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Part E: Integration and Summary of the Science

Introduction

The PAGAC's final step in developing this report was to integrate and summarize the key conclusions and supporting data that each subcommittee prepared and presented in their chapters (***Part G: The Science Base***). Each chapter in ***Part G*** provides a review of the scientific literature on physical activity and a selected health outcome or population, and the chapters' conclusions are supported by original publications cited in extensive reference lists.

Each subcommittee's major conclusions were reviewed and accepted by the PAGAC during its final meeting on February 28-29, 2008. Because much of the scientific review by PAGAC members and consultants was organized around specific health outcomes, the PAGAC decided that it needed, where possible, to integrate key findings for these various outcomes into general statements about the scientific support for health-related benefits of physical activity. This chapter provides the results of the Committee's summary and integration process. Using a plan outlined below, PAGAC members first summarized the type and strength of evidence for their major conclusions. This evidence is presented in a series of tables on **pages E-4 to E-22**

The Committee then integrated the evidence and conclusions by developing responses to a set of questions that are typical of those raised by health and fitness professionals and the general public about the scientific evidence on a number of issues about physical activity and health. These responses are supported by the information provided in the chapters in ***Part G: The Science Base***. The questions and answers can be found on **pages E-22 to E-35**.

Summarizing the Evidence

During the final PAGAC meeting, each subcommittee chair was asked to prepare a summary of key findings for discussion by the Committee, using the plan outlined in Table E.1. Each subcommittee's summary report was to include information on the type and magnitude of evidence reviewed, the strength of the evidence, characteristics of the physical activity most likely to produce the outcome, any evidence of a dose response, and any evidence that being sedentary puts a person at high risk (see Table E.1A). To determine the overall strength of the evidence for major health and fitness outcomes and to evaluate the issue of dose response for these outcomes, subcommittees considered the types of studies that addressed each specific question (see Table E.1B) and the general quality of these

studies (e.g., design, sample size, statistical power, measurement methods, follow-up, adherence). For each major outcome, but not for each study, subcommittee chairs were asked to assign a strength of evidence — strong, moderate, weak — based on the evidence they included in their review chapters (see Table E.1C). Also, in assigning the strength of the evidence, subcommittees included factors that support a causal relation between physical activity and a specific outcome, such as evidence of favorable changes in biomarkers considered to be in the causal pathway or a significant dose-response relation.

Table E.1. Process for Summarizing the Science

A. Instructions to Subcommittee Chairs

- Only major outcomes to be considered in summary
- Types and amounts of evidence available for this outcome
- Strength of the evidence (strong, moderate, weak)
- Based on current science characteristics of activity most likely to produce this outcome
  - *Type: aerobic, resistance, other*
  - *Intensity: light, moderate, vigorous (include comment on walking)*
  - *Frequency: times per week*
  - *Duration; minutes per day/week*
  - *Amount: MET-hours per week (or other measure if appropriate)*
  - *Accumulation: multiple bouts during day*
- Any evidence of dose response for amount or intensity
- Any evidence that being very sedentary puts person at highest risk. If possible, quantify.

B. Types of Evidence

- **Type 1**
  - Randomized controlled trials (RCT) (or meta-analyses) without major limitations
- **Type 2**
  - 2a – RCTs (or meta-analyses) with important limitations
  - *2b – Non-randomized clinical trials*
- **Type 3**
  - 3a – Well-designed prospective cohort studies and case-control studies
  - *3b – Other observational studies, e.g., weak prospective cohort studies or case-control studies; cross-sectional studies or case series*
- **Type 4**
  - *Inadequate, very limited, or no data in population of interest. Anecdotal evidence or no/little clinical experience*

C. Strength of the Evidence

- Strong, consistent across studies and populations
- Moderate or reasonable, reasonably consistent
- Weak or limited, inconsistent across studies and populations

While deciding on a plan for summarizing the evidence, PAGAC members discussed the possible use of an evidence-based rating system designed for the development of evidence-based guidelines for medical practice, such as those adopted by the American College of Cardiology and the American Heart Association in 2006 (1). This approach was dismissed for several reasons. First, a full application of these methodologies did not apply to the PAGAC mission, which was to review and evaluate the science, not to provide practice guidelines or recommendations. Second, Committee members were concerned that the criteria used to evaluate evidence for the safe and effective use of medical interventions or therapies (such as drugs or medical devices) developed to treat disease are not readily applicable for evaluating the effects of lifestyle changes on chronic disease prevention, where standards of experimental design such as double blinding are exceptionally difficult, if not impossible.

