,000 hours of participation ranged from 0.2 for walking as a commuting activity to 18.3 for squash. Injury rates were lower for commuting activities (range 0.2 to 0.5 per 1,000 hours of participation), lifestyle activities (range 0.33 to 1.01), and noncontact sports (range 0.3 to 4.7, median 1.6) than were the rates for limited contact sports (range 2.0 to 18.3, median 4.1) and collision and contact sports (range 6.7 to 9.1, median 7.8). The findings are based on a year long population-based random survey of Finns aged 15 to 74 years, 92% of whom agreed to record all physical activity sessions of 15 or more minutes and register all acute and overuse injuries that "caused a significant complaint to the subject" and that were related to the activities. Participation rates and related injuries were reported by telephone once every 4 months. It is interesting to note that injury rates for walking and cycling during commuting activities (0.2, 0.5, respectively) were one-sixth and one-fourth the rates for walking and cycling performed as sports or recreation (1.2, 2.0, respectively). This, too, indicates that the same activity done for different purposes and with different frequency, duration, and intensity leads to different injury rates.

Four other surveys of the general population also report appreciably lower injury rates among participants of non-contact activities such as walking, bicycling, gardening, golf, or swimming (14-17). The surveys, conducted in the United States, Canada, and Australia (2 surveys), report injury rates that are not directly comparable because of differing definitions of injury (e.g., medically attended versus any injury), differing time periods (e.g., 2 weeks versus 1 year), and the inclusion of different activities. Regardless, the relative safety of non-contact activities when compared to limited-contact, contact, and collision activities is present in all reports. In the 3 surveys in which activity-specific participation rates were provided, walking was the most commonly reported activity, generally by a substantial amount (14;16;17).

What Types of Sports Have the Lowest Rates of Injury for Children, Youth, and Young Adults?

Surveys of injuries among college sports (18;19), high school sports (20), and community organized sports leagues (21) have been conducted (Table G10.3).

Table G10.3. Game and Practice Injury Rates* for Collegiate Sports (Nationwide, 1988-2004),(18;19) High School Sports (Nationwide, 1995-1997), (20) and Children's Community Organized Sports (Pittsburgh, 1999-2000) (21)

Collegiate Sports

Sport	Level of Contact†	Game Injury Rate	Practice Injury Rate
Men's baseball	Limited	5.8	1.9
Men's basketball	Collision/contact	9.9	4.3
Men's lacrosse	Collision/contact	12.6	3.2
Men's ice hockey	Collision/contact	16.3	2.0
Men's soccer	Collision/contact	18.8	4.3
Men's wrestling	Collision/contact	26.4	5.7
Men's fall football	Collision/contact	35.9	3.8
Women's softball	Limited	4.3	2.7
Women's volleyball	Limited	4.6	4.1
Women's lacrosse	Collision/contact	7.2	3.3
Women's basketball	Collision/contact	7.7	4.0
Women's field hockey	Collision/contact	7.9	3.7
Women's ice hockey	Collision/contact	12.6	2.5
Women's gymnastics	Limited	15.2	6.1
Women's soccer	Collision/contact	16.4	5.2

*Injury rate, injuries per 1,000 athlete exposures
†Categories from reference 11

Table G10.3. Game and Practice Injury Rates* for Collegiate Sports (Nationwide, 1988-2004),(18;19) High School Sports (Nationwide, 1995-1997), (20) and Children's Community Organized Sports (Pittsburgh, 1999-2000) (21) (continued)

High School Sports

Sport	Level of Contact†	Game Injury Rate	Practice Injury Rate
Boys' baseball	Limited	5.6	1.8
Boys' basketball	Collision/contact	7.1	3.4
Boys' wrestling	Collision/contact	8.2	4.8
Boys' soccer	Collision/contact	10.2	2.5
Boys' football	Collision/contact	26.4	5.3
Girls' volleyball	Limited	1.2	2.8
Girls' softball	Limited	5.9	2.7
Girls' field hockey	Collision/contact	4.9	3.2
Girls' basketball	Collision/contact	7.9	3.2
Girls' soccer	Collision/contact	11.4	3.1

Community Organized Sports (Ages 7-13 Years)

Sport	Level of Contact†	Game Injury Rate	Practice Injury Rate
Boys' baseball	Limited	24	6
Boys' soccer	Collision/contact	26	10
Boys' football	Collision/contact	43	7
Girls' softball	Limited	11	7
Girls' soccer	Collision/contact	41	9

*Injury rate, injuries per 1,000 athlete exposures
† Categories from reference 11

The methods within each survey enable comparison of injury rates among different sports within the age-group of interest (i.e., collegiate athletes, high school athletes, or children aged 7 to 13 years in organized community sports leagues) and similar enough to allow an examination of general patterns. In all surveys, an athlete participating in a practice or game was an "athlete-exposure." From 1988-1989 through 2003-2004 the National Collegiate Athletic Association used standard methods to monitor the incidence of injury in 15 men's and women's collegiate sports (18;19). Each year approximately 250 schools voluntarily participated in the surveillance system. Injuries were counted if they occurred as a result of participation in practice or game, required medical attention by a team athletic trainer, and resulted in restricted participation for one or more days. From 1995 through 1997 data were collected from 250 athletic trainers working directly with high school sports programs on a daily basis (20). Injuries were counted if they caused cessation or participation on the day of or day after the onset; in addition, all fractures or dental injuries were counted. From 1999 to 2000, injury reports were collected from coaches in the community leagues for children aged 7 to 13 years in Pittsburgh (21). Injuries were counted if a coach came onto the field to check the condition of a player, if a player was removed from participation, or if a player needed any type of first aid during an event.

In the surveys of college and high school athletes, injuries were less common in limited contact sports than collision or contact sports. Among children's community leagues, injury rates were higher for football than for baseball, softball, or soccer, but the differences between sports were less apparent than for the older youths. None of the surveys included non-contact sports such as swimming or golf. In all 3 surveys, injuries were less common in practice than games.

Question 2. How Does the Dose of Physical Activity Affect the Risk of Musculoskeletal Injury?

Conclusions

The risk of activity-related injury (but not necessarily overall injury) is directly related to a person's usual amount of physical activity. Research with a variety of populations and methods also shows that when individuals increase their usual amount of physical activity the risk of injury is related to the size of the increase. A series of small increments in physical activity each followed by a period of adaptation is associated with lower rates of musculoskeletal injuries than is an abrupt increase to the same final level.

Fewer studies are available to examine the independent contributions to injuries of the components of physical activity — frequency, duration, intensity. However, available research indicates that each component is a contributory factor and that the composite amount is a more important determinant of risk than any component by itself.

Currently available information suggests that the commonly recommended level of regular physical activity, about 500 metabolic equivalent (MET)-minutes per week, has a low (but not precisely measured) rate of associated musculoskeletal injury. However, little information has been reported about the risks of injury at this level.

Rationale

The dose of activity is determined by its frequency, duration, and intensity. Both dose and change in dose are important determinants of musculoskeletal injuries and, to a large extent, are under personal control. This is especially important because many Americans are inactive and should be encouraged to increase the amount of physical activity in which they engage. For discussion purposes, studies providing insight into the relationship between changes in dose of activity and risk of injury can be grouped into 3 categories:

- People who have self-selected their current activity program;
- People with previously differing levels of activity who all adopt the same activity program simultaneously (e.g., military recruits); and
- People with previously similar levels of activity who are assigned different but higher levels of activity (e.g., intervention research).

Evidence from each of these 3 groups of studies indicates that: 1) the amount of activity is directly related to the risk of musculoskeletal injury and 2) the change in amount of activity is directly related to risk of musculoskeletal injury. Military recruits who are the least fit or least physically active before basic training and experimental subjects who are assigned higher amounts of activity are the most likely to become injured. Stated another way, the same amount of new activity is more likely to cause injury in sedentary individuals than in active individuals. These findings suggest that a series of small increments in physical activity each followed by a period of adaptation is associated with lower rates of musculoskeletal injuries than is an abrupt increase to the same final level. Previous physical activity recommendations for children (22), adults (23), and older adults (24) have suggested gradual augmentation of activity levels to prevent injuries and improve adherence.

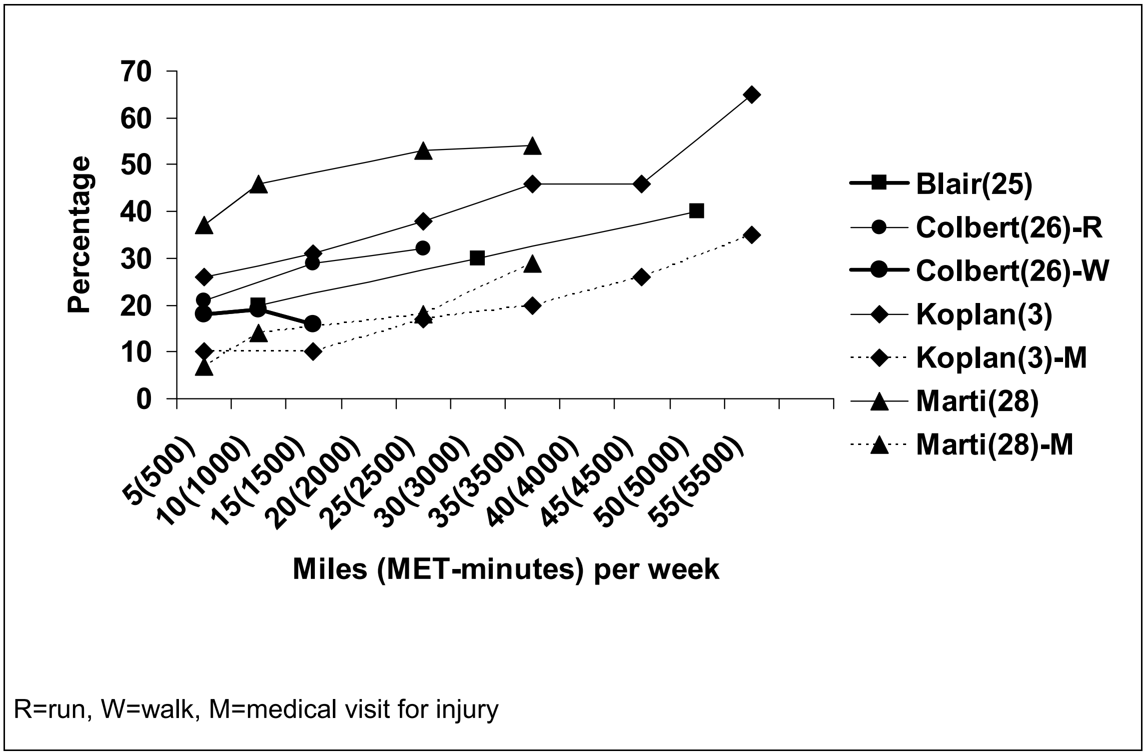
What Is the Relationship Between Self-Selected Doses of Activity and Risk of Injury?