The Committee also recognized that because of logistical, cost, and ethical issues, few RCTs have been conducted to link physical activity to reduced rates of chronic diseases. This situation is not very different from that linking other health-related behaviors to the prevention of clinical outcomes. A good example is cigarette smoking. For obvious ethical reasons, no one has conducted an RCT of the impact of starting cigarette smoking on health outcomes, such as lung cancer, chronic obstructive pulmonary disease, or coronary heart disease. A similar situation exists for the relation between saturated fat or trans-fatty acid intake and the prevention of coronary heart disease. Yet, the weight of evidence is believed to be so strong from observational studies that urging the public to stop smoking or reduce their intake of saturated fat or trans-fatty acids are major components of national public health campaigns. Similarly, data linking physical activity to lower rates of all-cause mortality, coronary heart disease, stroke, and type 2 diabetes based on observational studies are strong and, further, are supported by RCTs showing significant favorable effects on key biomarkers for these conditions. The result of these deliberations by the PAGAC was the development of the evidence rating criteria presented in Table E-1.

Selected PAGAC members were then asked to integrate the main conclusions from these subcommittee summaries under the headings of youth, adults, older adults, understudied populations, and adverse events. These summary conclusions were presented to PAGAC members, and each set of conclusions was discussed and edited. A final set of conclusions was developed using a consensus process.

Following the PAGAC meeting on February 28-29, 2008, the Committee prepared the following information, which summarizes the major conclusions of each committee. The sum of the evidence provided here for a wide range of health and fitness outcomes strongly supports the value of being physically active versus being sedentary throughout the lifespan.

Health Outcome: All-Cause Mortality
Types of studies? Type 3a – extensive
What is the nature of the association of physical activity (PA) with All-Cause Mortality? There is a clear inverse relationship between PA and all-cause mortality. Strength of evidence: Strong
What is the effect size? There is about a 30% risk reduction across all studies, comparing most with least active subjects. Strength of evidence: Strong
Is there any evidence for an effect of sex, age, or race/ethnicity? There is evidence that this association exists for both men and women, as well as for people both younger than age 65 years or 65 years of age and older. There is also evidence that this association exists for different race/ethnic groups. Strength of evidence: Sex = Strong, <65 & 65+ years = Strong, Race/Ethnicity = Reasonable
Is there a dose-response effect? There is an inverse dose-response relation for total volume of PA (i.e., total energy expenditure). The shape of the dose-response curve appears curvilinear in that larger risk decreases are seen at the lower end of the physical activity spectrum than at the upper end. There are limited data on an inverse dose-response relation for intensity, which is independent of its contribution to the total volume of PA (i.e., limited data suggest that vigorous physical activity may be associated with further risk reduction compared with moderate-intensity activity when the total volume of energy expenditure is the same). Strength of evidence: Volume = Strong, Intensity = Limited
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) Data indicate at least 2 to 2.5 hours per week of moderate-to-vigorous physical activity are needed to see significantly lower risk (Strong). Data are primarily for aerobic leisure-time physical activity (LTPA) (Strong). There are also specific data showing that walking at least 2 hours per week is associated with significantly lower risk (Strong). Some evidence also indicates that all activities count (Reasonable) This amount — 2 to 2.5 hours per week of moderate-to-vigorous PA — does not represent a threshold level for risk reduction. The data consistently support a “some is good; more is better” message (Strong). Some data indicate that among populations where physical activity levels are likely to be low (e.g., middle-aged and older women; older men), significantly lower mortality rates are observed at levels less than 2 to 2.5 hours per week of moderate-to-vigorous PA (Limited).

Health Outcome: All-Cause Mortality (continued)
What is the evidence on accumulation? (Strength of evidence in parentheses) No direct data on multiple short bouts versus one long bout. However, indirect data come from epidemiologic studies showing an inverse association with total volume, where the PA is likely to be accumulated from activities of different (but unknown) durations (Reasonable).
What other unique comments should be made about the evidence of PA with this health outcome? (Strength of evidence in parentheses) The association of PA and all-cause mortality is independent of body mass index (Strong); this association is seen regardless of whether persons are normal weight, overweight, or obese (Reasonable).