The clearest evidence of the direct relationship between dose of activity and risk of injury comes from 7 studies of running injuries. Individuals who run 40 miles per week or more (4,000 or more MET-minutes per week)[2] are 2 to 3 times more likely to have had a running injury in the past 12 months than are individuals who run 5 to 10 miles per week (500-1,000 MET-minutes per week) (3;8;25-29) (Figure G10.1).

Five studies were retrospective cohort studies and 2 were prospective cohort studies. Injuries in all studies were self-reported but definitions varied. Three counted symptoms that caused the runner to modify his or her usual program, take medication, or seek medical advice (3;27;29), 2 counted symptoms recognized by the participant as an injury (8;28), 1 counted only injuries for which medical care was sought (26), and 1 counted only injuries that caused the runner to stop running for at least 7 days (25). Despite varying definitions, all studies reported increases in the risk of injury as the number of miles per week increased. For those studies providing information separately about injuries for which medical attention was sought, the findings were similar (3;26;28). The trends were similar for males and

[2] The speed of running is assumed to be 10 minutes per mile, an intensity of 10 METs.

Figure G10.1. Percentage of Recreational Runners or Walkers Injured by Average Number of Miles Run per Week



M, medical visit for injury; R, run; W, walk

Figure G10.1. Data Points

Study	5 (500)	10 (1000)	15 (1500)	20 (2000)	25 (2500)	30 (3000)	35 (3500)	40 (4000)	45 (4500)	50 (5000)	55 (5500)
Blair (25)	–	20	–	–	–	30	–	–	–	40	–
Colbert (26)-R	21	–	29	–	32	–	–	–	–	–	–
Colbert (26)-W	18	19	16	–	–	–	–	–	–	–	–
Koplan (3)	26	–	31	–	38	–	46	–	46	–	65
Koplan (3)-M	10	–	10	–	17	–	20	–	26	–	35
Marti (28)	37	46	–	–	53	–	54	–	–	–	–
Marti (28)-M	7	14	–	–	18	–	29	–	–	–	–

females and for runners of different ages. No information about race or ethnicity is reported by any of these studies. Similar findings have been reported for triathletes, another group for which estimating the dose of activity is relatively straightforward (30;31).

What Are the Relative Importances of Frequency, Duration, and Intensity to the Risk of Musculoskeletal Injury?

Although the evidence is limited, in these studies of runners the total dose of running appears to be more important than any of its components. Among the studies of running injuries, only 2 reported information about the relationship between frequency and injury risk. One reported that greater frequency (number of days per week of running) was significantly related to injury even after total dose (i.e., miles per week) and other factors were taken into account (29); the other reported that the relationship was not significant after adjustment for other factors, including total amount (27). Two studies reported on the relationship between duration of episodes and injury. One reported a significant relationship between minutes of running per week and injury even after other factors were taken into account (8); the other, in a multivariate analysis, reported an association between the distance of the longest run per week and injury (29). None of the 4 studies that examined the usual speed of running observed a relationship after total amount and other factors were taken into account (3;25;28;29). Two of these studies, however, reported that competitive runners were more likely to be injured than recreational or noncompetitive runners (28;29). Similar findings have been reported for competitive versus club athletes in other sports (31;32). Competitiveness may be a surrogate for relative intensity, suggesting that the athletes at greatest risk of injury are those performing near the top of their capacity.

Is the Risk of Injury per Mile Equivalent for Runners With Different Weekly Mileages?

Although the risk of injury is directly related to the volume of activity, the risk per unit of exposure appears to diminish as the volume of exposure increases. Among runners, the risk of injury per mile is about 10-fold higher at 5 miles per week (500 MET-minutes per week) than 40 miles per week (4,000 MET-minutes per week) (28;33). A similar observation has been made for subjects in the Aerobics Center Longitudinal Study (34). The annual risk of injury for persons expending about 2,000 kilocalories per week (1,632 MET-minutes per week)[3] in exercise was 22% or about 11% per 1,000 kilocalories per kilogram (816 MET-minutes per week) of exercise; the annual risk for persons expending 10,000 kilocalories per week (8,160 MET-minutes per week) was 65% or about 6.5% per 1,000 kilocalories (816 MET-minutes). These findings are consistent with the suggestion that any given increase in volume of activity (e.g., adding 500 MET-minutes per week of activity) produces a greater increase in risk of injury for those who are less active than it does for those who are more active.

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[3] Assumes 1 MET-minute = 0.82 kilocalorie. Assumes 70 kilogram body weight in formula: MET-min*3.5*70/200 = kilocalorie.

What Is the Relation Between an Assigned Dose of Physical Activity and Injury Among Persons of Different Levels of Fitness or Physical Activity Habits?

Military recruits are young healthy adults who undergo 2 to 3 months of rigorous, often vigorous, aerobic and muscular training, primarily running, marching, drill, and general conditioning exercises. Typically, recruits have 5 to 6 days of activity per week with, on average, 40 minutes of running or marching, 10 minutes of drill (learning to march in unison), 10 minutes of general condition (calisthenics), and 10 minutes of stretching per day, for a weekly total of about 2,725 to 3,270 MET-minutes (35). This level of physical activity is approximately 6 times the currently recommended amount for the population (36). Recruits experience high levels of overuse musculoskeletal injuries during this period (11% to 37% for men, 22% to 67% for women) (37). The symptomatic onset of injuries corresponds closely to the dose of activity (38) (Figure G10.2).

What Factors Are Most Consistently Associated With High Rates of Musculoskeletal Injuries During Basic Training?

Low levels of aerobic fitness and prior physical activity are 2 of the most consistently observed risk factors for injuries among the recruits. Six studies have demonstrated an inverse relationship between measures of aerobic fitness and risk of injury (35;39-43) (Figure G10.3). Aerobic fitness was determined by timed distance runs ranging from 0.75 to 2.0 miles or, in one case, peak VO_2 (40). Outcomes included time loss injuries (39;40), lower extremity injuries (35), and stress fractures (41-43). Participants in the studies were either all male, all female, or stratified by sex.

These same studies have reported similar findings for a variety of measures of pre-training physical activity practices, including frequency of running, frequency of physical activity producing a sweat, frequency of physical activity in general, self-assessed physical activity levels, and self-assessed relative fitness level (35;39-43). Similar findings have been reported when the recruits have been followed beyond the initial basic training period (44;45). Students in physical education classes (46) and participants in aerobic dance classes (47) also have been shown to be more likely to be injured if they are less physically active outside of class.

Modifications of the basic training program (e.g., less running) (48;49) or providing a formal pre-training program to recruits with low fitness (50) have resulted in reductions in the incidence of injuries among recruits in basic training while maintaining fitness goals (51).

Figure G10.2. Hours of Drill per Marching Plus General Conditioning (Solid Line, Left Axis) and Injuries per 100 Recruits (Dotted Line, Right Axis) by Week of Training

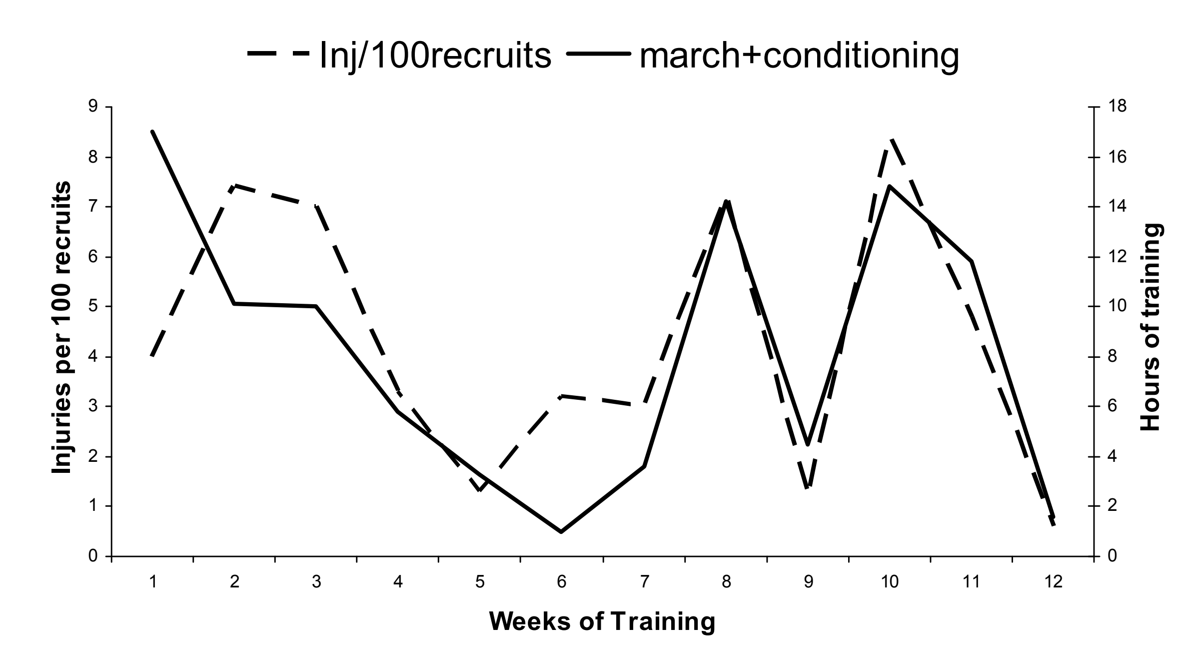
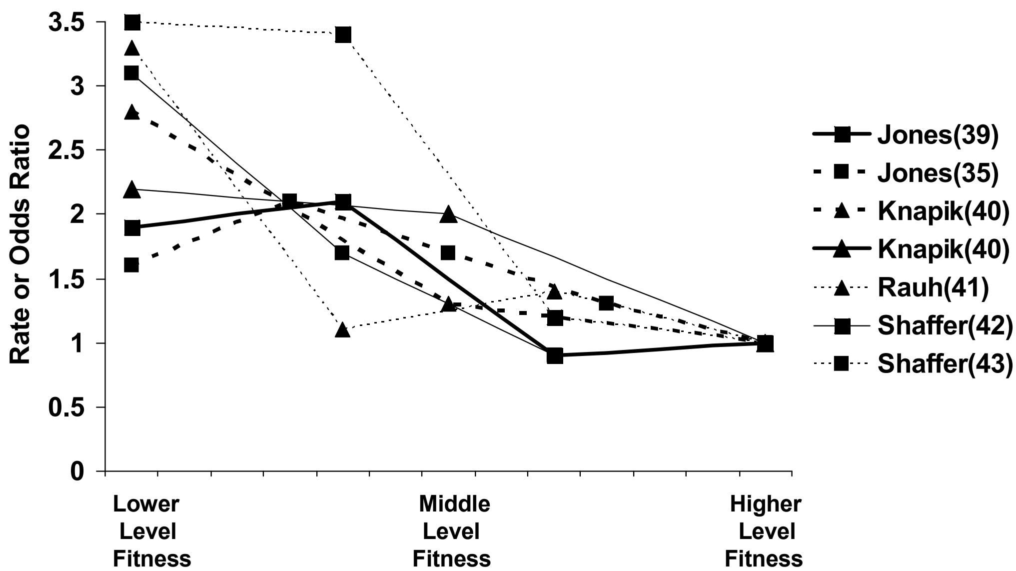


Figure G10.2. Data Points

Weeks of Training	Injuries per 100 recruits	March+conditioning
1	4.0	17.0
2	7.4	10.1
3	7.0	10.0
4	3.3	5.8
5	1.3	3.3
6	3.2	1.0
7	3.0	3.6
8	7.2	14.2
9	1.2	4.5
10	8.4	14.8
11	4.8	11.8
12	0.6	1.6

Figure G10.3. Rate or Odds Ratio for Injury Among Military Recruits During Basic Training by Aerobic Fitness at Entry



Solid lines=males, dotted lines=females, boxes=bivariate, triangles=multivariate
Rauh(41), Shaffer(42), Shaffer(43) limited to stress fracture injuries

Figure G10.3. Data Points

Study	Fitness Level 0	Fitness Level 1	Fitness Level 2	Fitness Level 3	Fitness Level 4	Fitness Level 5	Fitness Level 6	Fitness Level 7	Fitness Level 8	Fitness Level 9	Fitness Level 10	Fitness Level 11	Fitness Level 12
Jones (39)	1.9	–	–	–	2.1	–	–	–	0.9	–	–	–	1
Jones (35)	1.6	–	–	2.1	–	–	1.7	–	–	1.3	–	–	1
Knapik (40)	2.8	–	–	–	–	–	1.3	–	–	–	–	–	1
Knapik (40)	2.2	–	–	–	–	–	2	–	–	–	–	–	1
Rauh (41)	3.3	–	–	–	1.1	–	–	–	1.4	–	–	–	1
Shaffer (42)	3.5	–	–	–	3.4	–	–	–	1.2	–	–	–	1
Shaffer (43)	3.1	–	–	–	1.7	–	–	–	0.9	–	–	–	1

Are These Findings Consistent With Principles of Exercise Training Programs?

The findings in military recruits, students, and runners are consistent with the 2 major principles of exercise training programs: 1) overload and adaptation, and 2) specificity of response (52). The overload and adaptation principle states that function is improved when tissues (e.g., muscles) and organs (e.g., heart) are exposed to an overload (i.e., a stimulus greater than usual) and provided time to recover and adapt. Repeated exposures to a tolerable overload are followed by adaptation of the tissues and organs to the new load and improvements in performance and function. Too large an overload or insufficient time for adaptation, however, leads to injury and malfunction. The principle of specificity states that the adaptation and improved function is limited to the tissues and organs that have been overloaded. Training the muscles of the legs, for example, does not improve strength in the arms and shoulders.

In summary, these studies indicate that the risk of musculoskeletal injury is directly proportional to the gap between one's accustomed level of activity and the level of activity currently being performed. The larger the overload the smaller the chance of adaptation and the greater the chance of injury.

What Is the Relation Between Different Assigned Doses of Physical Activity and Injury Among Persons of Similar Levels of Fitness or Physical Activity Habits?

Assigning different physical activity regimens to groups of people who are otherwise similar would provide experimental evidence about the relative risks of different activity regimens. Although substantial numbers of clinical trials with physical activity as an exposure have been done in recent years, information about musculoskeletal injuries incurred during the trials and their relation to dose of activity is sparse. Comparison among studies is difficult because the assigned activity, outcome measures, period of study, and level of detail about injuries differ markedly (Table G10.A1, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/).

The amount and type of information has varied over time. Earlier reports that included males aged 25 to 60 years, and used vigorous activity reported high injury rates, nearly 50% (53-55). A few studies specifically investigated the relationship between the dose of activity and the incidence of injury (56-59) and, taken together, have reported that the incidence of injury appears to be related to each of the components of dose, frequency, duration, and intensity. More recent research has focused on interventions to promote moderate intensity physical activity. These studies suggest that the incidence of injuries attributable to recommended levels of moderate intensity physical activity appear to be low (60-65), but their actual incidence, severity, and effect on long-term physical activity participation are largely unknown. The study for which injury rates for both intervention and control subjects appeared to be most thoroughly reported found equivalent rates of musculoskeletal problems (64). A systematic review of interventions to prevent lower limb soft tissue running injuries concluded "it is not possible to suggest an optimal training load" (66), but that injuries are associated with frequency, duration, intensity, or total amount of training.

An observation noted in both early and more recent publications is the apparent frequency of injuries during the first weeks of the intervention (53;67). One researcher advocated 8 to 10 weeks of preparative training before actually beginning a trial (53); another reported that half of all injuries occurred within the first 4 weeks of a 24-week program (67).

In summary, reports from experimental studies suggest that frequency, duration, and intensity all contribute to the risk of physical activity-related adverse musculoskeletal events, that a substantial increase in activity level leads to high rates of musculoskeletal problems, and that moderate intensity physical activity appears to have low (but not precisely measured) injury rates.

Are Injury Rates for Walking Less Than Injury Rates for Running?

On the surface, musculoskeletal injury rates from walking appear to be less than injury rates for running. Annual injury rates among runners range from 12% to 50% (median 35%) (2;3;12;25;27-29); for walkers they range from 3% to 20% (2;12;16;17). A direct comparison of injury rates for joggers and walkers reported rates of 75% and 54%, respectively, for all reported injuries, and 25% and 21%, respectively, for injuries requiring 7 days of inactivity (59). In a study of injury and adherence rates, the injury rate increased from 5% during the 13 weeks of mostly walking to 57% during the weeks of mostly jogging (56).

The apparent differences in injury rates for walking and running deserve closer scrutiny, however. Although the higher injury rates for running compared with walking are generally assumed to be due to higher impact forces (68) and greater tension on muscles and tendons, some or all of the difference may be due to the higher volume of activity performed by runners. For example, the relative difference in injury risk between people walking or running for recreation or sport is larger when the exposure is minutes of participation (1.2 versus 3.6 injuries per 1,000 hours of participation) than when the exposure is MET-minutes of participation (5.0 versus 6.0 injuries per 10^6 MET-minutes of participation) (Table G10.2) (12). In addition, 19% of persons expending 600 MET-minutes per week while walking were injured compared with 21% of persons expending 700 MET-minutes per week while running (Table G10.A2, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/) (26). Data such as these suggest the risk of injury from walking or running depends largely upon the total amount of energy expended. At least 2 studies, however, have reported that the risk of injury attributable to walking is seemingly independent of volume for reasonable volumes (8;26;69). In one case, the volume of walking was largely determined by walking more minutes per session (8;26), in the other by using inclined treadmills to raise the intensity (69).

To summarize, it is not yet certain whether walking is intrinsically safer than running or whether the reported lower rates of injury from walking are because the total volume of activity (combination of duration, frequency, and intensity) is less for walkers than for runners.

Question 3. Are Individuals at Increased Risk of Sudden Adverse Cardiac Events When They Are Being Physically Active?

Conclusions

During periods of vigorous physical activity all individuals, even regularly active individuals, are at higher risk of sudden adverse cardiac events (e.g., sudden death, myocardial infarction) than during periods when they are being less active. However, active people are at less risk than inactive people both during activity and during inactivity. When the risks during activity and at rest are averaged over the whole day, active people have a lower risk.

The risks of sudden adverse cardiac events are greater for those who remain sedentary than for those who increase their regular level of physical activity in a gradual manner. Risks of sudden cardiac adverse events are lower for light- and moderate-intensity activities than for vigorous activities, and likely depend on relative intensity as much or more than absolute intensity.