Health Outcome: Cardiorespiratory Health
Types of studies? Type 3a – extensive for coronary heart disease (CHD), cardiovascular disease (CVD), and stroke Type 1 – extensive for hypertension, atherogenic dyslipidemia, and cardiorespiratory fitness
What is the nature of the association of PA with Cardiorespiratory Health? There is a clear inverse relation between PA and cardiorespiratory health (CHD, CVD, stroke, hypertension, and atherogenic dyslipidemia). The data imply relations with physical activity volume, with less information about intensity and none for frequency and duration per session for CVD clinical events. Physical activity improves cardiorespiratory fitness. Fitness has direct dose-response relations between intensity, frequency, duration, and volume. There is limited evidence for an accumulation effect. Strength of evidence: Strong
What is the effect size? There is a 20% to 35% lower risk for CVD, CHD, and stroke. Participation in aerobic activity improves cardiorespiratory fitness in a dose-response fashion according to the frequency, duration, intensity, and total volume of the exposure. Percentage increases are highly dependent on fitness levels at baseline, sex, and age of the study population, and range from 4.5% with low-volume brisk walking to close to 20% with high-volume, high-intensity exercise training. Strength of evidence: Strong
Is there any evidence for an effect of sex, age, race/ethnicity? These associations exist for both men and women and individuals of all ages. There is no evidence for sex-specific, age-specific, or race/ethnic specific effects when volume is the exposure rather than relative intensity. Strength of evidence: Sex = Strong, Age = Strong, Race/Ethnicity = Reasonable

Health Outcome: Cardiorespiratory Health (continued)
Is there a dose-response effect? There is a dose-response relation for CVD and CHD. There appears to be an L-shaped relation for stroke. The relations are all most closely related to volume, with less information about intensity and none for frequency and duration of sessions. Minutes per week is a less powerful parameter of dose response than is volume per week (kilocalories per week; MET-minutes per week). Physical activity improves cardiorespiratory fitness. For fitness there are direct dose-response relations between intensity, frequency, duration, and volume. There is mixed evidence for an accumulation effect. Strength of evidence: Strong
What is an effective physical activity dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) At least 800 MET-minutes per week or 12 miles per week (moderate and/or vigorous); includes specific data on brisk walking at least 2 hours per week (Strong). Data are primarily for aerobic LTPA (Strong) on top of usual activities of daily living. Risk reductions start to be seen at levels below 800 MET-minutes per week or 12 miles week (Reasonable).
What is the evidence on accumulation? Very limited and mixed data available and mostly for cardiorespiratory fitness. Sparse evidence for other CRH outcomes. Strength of evidence: Limited
What other unique comments should be made about the evidence of PA with this health outcome? Notable lack of evidence for frequency, duration, and intensity effects on hard cardiorespiratory health outcomes (CVD, CHD, and stroke) and lack of trial evidence for duration and intensity for cardiovascular risk factors (hypertension and atherogenic dyslipidemia).

Health Outcome: Metabolic Health
Types of studies? Type 2a (small body) and 3a (reasonable body) for type 2 diabetes Type 3a/b (reasonable body) for metabolic syndrome
What is the nature of the association of PA with Metabolic Health? There is a clear inverse relationship between PA and metabolic health, including the prevention of type 2 diabetes and metabolic syndrome. Strength of evidence: Strong
What is the effect size? There is a 30% to 40% lower risk for type 2 diabetes and metabolic syndrome in at least moderately active people compared to sedentary individuals. Strength of evidence: Strong

Health Outcome: Metabolic Health (continued)
Is there any evidence for an effect of sex, age, race/ethnicity? This association exists for both men and women, as well as for older and younger persons. There is reasonable evidence to show the association exists for different race/ethnic groups. Strength of evidence: Sex = Strong, Age = Strong, Race/Ethnicity = Reasonable
Is there a dose-response effect? There is an inverse dose-response association between volume of PA and the development of metabolic syndrome as well as the development of type 2 diabetes. Strength of evidence: Reasonable
What is an effective PA dose regarding: mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) Data indicate at least 120 to 150 minutes per week of moderate-to-vigorous PA is needed to see significantly lower risks (Strong). Data are primarily for aerobic LTPA (Strong). Risk reductions start to be seen at levels below the 120 to 150 minutes per week level of PA (Reasonable).
What is the evidence on accumulation? There are limited data on accumulation.
What other unique comments should be made about the evidence of PA with this health outcome? There is limited evidence that PA helps to control HbA1c levels. There is very limited evidence that PA helps to prevent gestational diabetes.