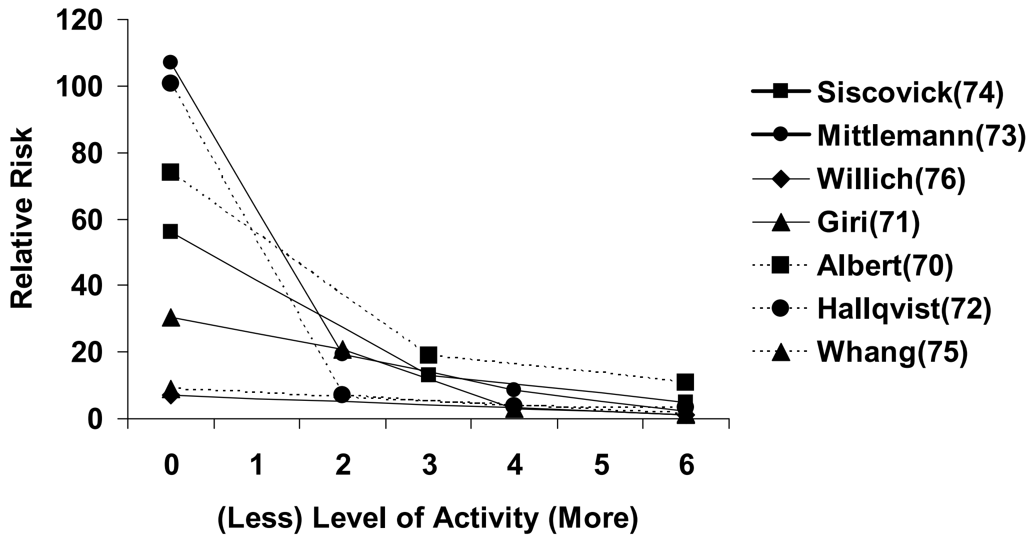
Because cardiovascular risks are more closely associated with intensity of activity than with frequency or duration, common practice in aerobic activity programs is to increase frequency and duration of activity before increasing intensity. Although the safety of specific amounts of increase have not been empirically established, the available scientific literature suggests that adding a small and comfortable amount of light to moderate intensity activity, such as walking, 5 to 15 minutes per session, 2 to 3 times per week, to one's usual activities has a low risk of musculoskeletal injury and no known risk of sudden severe cardiac events.

Current recommendations for physical activity state that asymptomatic men and women who plan prudent increases to their daily physical activities do not need to consult a health care provider before doing so. The incidence of activity-related cardiovascular or musculoskeletal adverse events has not been shown to be reduced by a medical consultation.

Rationale

As shown elsewhere in this report (see ***Part G. Section 1: All-Cause Mortality*** and ***Part G. Section 2: Cardiorespiratory Health),*** the cardiovascular benefits of regular physical activity for adults outweigh the associated cardiovascular risks, including the risk of sudden cardiac death and myocardial infarction. In addition, 7 epidemiologic studies published between 1984 and 2006 compared the incidence of sudden adverse cardiac events (i.e., cardiac arrest, sudden death, myocardial infarction) during or shortly after vigorous physical activity between less and more active people (Table G10.A3, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/). These studies uniformly reported a lower risk per minute of activity for more active people (Figure G10.4) (70-76).

Figure G10.4. Risk of Sudden Adverse Cardiac Event by Level of Activity



Relative Risk=risk per minute of vigorous activity/risk per minute of not vigorous activity
Definitions of level of activity differ across studies

Figure G10.4. Data Points

Study	Level of Activity 0	Level of Activity 1	Level of Activity 2	Level of Activity 3	Level of Activity 4	Level of Activity 5	Level of Activity 6
Siscovick (74)	56	–	–	13	–	–	5
Mittlemann (73)	107	–	19.4	–	8.6	–	2.4
Willich (76)	6.9	–	–	–	–	–	1.3
Giri (71)	30.5	–	20.9	–	2.9	–	1.2
Albert (70)	74.1	–	–	18.9	–	–	10.9
Hallqvist (72)	100.7	–	6.9	–	3.7	–	3.3
Whang (75)	9	–	–	–	–	–	1.5

Two of the studies also report that the absolute rate of sudden death during vigorous physical activity is quite low (70;75).

In all 7 studies, the overall relative risk of vigorous physical activity was elevated (median 4.9). When stratified by usual level of activity, the median relative risk of adverse event during vigorous physical activity was 56 for the least active group in each study compared with a median relative risk of 2.4 for the most active group.

Six of the studies used case-crossover methodology, a technique useful for examining a brief period of risk related to a brief exposure, in which cases serve as their own control. One study (74) was exclusively a case control study; others augmented the case-crossover design with case-control designs (72;76) or performed the case-crossover analysis within a cohort design (70;75). In 6 of the studies, vigorous physical activity was defined as requiring 6 or more METs; in one it was defined as 5 or more METs (75).

All the studies included middle to older aged adults and, therefore, provide no information about populations younger than 40 years of age. Two studies included only males (70;74), one included only females (75), and in the remainder, 23% to 32% of the participants were female. One study reported that 90% of subjects were white (71); others provided no information about the racial composition of the study samples. Three studies excluded persons with cardiovascular disease or other "major" chronic conditions (70;74;75).

Three studies provided information about the weighted or average risk of sudden adverse cardiac events in addition to the relative risk per minute of vigorous activity. Because active people are active for more minutes than are inactive people, it is possible that the average risk of sudden adverse cardiac events might be higher for them. Two studies reported that the average risk of events declines with higher levels of regular physical activity (74;75); one reported no difference (70). Data from one of the studies shows that even though the risk of the active person during activity exceeds the average risk of an inactive person, the average risk of an active person over a 24-hour period is less (Figure G10.5) (74;77). In the words of one investigator, to speak of sudden death as a risk of exercise is misleading. Sudden death is, more accurately, a risk of inactivity (78).

Two studies estimated the absolute incidence of sudden cardiac deaths, reporting $3.5*10^{-6}$ and $3*10^{-8}$ per hour of vigorous activity for men (70) and women (75), respectively, confirming the low incidence of such adverse events.

What Do These Findings Imply for Light- or Moderate-Intensity Physical Activity?

The previously described studies investigated risks associated with vigorous physical activity (generally 6 or more METs). The cardiovascular risks of light or moderate intensity physical activity are expected to be less, but quantitative estimates are rare. One of the studies described above (76) reported the relative risk of mild-to-moderate activity to be 0.9, essentially equivalent to the relative risk of sedentary activity (1.1) and sleep (0.8). Among Finnish men, the risk of sudden cardiovascular death during "non-strenuous" activity was reported to be about one-third the risk during "strenuous" activity (79). In an evaluation of an intervention promoting walking among healthy sedentary persons aged 70 to 89 years, abnormal heart rhythms were more common among subjects in the intervention arm than among control subjects (64). The intervention encouraged walking at moderate intensity with a goal of at least 150 minutes per week.

Figure G10.5. Risk of Cardiac Arrest During Vigorous Activity and at Rest by Usual Level of Activity

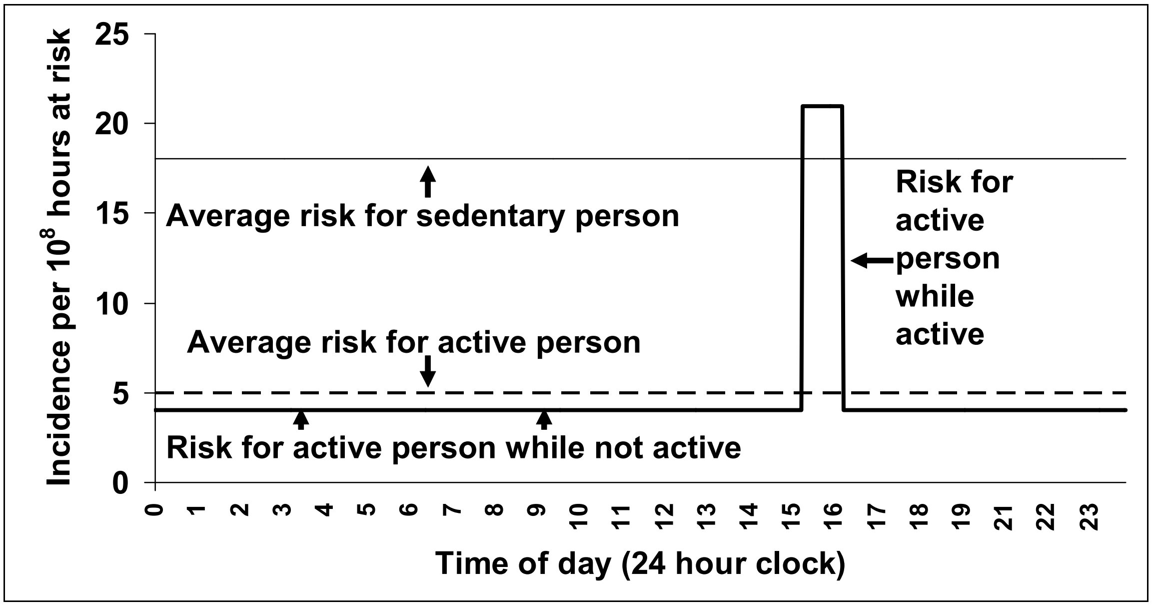


Figure G10.5. Data Points

Risk by Level of Activity	Incidence of Cardiac Arrest per 10^8 Hours at Risk
Average risk for sedentary person	18
Average risk for active person	5
Risk for active person when not active	4
Risk for active person when active	21

In summary, information about the activity-related cardiovascular risks of moderate or light activity is limited. Available information is consistent with the expectation that the risks are substantially lower than those associated with vigorous activity. One would also expect the risks to be lower for regularly active persons than sedentary persons, as is the case for vigorous physical activity.

What Do These Findings Imply for Activities of Low Absolute but High Relative (Perceived) Intensity?

These 7 studies examined the risks of activities requiring 6 or more METs (in one case, 5 or more METs). Individuals, however, vary in their capacity to perform activities with high energy requirements. In general, capacity is lower for females than males, declines with age, appears to be influenced by genetics, and is modulated by routine physical activity practices. Activities requiring about 6 METs of energy expenditure generally cannot be done by persons 80 years and older, are perceived as hard to very hard for middle aged and older adults, and as moderately intense for young adults (Table G10.4) (80).

Table G10.4. Absolute Intensity by Age Group and Relative (Perceived) Intensity (80)

Relative (Perceived) Intensity	Absolute Intensity (METs) in Healthy Adults Young (20-39 yr)	Absolute Intensity (METs) in Healthy Adults Middle-Aged (40-64 yr)	Absolute Intensity (METs) in Healthy Adults Older Adults (65-79 yr)	Absolute Intensity (METs) in Healthy Adults Oldest Adults (80+ yr)
Very light	<2.4	<2.0	<1.6	≤1.0
Light	2.4-4.7	2.0-3.9	1.6-3.1	1.1-1.9
Moderate	4.8-7.1	4.0-5.9	3.2-4.7	2.0-2.9
Hard	7.2-10.1	6.0-8.4	4.8-6.7	3.0-4.25
Very hard	≥10.2	≥8.5	≥6.8	≥4.25
Maximal	12.0	10.0	8.0	5.0

MET, metabolic equivalent

To the extent that regular physical activity habits influence these general findings, sedentary persons would find the relative intensity of any activity of 6 METs to be higher than indicated by the table and very active persons would find it to be lower. As a result, when performing the same activity, sedentary individuals experience more cardiovascular stress than do active individuals. This, plus the fact that sedentary individuals are probably more likely to have atherosclerotic coronary arteries, helps explain the elevated risk of sudden adverse cardiac events among sedentary individuals during activity defined as vigorous on an absolute scale.

As a result, perceived intensity or level of exertion may be a better indicator of cardiovascular stress than absolute intensity (5). Several scales of perceived exertion have been developed and are in use. The terms used to describe a mid-range of exertion are “fairly light” to “somewhat hard,” “weak” to “moderate,” or “light.” Available evidence suggests that individuals striving to be more physically active should, especially initially, adjust their perceived effort to this light to moderate level. They should not strive to perform at an arbitrary absolute level, such as walking at a set pace of 3.5 or 4 miles per hour.

What Do These Findings Imply for Persons Interested in Increasing the Amount or Intensity of Their Physical Activity Practices?

These findings, as did the research findings for the risk of musculoskeletal injuries, indicate that the sedentary persons are most in need of increasing their physical activity level and are those who are also at greatest risk of adverse events when performing activities. The risk of sudden adverse cardiac event is inversely related to the amount of vigorous physical activity (Figure G10.6) (77).

Figure G10.6. Risk of Cardiac Arrest During Activity and at Rest by Usual Level of Activity

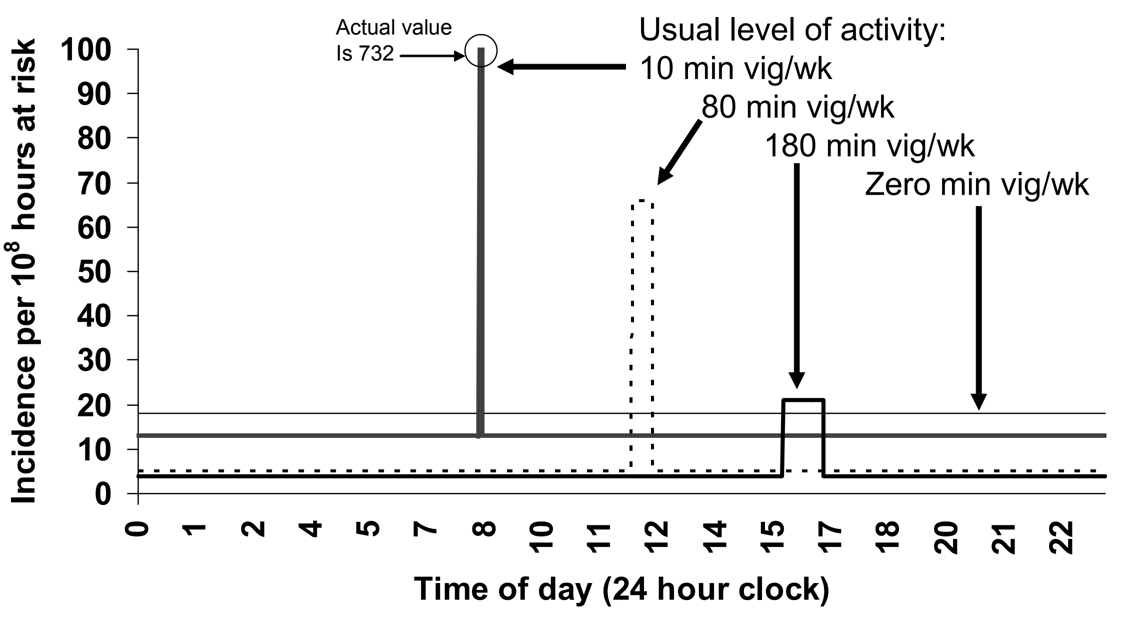


Figure G10.6. Data Points

Risk by Level of Activity	Incidence of Cardiac Arrest per 10^8 Hours at Risk
Risk for person with no minutes per week of vigorous physical activity	18
Risk for person with 10 minutes per week of vigorous physical activity while sedentary	13
Risk for person with 10 minutes per week of vigorous physical activity while vigorously active	732
Risk for person with 80 minutes per week of vigorous physical activity while sedentary	5
Risk for person with 80 minutes per week of vigorous physical activity while vigorously active	66
Risk for person with 180 minutes per week of vigorous physical activity while sedentary	4
Risk for person with 180 minutes per week of vigorous physical activity while vigorously active	21

The risks of remaining sedentary, however, are greater than the risks of becoming active, especially if increases in activity are prudent. For cardiovascular risk, the intensity of the activity is of greatest concern (81). Because the cardiovascular risks are more closely associated with intensity than with frequency or duration, common practice in aerobic activity programs is to increase frequency and duration of activity before increasing intensity (52). Although the safest method of increasing one's physical activity has not been empirically established, drawing upon the principle of overload and adaptation of exercise science and the experience of supervisors of cardiac rehabilitation programs, walking so that the perceived intensity is in the light to moderate range (5) until one is able to walk 20 to 30 minutes per session for several weeks is an acceptable and safe way to begin. For older adults who are increasing their physical activity level, cardiovascular adaptation to an augmented activity regimen may take as long as 20 weeks or more (82), suggesting that activity levels should be increased at monthly rather than weekly intervals.

Are There Any Types of Heart Problems or Other Medical Problems for Which Vigorous Physical Activity, Even by Regularly Active Individuals, Poses More Risk Than Benefit?

Unlike atherosclerotic coronary artery disease, for which regular (including vigorous) physical activity is beneficial, hypertrophic cardiomyopathy, anomalous coronary arteries, long QT syndrome, Marfan syndrome, and other congenital cardiac anomalies are not benefited by regular, especially vigorous, physical activity. The risks posed by these conditions rises with the intensity of activity performed. Therefore, although regular moderate-intensity physical activity may benefit individuals with these conditions by reducing the risk of atherosclerotic disease, diabetes, obesity, and other conditions related to under activity, vigorous physical should be avoided (81). People with sickle trait, a trait more common among African Americans than other groups, are more likely to suffer rhabdomyolysis and sudden death during exercise than those who do not carry the trait (83;84).

How Do These Studies Apply to Children, Adolescents, and Young Adults?

The studies reviewed for this chapter do not apply because children, adolescents, and young adults rarely have atherosclerotic heart disease. In contrast to adults for whom activity-related sudden adverse cardiac events is almost always due to atherosclerotic coronary artery disease, activity-related sudden adverse cardiac events among youth are primarily due to congenital abnormalities.

Nontraumatic sports deaths (e.g., cardiovascular, hyperthermia, rhabdomyolysis, and sickle cell trait) in high school and college athletes are uncommon, with incidence rates of about 7.5 per million per year among male athletes and 1.3 per million per year among female athletes (85). About 75% of the deaths are due to cardiovascular causes. Because these deaths are so uncommon, the evaluation of various screening mechanisms is difficult (86;87).

For children, adolescents, and young adults (ages 1 to 24 years) the U.S. Preventive Services Task Force (USPSTF) recommends "counseling patients to incorporate regular physical activity into their daily routines" (88). However, the USPSTF recommends against routine electrocardiographic screening as part of the periodic or pre-participation sports physical exam (88). Current recommendations of the American Heart Association are that high school and collegiate athletes should be evaluated by a "healthcare worker with the requisite training, medical skills, and background," and that the evaluation "should include a complete medical history and physical examination" including blood pressure measurement (86). For a detailed discussion of issues related to physical activity and youth, see ***Part G. Section 9: Youth.***

Is a Health Care Evaluation Necessary Before Augmenting One's Current Physical Activity Practices?

Evidence that persons who consult with a health care provider before increasing their physical activity receive more benefits or suffer fewer adverse effects than persons who do not is not available. Also unknown is the extent to which official recommendations to seek medical advice before augmenting one's regular physical activity practices may reduce participation in regular moderate physical activity by implying that being active may be less safe and provide fewer benefits than being inactive (78).

Recent recommendations have suggested that asymptomatic men and women who plan sensible increases in light to moderate physical activity do not need to consult a health care provider before doing so (36;81). Others, generally concurring with the safety of small increases in light to moderate activity, have recommended that "previously inactive" men aged 40 years and older, women age 50 years and older, and people who have chronic disease or risk factors for chronic disease should consult a physician before starting a vigorous activity program (23;89;90).

These two perspectives, one calling attention to the safety of small increases and the other to the risks of large increases, are consistent with the findings of this chapter. A substantial increase in physical activity over one's customary routine — either as a single episode, as shown in the studies of acute adverse cardiac events, or as a more sustained program, as for the military recruits — is associated with higher risks of adverse events than are smaller and more gradual increases. The risk is associated with the magnitude of the relative discrepancy between the usual level and new level of activity rather than with other personal characteristics. Adding a small and comfortable amount of walking, such as 5 to 15 minutes 2 to 3 times per week, to one's usual daily activities has a low risk of musculoskeletal injury and no known risk of sudden severe cardiac events. Choosing a comfortable level of effort, initially increasing only frequency and duration of activities, and allowing adequate time for adaptation to each new level of activity minimizes the already low risk of injuries or other problems.

Question 4. What General Factors Influence the Risks of Musculoskeletal Injury and Other Adverse Events Related to Physical Activity?

Conclusions

In addition to the type, dose, and relative size of increase of physical activity, the risk of musculoskeletal and other adverse events is related to several key factors:

- Demographic and personal characteristics. Low levels of physical activity or fitness and previous musculoskeletal injuries are two of the most important individual-level risk factors for injuries and other adverse events.

- Quality and appropriateness of equipment, including protective gear. Proper equipment (e.g., bicycle helmets) reduces risk.

- Safety of the environment. Safe places for children to play, structures that limit vehicular speed, and mechanisms that keep pedestrians and bicyclists separated from motor vehicles reduce the risk of activity-associated injuries. Fear of crime is a barrier to physical activity although no evidence exists that people are at greater risk of crime during periods of activity than periods of inactivity.

- Prudent attention to each of these components of activity-related risk can reduce the rate of adverse events and enlarge the benefit to risk ratio.

Rationale

Demographic and Personal Characteristics

Demographic and personal characteristics influence the type and amount of physical activity people do and, thereby, influence the risk of injury. This section, however, is concerned not with whether these characteristics influence the choice of activity but whether they influence directly the risk of injury. Two types of questions may be of interest. First, do people with different characteristics (e.g., old or young) but doing the same amount and type of activity have the same risk of activity-related injury? Second, do people with the same characteristic (e.g., overweight) but different activity habits (i.e., active or inactive) have the same risk of injuries from all causes? Information is not always available to address both questions.

Age

Are older and younger people at the same risk of activity-related injury? One would expect the risk of injuries and other adverse events to increase with age. The physiologic changes of aging, such as the decline in maximal heart rate and cardiac output, decline in connective tissue elasticity, decline in balance, and fall in the speed of reflexes, all would appear to make older people more easily afflicted by physical activity-associated adverse events.

Surprisingly few studies have actually examined the topic. Studies of military recruits report higher injury rates among older recruits even though the oldest recruits are in their mid to upper 20s (35;91). Surveys of active adults of all ages, however, report lower injury rates among older than younger persons (9;12;14;17;92). This surprising finding presumably arises from a confounding of age with exposure — the fact that older individuals cannot perform and do not attempt to perform at levels comparable to younger persons.

Are active and inactive people of similar age equally likely to be injured? The incidence of injuries from all causes (not only activity-related injuries) is a function of both age and level of physical activity. Among younger people, physically active people report more injuries requiring medical attention than inactive people; whereas among older people inactive people report more injuries (Table G10.5) (9).

Table G10.5. Annual Incidence* of Self-Reported Injury Requiring Medical Advice by Age Group and Leisure-Time Physical Activity Level (9)

Age Group (years)	Overall	Active†	Insufficiently‡ Active	Inactive§
18-24	116.6	126.4	132.5	96.5
25-34	97.3	112.7	85.1	91.8
35-44	87.0	93.0	75.5	91.2
45-64	76.4	72.6	76.5	81.6
65+	68.1	60.6	56.1	74.4

* Incidence per 1,000 population
† Meet current physical activity recommendations
‡ Report some leisure-time light-moderate or vigorous physical activity but do not meet current recommendations
§ Report no leisure-time light-moderate or vigorous physical activity

Are children and adolescents more susceptible to overuse injuries? The growing child or adolescent may have an increased susceptibility to certain repetitive stress injuries such as traction apophysitis (e.g., Osgood-Schlatter disease), injuries to the immature spine, or others (93). These established developmentally-linked injuries and the growth of organized competitive sports for youth and the sometimes prolonged and intensive training attendant with successful participation in those sports has raised concern about "the sensibility and safety of high-level athletics for any young person" (94). Little empirical evidence is available on which to assess the magnitude and risk factors for the problem. Drawing upon expert opinion and clinical experience, recommendations, the American Academy of Pediatrics makes the following recommendations (94;95):

- Participation in sports should be at a level consistent with the child's abilities and interests;
- Athletes should take off 1 to 2 days per week and 2 to 3 months per year from any specific sport;
- Athletes should participate on only 1 team per season;
- Athletes should not increase their training load by more than 10% per week;
- Coaches, trainers, and parents should be alert to the possibility of overuse injuries;
- Treatment recommendations should include alternatives to "rest only" programs because they are not likely to be followed; and
- Fun, sportsmanship, skill acquisition, and safety should be emphasized.

Although overuse injuries may be a concern for some children and youth, for the large majority of children insufficient physical activity is a greater concern than too much activity (See ***Part G. Section 9: Youth*** for a detailed discussion of this topic).

In summary, for a specific dose of activity older people are more likely than younger people to be injured. In practice, however, older people consciously or unconsciously appear to moderate their physical activity so that they become injured less frequently than do younger persons. When compared to inactive individuals, physically active younger persons are injured more frequently than inactive younger persons whereas physically active older persons are injured less frequently than inactive older persons.

Sex

Currently available research suggests that, aside from stress fractures and injuries to the anterior cruciate ligament of the knee, which are more common in females (51;96;97), males and females appear to be equally susceptible to activity-related injuries (34;37;98-100). In population surveys, males are more likely to report having been injured than females (34), but they are also more likely to report being physically active (101). In military studies in which males and females partake of the same dose of activity, females are about twice as likely as males to be injured (10;102), but they, as a group, are also less physically fit than males at the beginning of basic training (102;103). When injury rates are adjusted for initial physical fitness, the risks of injury for females and males are equivalent (98;102;103). This is consistent with findings from college athletes in which sport- and sex-specific injury rates are similar for males and females (99;100).

Race and Ethnicity

The influence of race and ethnicity on activity-related musculoskeletal injuries has been uncommonly reported. Most studies of military recruits report no differences among race and ethnic groups in the incidence of musculoskeletal injuries (35;40-42). In one study, the incidence of stress fractures was higher for whites than blacks (104). However, certain health conditions that are more common in one race or ethnic group may influence injury or illness rates. For instance, people with sickle trait, a trait more common among African Americans than other groups, are more likely to suffer rhabdomyolysis and sudden death during exercise than those who do not carry the trait (83;84).

Anatomical Characteristics

The few studies that have examined anatomical factors suggest that self-reported leg-length discrepancies (105), and clinically measured high arches (106), genu valgum (knock knees) (107) and high quadriceps angle (107;108) are associated with higher risks of musculoskeletal injuries than is the case for persons who do not have these anatomical characteristics.

Behavioral Factors

Fitness and physical activity. Low levels of physical fitness and physical activity are among the most important risk factors for musculoskeletal injuries and sudden adverse cardiac events. Please see the detailed discussion earlier in this chapter on the relationship between physical activity, injuries, and levels of physical fitness.

Stretching. Persons with high or low levels of flexibility appear to be more likely to be injured than persons in the middle range of flexibility (35;40). However, stretching, per se, has not been shown to be effective for either injury prevention or improved performance (109). Some evidence indicates that stretching combined with other actions, including warm up, strength training, or general conditioning, prevents injuries (109).

Warming up and cooling down. Warming up and cooling down before and after exercising are commonly recommended to prevent injuries and adverse cardiac events. Although evidence is limited, various combinations of warm-up, strength training, conditioning, and stretching are associated with lower rates of musculoskeletal injuries (109).

Following a survey of major cardiovascular complications during exercise training at cardiac rehabilitation programs, which reported that 44 (72%) of 61 adverse events occurred near the beginning or at the very end of the session (110), careful warming up and cooling down have become standard practice in cardiac rehabilitation programs. Evidence consistent with myocardial ischemia during sudden strenuous exercise without warm-up has been noted in some studies (111-113) but not others (114). In the period immediately after strenuous exercise catecholamine blood levels are elevated, posing potential risk, especially for persons with coronary artery disease (115).

Despite limited evidence of helpfulness, guidelines recommend 10 to 20 minutes of stretching and progressive warm-up activity before the main activity session (116). Following the main activity, 10 to 20 minutes of gradually diminishing activity is recommended.

Existing Health and Medical Conditions and Behaviors

Tobacco use. Cigarette smoking (40;45;117) and smokeless tobacco use (91) have been associated with higher rates of musculoskeletal injuries among military recruits undergoing basic training. The associations are strong (2- to 3-fold), are directly related to the usual number of cigarettes smoked, and persist after controlling for other risk factors, such as physical fitness.

Prior musculoskeletal injuries. Prior injury is one of the most consistently reported and strongest risk factors for future injury, with the risk generally reported to be about two-fold (10;29;34;35;41;47;108;118;119). Reinjury may occur because the original injury has not healed or the wound and surrounding structures have been inadequately rehabilitated (34), or because the primary risk factor has not been modified (e.g., structural or training defect). Prior or current injury is one of the most common barriers to participation in regular physical activity at recommended levels (1-4).

Pregnancy. Current recommendations state that participation in a wide range of aerobic and recreational activities of moderate intensity is safe for healthy pregnant women with uncomplicated pregnancies (120;121). Given the many years, however, of clinical and public health efforts to promote and provide appropriate medical care for pregnant women, surprisingly little is considered firmly established about the benefits and risks to pregnant women and their fetuses of physical activity. A systematic review by Kramer and McDonald (122) noted that insufficient data from small clinical trials whose methodological quality was not high made it difficult to infer important risks or benefits of physical activity for the woman or the fetus. Potential benefits specific to pregnancy, such as preventing gestational diabetes and maternal weight control and promoting maternal fitness, easier and less painful deliveries, and improved mental health, have been suggested by epidemiologic studies but are not yet firmly established. (See ***Part G. Section 11. Understudied Populations*** for a detailed discussion of physical activity and pregnant women.) Prenatal medical evaluation is recommended for every pregnant woman to be sure that she does not have one of the rare but absolute contraindications for physical activity during pregnancy (120) and to develop an appropriate physical activity program during the pregnancy and postpartum period.

Overweight and obesity. Studies of activity-related injuries among military recruits, runners, and other active people report varied findings. Some report no association (3;28) between weight status and risk of activity-related injuries, and others report elevated rates among those with higher body mass index (BMI) (118;123). Still others report elevated rates among military personnel with lower and higher BMI (39;45) compared to those in the middle range.

Given the mixed findings and the fact that these groups contain few overweight and almost no obese individuals, the results from these studies are difficult to apply to overweight and obese individuals. For injuries of any cause, not just activity-related injuries, population-wide studies indicate that overweight and obese individuals are more likely than persons of normal weight to report a medically attended injury (Table G10.6) (9;124).

Table G10.6. Rate or Odds Ratio of Medically Attended Injury of Any Cause, by BMI Category

Subjects of 2000-2002 NHIS (9) BMI Range	Subjects of 2000-2002 NHIS (9) Rate Ratio	Subjects of 1999-2002 MEPS (124) BMI Range	Subjects of 1999-2002 MEPS (124) Odds Ratio
–	–	<18.5	0.97
<25.0	1.00	18.5-24.9	1.00
25-29.9	1.09	25.0-29.9	1.15
≥30	1.17	30.0-34.9	1.24
–	–	35.0-39.9	1.26
–	–	≥40.0	1.48

BMI, body mass index; NHIS, National Health Interview Survey; MEPS, Medical Expenditure Panel Survey

Another way to look at this issue is to ask whether active and inactive overweight people are at equal risk of activity-related injuries. One study has found that obese persons who are regularly active have been reported to be nearly 15% less likely to be injured from any cause than inactive obese persons (9).

Acute upper respiratory tract infections (URTI). Although evidence is not yet abundant, current scientific literature suggests that people who are physically active at currently recommended levels suffer fewer URTI than either sedentary individuals or athletes participating in intense exercise training.

Recent studies of children (125), adolescents (126), adults (127), postmenopausal women (128), and elderly adults (129) all report fewer URTI among more active individuals than among less active. Another study among the elderly reported no difference in the incidence of URTI but less fever and activity restriction among active than inactive persons (130).

In contrast, recent studies that include persons participating in intense exercise training such as elite athletes report either no difference between groups (131;132) or the highest rates of URTI among the athletes at the highest level of competition (133-135). In studies with elite athletes the curves showing infection rates across groups display a "J" shaped dose-response curve, with the inactive participants having slightly elevated rates, moderately active individuals the lowest rates, and the extremely active participants the highest rates of URTI.

Engaging in moderately intense physical activity during a URTI appears to be safe. Vigorous activity is discouraged, especially if evidence of systemic involvement, such as fever, muscle aches, swollen lymph nodes, or extreme fatigue, exists (136;137).

Chronic diseases. For many chronic diseases, including the most prevalent conditions such as atherosclerotic heart disease, diabetes, arthritis, or chronic lung disease, participation in an appropriately designed physical activity program is therapeutically beneficial (138-141). Review and discussion of the evidence pertaining to physical activity as a treatment for specific conditions is beyond the scope of this chapter. For some severe conditions physical activity may be contraindicated or severely restricted; the Canadian Society for Exercise Physiology supported by Health Canada has proposed a list of such conditions (142).

Current recommendations state that most people with a chronic disease can safely add several minutes of walking or other light to moderate intensity activity to their everyday activities. Persons with cardiovascular disease, diabetes, or other active chronic conditions who want to begin engaging in **vigorous** physical activity and who have not already developed a physical activity plan with their health care provider may wish do so (36;81). Appropriately designed physical activity regimens for individuals with a wide range of disabilities has been shown to be safe and effective (see ***Part G. Section 11: Understudied Populations,*** for a detailed discussion of physical activity and people with disabilities).

Quality and Appropriateness of Equipment

Shoes

Comfortable shoes that fit properly are associated with less foot pain, fewer blisters and ulcers, and lower risk of future development of foot problems than are poorly fitting shoes. This is true for all people, regardless of activity. Proper footwear is especially important for persons with diabetes or other conditions that interfere with circulation or sensation of the feet. Recent reviews indicate that shock absorbing inserts reduce the incidence of stress fractures in military personnel (143) and that external ankle supports reduce the incidence of ankle sprains during high-risk activities such as basketball or soccer (144). The value of pronation control and cushioning in running shoes, and lateral stability, torsion control, traction, and cushioning in court shoes is generally assumed despite limited scientific support (145). Comfort is one of the, if not the, most important aspects of a sport shoe.

Clothing

For pedestrians and cyclists, the use of red, yellow, and orange fluorescent materials improves recognition by drivers of vehicles, and lamps, flashing lights, and reflective materials help at night (146). However, neither the use of fluorescent materials during the day nor lights or reflective gear at night has been shown to reduce collisions or injuries. Proper clothing also reduces the risk of injury from cold or hot temperatures (see section on Climate, below) (147;148).

Bicycle Helmets

The protective effects of bicycle helmets have been firmly established, and their use is recommended for commuting, recreational, and competitive bicycling. A recent meta-analysis estimated that the use of bicycle helmets reduced the risk of death by nearly 75%, risk of head injury and brain injury by about 60%, and risk of facial injury about 50% (149). An estimated 107,000 unnecessary bicycle-related head injuries, $81 million in direct medical costs, and $2.3 billion in indirect health costs in 1997 resulted from bicyclists in the United States not wearing helmets (150).

Other Gear and Equipment

Proper protective equipment has been shown to reduce the rate of specific types of injuries in a variety of activities. Breakaway bases and reduced-impact balls in baseball and softball, mouth guards in basketball, helmets in football, full face shields in hockey, wrist guards in in-line skating, binding adjustments in skiing, and other protective gear have been shown to reduce injuries (151).

Safety of the Environment

Physical activity is performed in many different environments, including outdoor and indoor facilities, urban and rural settings, and hot and cold temperatures. Many features of these environments influence the risk of injuries. A common environment for physical activities such as walking, gardening, bicycling, and playing is residential neighborhoods. Two-thirds (66%) of respondents to a recent survey reported their neighborhood as a site for physical activity (152). The next paragraphs pertain to risk factors within residential neighborhoods, namely, traffic, crime, air pollution, and weather.

Safety from Traffic and Crime

Traffic safety in neighborhoods. Injury rates of pedestrians and cyclists in the United States are 2- to 4-fold higher than in Germany and the Netherlands (153). Two important features of safe walking and biking are lower traffic speed and separation from traffic. Neighborhoods can be modified to reduce traffic speed and to assure separation between pedestrians, cyclists, and motor vehicles. Mechanisms to slow traffic, sometimes referred to as traffic calming, include 1) vertical deflections (e.g., speed bumps), 2) horizontal deflections (e.g., bends), 3) road narrowing, and 4) medians, four-way stops, and small roundabouts (154-156). Mechanisms to separate pedestrians and cyclists from traffic include installation and maintenance of 1) sidewalks and bicycle lanes, 2) pedestrian over- and underpasses, and 3) fences or parkways between sidewalks and streets (155;157). Methods of reducing the risk at crossings — areas shared by pedestrians, bicyclists, and motor vehicles — include the installation of traffic signals, pedestrian prompting devices (e.g., signs), in pavement flashing lights to warn drivers when pedestrians are present, traffic signals with exclusive walk signal phasing, refuge islands, raised medians, and improved nighttime lighting (155;158;159). Less is known about creating safe environments for bicycling than for walking (160).

Safe walking to school. When asked why their children do not walk to school, 30% of parents cite traffic safety concerns and 12% cite fear of crime (161). Special programs have been implemented specifically to improve the safety from both traffic and crime for children going to and from school. The Federal Highway Administration's *Safe Routes to School* provides funding to states for educational and environmental change to encourage walking and biking to school (162). An online newsletter reports that pedestrian injuries were not increased in spite of more children walking and biking to school with Safe Routes to School programs (163).

Crime reduction. Fear of violent crime is a barrier to participation in physically active pursuits. Adults, adolescents, and children who live in neighborhoods perceived to be unsafe have been shown to be less physically active compared to those living in areas perceived to be safe (164;165). No evidence exists that people are at greater risk of violent crime (e.g., assault, rape) during periods of activity than periods of inactivity. When considering walking, running, or other physical activities in an unfamiliar place, crimes are less likely to occur in places that are well lit, where other people are present, and that are lacking signs of neglect such as litter, graffiti, empty buildings, buildings in disrepair (e.g., broken windows) (154).

Safety tips to protect from traffic and crime are available (Table G10.7) (166). They have face-validity although few have empirical support.

Table G10.7. Safety Tips to Avoid Becoming Victim of Crime, Avoid Traffic Injuries, or Minimize the Effects of Either*

1. Carry identification
2. Bring a partner, human or canine
3. In unfamiliar areas, inquire about safety
4. Leave word where you are going and when you'll be back
5. Stay alert and aware of surroundings
6. Don't wear headphones
7. Avoid unlit areas
8. Avoid unpopulated areas and deserted streets
9. Ignore verbal harassment
10. Carry cell phone or money to make a phone call
11. Carry a noisemaker
12. Contact police immediately if something happens

* Source: Adapted from Road Runners Club of America (2007)

Air Pollution

The balance between the risks and benefits of being physically active in air polluted at levels commonly experienced in the United States is not established. Air pollution is a complex mixture of gases, liquids, and particulate matter. Levels and constituents of air pollution vary among and within cities. Air pollution is generally most intense near busy roadways and industrial sites. It can be indoors or outdoors depending on the type and origin of the pollutants.

Both long- and short-term exposure to air pollution have been shown to increase all-cause, cardiovascular, and pulmonary mortality, hospital admissions, emergency room visits, and symptoms (167;168). The Environmental Protection Agency has developed an Air Quality Index and, depending upon the value of the index, individuals may be advised to reduce or avoid "prolonged or heavy exertion" out of doors (169).

Physical activity increases the volume of inhaled air and exposure to airborne toxins and allergens (170). Elevated levels of air pollution are associated with reductions in maximal exercise performance (171;172). Exercisers have been warned to avoid exercising near heavy traffic and industrial sites, especially during rush hour (170;173). Such recommendations may be reasonable for individuals who can easily modify the location or time for exercise. However, they may be a barrier to regular physical activity for people with less flexible daily demands. In addition, they take into account only short-term adverse effects of physical activity in polluted air. The long-term benefits of regular physical activity in polluted air may outweigh the short-term risks. Lower mortality rates among more active than less active individuals in a polluted industrial community have been reported (174). Regular physical activity in a polluted environment may ameliorate the adverse effects of pollution just as it reduces the adverse health effects of obesity and diabetes.

No evidence exists that physical activity in air polluted to the current levels of American cities negates the benefits of physical activity. From a health perspective, it would be preferable to reduce air pollution than reduce the already low physical activity levels of Americans.

Temperature Extremes

It is safe for healthy people to be physically active in a wide range of normally encountered temperatures. Proper clothing is important. Acclimatization — physiologic adaptation (e.g., greater volume and less concentrated sweat) to repeated exposures to warm weather — occurs over several weeks and increases the safety warm weather activity. A protective acclimatization to very cold weather does not occur. Specific guidelines regarding activity in extremely cold (148) and hot (147) conditions have been published, as have guidelines for maintaining adequate hydration in these settings (175).

Question 5. Do the Benefits of Regular Physical Activity Outweigh the Risks?

Conclusions

The benefits of physical activity outweigh the risks.

Rationale

Outcomes that encompass a broad spectrum of medical maladies — such as all-cause mortality, functional health, or medical expenditures — sum both positive and negative effects of physical activity. All-cause mortality, for example, encompasses deaths caused and prevented by activity; and medical expenditures include costs incurred and avoided because of physical activity.

Physically active people have lower all-cause mortality rates, higher levels of functional health, and lower medical expenditures. (See ***Part G. Section 1: All-Cause Mortality*** and ***Part G. Section 6: Functional Health.***) Studies of the influence of physical activity on medical expenditures consistently report lower costs for active individuals when compared with inactive individuals. The savings may be lower or even absent for younger persons, but for adults and older adults physical activity is associated with lower medical costs. These medical expenditures include costs associated with adverse effects and, therefore, indicate an overall benefit from participation in regular physical activity.

Are Medical Expenditures Lower for Physically Active People Than for Inactive People?

Studies of the relationship between medical expenditures and physical activity generally are of two types: direct comparisons of the expenditures of more and less active people, and estimates of the excess costs incurred by inactive people because they are more likely than active people to develop certain conditions such as heart disease, diabetes, or colon cancer.

Direct Comparisons

Eight studies published in the last decade have compared direct medical expenditures for active and inactive individuals who are members of the same group or population, such as employees of a company, enrollees in a health plan, or respondents to national surveys (see Table G10.8 below. Table G10.A4, which also summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/) (176-183). All report lower medical costs for active persons. For 7 studies, the reductions ranged from 6% to 22% (median, 13%) (176;177;179-183); the eighth reported that costs were reduced 4.7% for each day per week of physical activity (178). All minimized the confounding potential of chronic diseases through exclusion, adjustment, or stratification. All adjusted their findings for age and sex, 6 adjusted for BMI (177-181;183), and 4 adjusted for smoking (177-179;183). Subjects in all of the studies were adults or older adults, with mean ages ranging from 45 years to 75 years.

Table G10.8. Medical Expenditures for Active Versus Inactive Persons

Subjects, Researchers (Citation)	Study Period	Cost Ratios
Members of health plan (178)	1995–1996	4.7% reduction in costs per active day/week
Beneficiaries of National Health Insurance (Japan) (179)	1995–1998	1.00 (ref) walk <31 min/ week 0.97 walk 31-60 min/ week 0.87 walk >60 min/ week
Members of HMO (176)	1997–2000	1.00 (ref) active 0.79 active
Employees of large company (181)	1996–1997	1.00 (ref) 0 times/ week 0.89 1-2 times/ week 0.91 3+ times/ week
Respondents of NHIS and MEPS (182)	1996	1.00 (ref) inactive, no CVD 0.93 active, no CVD 1.00 (ref) inactive, with CVD 0.60 active, with CVD
Respondents of NHIS and NMES with symptoms of depression (183)	1987	1.00 (ref) inactive 0.94 active
Retirees of large company (180)	2001–2002	1.00 (ref) 0 times/ week 0.86 1-3 times/ week 0.78 4+ times/ week
Respondents to NHIS and MEPS with mental disease (177)	1996	1.00 (ref) inactive with mental disease 0.81 active with mental disease

CVD, cardiovascular disease; HMO, health maintenance organization; MEPS, Medical Expenditure Panel Survey; NHIS, National Health Interview Survey; NMES, National Medical Expenditure Survey; ref, reference, value

Estimated Costs

A review summarizing the findings of 10 studies from 6 countries (US-3, Canada-2, Holland-2, Australia-1, Switzerland-1, UK-1) of the annual excess cost (in 2003 $US) per inactive person per year reports a range from -$109 to $1305 (median $172) (184). These studies are done by combining population-wide estimates of physical activity from national surveys with estimates of relative risk of inactivity for specific diseases from observational research studies. Four of the reviewed studies included both direct and indirect costs; 6 included only direct costs. The one study suggesting that inactive individuals have lower medical expenditures stratified the data by age, reporting an annual cost saving of $109 per inactive person aged 15 to 44 years compared with an expense of $87 per inactive person age 45 years and older. Similar methods have been used to develop estimates for 5 States (GA, MN, NY, SC, WA), with annual per capita direct medical costs attributable to physical inactivity ranging from $19 (WA) to $79 (GA) (185).

Overall Summary and Conclusions

The benefits of regular physical activity outweigh the inherent risk of adverse events. Still, adverse events are common and are an impediment to more widespread participation in regular physical activity. Selection of low risk activities and prudent behavior while doing any activity can minimize the frequency and severity of adverse events and maximize the benefits of regular physical activity.

The chapter has focused on musculoskeletal injuries, the most common type of physical-activity associated adverse event, and sudden adverse cardiac events, one of the most severe adverse events. The chapter also has emphasized the key factors of any physical activity program, which are:

- The type of activity;
- The dose of activity as determined by the frequency, duration, and intensity of participation; and
- The rate of progression or change in the dose of activity.

Proper attention to each of these can substantially reduce the risk of adverse events.

The overall conclusions of this chapter can be summarized as follows:

Risk of adverse events and type of activity. Activities with fewer and less forceful contacts with objects or other people have appreciably lower injury rates than collision or contact sports. Walking for exercise, gardening or yard work, bicycling or exercise cycling, dancing, swimming, and golf, already popular in the United States, are activities with the lowest injury rates.

Risk of adverse events and amount of activity. The amount of physical activity is directly related to the risk of musculoskeletal injury. Injury rates at the level of activity commonly recommended (150 minutes per week of moderate intensity activity, or about 500 MET-minutes per week of activity) have been uncommonly documented but appear to be low.

Risk of adverse events and change in amount of activity. The risk of injury is directly related to size of increase in the amount of physical activity performed. A series of small increases in activity each followed by a period of adaptation is expected to cause fewer injuries than larger increases. Adding a small and comfortable amount of walking, such as 5 to 15 minutes 2 to 3 times per week, to one's usual daily activities has a low risk of musculoskeletal injury and no known risk of sudden severe cardiac events. Frequency and duration of aerobic activity should be increased before intensity. Increases in activity level may be made as often as weekly among youth, whereas monthly is more appropriate for older or unfit adults. Attainment of the desired level of activity may require a year or more, especially for elderly, obese, or habitually sedentary individuals.

Risk of sudden adverse cardiac events. The risk of sudden adverse cardiac events (e.g., sudden death, myocardial infarction) are higher during periods of vigorous physical activity than during periods of less intense activity or while at rest for all individuals. However, active people are at less risk than inactive people both during activity and during inactivity. When the risks during activity and at rest are averaged over the whole day, active people have a lower average risk than do inactive people.

The risks of sudden adverse cardiac events are greater for those who remain sedentary than for those who increase their regular level of physical activity, especially if the increase is gradual. Risks of sudden cardiac adverse events are lower for light- and moderate-intensity activities, and likely depend on relative intensity as much or more than absolute intensity. The first changes in an aerobic activity program should be in the frequency and duration rather than the intensity of the activity.

The information about activity-related musculoskeletal and cardiovascular adverse events reviewed in this chapter is consistent with previously made recommendations that asymptomatic men and women who plan prudent increases to their daily physical activities do not need to consult a health care provider before doing so. Evidence that persons who consult with a health care provider before increasing their physical activity receive more benefits or suffer fewer adverse events than persons who do not is not available. Symptomatic persons or those with cardiovascular disease, diabetes, or other active chronic conditions who want to begin engaging in **vigorous** physical activity and who have not already developed a physical activity plan with their health care provider may wish to do so.

Personal characteristics and behaviors associated with higher risks of adverse events. Previous musculoskeletal injuries and low levels of physical activity or fitness are two of the most important individual level risk factors for injuries and other adverse events.

Other factors associated with higher risks of adverse events. Proper equipment, such as bicycle helmets, reduces risk. Neighborhood characteristics that limit vehicular speed and keep pedestrians and bicyclists separated from motor vehicles also reduce the risk of activity-associated injuries. Fear of crime is a barrier to physical activity although there is no evidence that people are at greater risk of crime during periods of activity than periods of inactivity.

Consistency of current findings with previous physical activity recommendations. Adverse events have received relatively little attention in previous physical activity recommendations. When mentioned, however, the statements are consistent with the information presented in this chapter. Several mention the importance of gradual increases in physical activity (22-24;80;186), and several acknowledge the fact that injuries are a potential barrier to participation in physical activity (23;24;80;187).

Research Needs

This review of the literature related to physical activity and adverse events identified a number of questions that would benefit from additional research:

Are active and inactive individuals at equal risk of unintentional injuries? Although physically active individuals are likely to incur more activity-related injuries, limited evidence suggests that they may suffer fewer non-activity-related injuries and, therefore, experience no more and maybe fewer overall injuries than inactive people. The severity of injury and the type and amount of physical activity are likely to be important determinants of the relationship.

What is the appropriate starting dose of activity for individuals who have been inactive? Recommendations to "gradually" increase one's physical activity are commonly made but there is little information to support specific recommendations for an initial dose that will maximize continued participation and minimize adverse events.

What are the appropriate size and frequency of increases in physical activity? Recommendations to increase "gradually" are common but there is little information to support specific recommendations. Size and frequency of increase may also vary by age, length and severity of inactivity, and other factors.

What are the incidence and risk factors for adverse events associated with walking? Current literature suggests that risks may be unrelated to either total volume of walking or intensity (using elevated treadmills). Are these findings substantiated in other settings and populations?

What are the most effective methods of reducing the incidence and severity of adverse events among people who are increasing their physical activity practices? The type, dose, rate of increase, proper protective gear, and safety of the environment are major determinants of injury risk and adherence to an activity regimen. Little is known about the most effective methods of encouraging and enabling the public to safely increase their physical activity practices.

Is there value, and if so for whom, to seeking advice from a health care provider before increasing one's physical activity practices? Although it does not address the preceding question fully, one approach to reducing adverse events among persons who are increasing their physical activity levels has been to suggest that some people (usually those who are older or have one or more chronic conditions) should receive permission and guidance from a health care provider before participating in vigorous physical activity. The benefits and costs of such a suggestion are unknown. Does a recommendation for people to develop an activity plan with a health care provider prevent adverse events? Does it reduce participation in physical activity? If both, what is the balance at the population level? Are such recommendations justified for certain population subgroups? If so, which ones?

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