Health Outcome: Energy Balance
Types of studies? ***Weight maintenance (less than 3% change in body weight):*** Type 1, 2, 3a ***Weight loss (at least 5% loss of body weight):*** Type 1 ***Weight maintenance following weight loss:*** Type 2 ***Abdominal obesity:*** Type 1, 2

Health Outcome: Energy Balance (continued)
What is the nature of the association of PA with Energy Balance? (Strength of evidence in parentheses) ***Weight maintenance (less than 3% change in weight):*** There is a favorable and consistent effect of aerobic PA on achieving weight maintenance (Strong). The evidence is less consistent for resistance training, in part, because of the compensatory increase in lean mass (Moderate), and the smaller volumes of exercise employed. ***Weight loss (at least 5% loss of weight):*** The amount of weight lost due to PA (alone) is dependent on the volume of activity, and few studies have used a volume of PA large enough to achieve a 5% weight loss. If an isocaloric diet is maintained throughout the PA intervention, weight loss is similar to what is observed for dietary interventions and clearly exceeds 5% (Strong). ***Weight maintenance following weight loss:*** PA promotes less weight regain after a period of significant weight loss (Moderate). ***Abdominal obesity:*** A decrease in total abdominal adiposity and intra-abdominal adiposity is associated with aerobic PA (Moderate to Strong). The effect is less well described for resistance training (Weak).
What is the effect size? (Strength of evidence in parentheses) ***Weight maintenance (less than 3% change in weight):*** Aerobic PA has a consistent effect on achieving weight maintenance (Strong); resistance training has a moderate effect (Limited). ***Weight loss (at least 5% loss of weight):*** PA alone has no effect on achieving a 5% weight loss, except at very large volumes of PA or when an isocaloric diet is maintained throughout the PA intervention (Strong). ***Weight maintenance following weight loss:*** Aerobic PA has a reasonably consistent effect on weight maintenance following weight loss (Moderate). ***Abdominal obesity:*** Aerobic PA has a consistent effect on total abdominal adiposity and a smaller effect on intra-abdominal adiposity (Strong). Resistance training has a small and less consistent effect on total abdominal and intra-abdominal adiposity (Limited).
Is there any evidence for an effect of sex, age, race/ethnicity? There is some evidence that the amount of physical activity needed to maintain a constant weight differs between men and women and increases with age. However, the evidence is not sufficient to recommend differential physical activity regimens based on sex or on age alone. The paucity of literature, particularly of the stronger longitudinal cohort or randomized controlled intervention study designs, makes it unwise to draw conclusions as to whether the physical activity recommendation should differ by racial/ethnic or socioeconomic status groups. Strength of evidence: Sex = Weak, Age = Weak, Race/Ethnicity = Weak

Health Outcome: Energy Balance (continued)
Is there a dose-response effect? (Strength of evidence in parentheses) ***Weight maintenance (less than 3% change in body weight):*** There is no evidence for a dose-response effect for PA and weight maintenance, as it has not been specifically tested. ***Weight loss:*** There is a clear, consistent dose-response effect of aerobic PA on weight loss (Strong). ***Weight maintenance following weight loss:*** A dose-response is present — those performing the larger volumes of aerobic PA had less weight regain (Moderate). ***Abdominal obesity:*** Larger, well-designed studies report a dose-response relationship for aerobic PA related to abdominal obesity measures (Moderate).
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) ***Weight maintenance (less than 3%):*** The optimal amount of physical activity needed for weight maintenance over the long-term is unclear. However, there is clear evidence that physical activity provides benefit for weight stability. There is a great deal of inter-individual variability with physical activity and weight stability, and many persons may need more than 150 minutes of moderate-intensity activity per week to maintain weight. Data from recent well-designed RCTs lasting up to 12 months indicate that aerobic physical activity performed to achieve a volume of 13 to 26 MET-hours per week is associated with approximately a 1% to 3% weight loss, which is generally considered to represent weight stability. Thirteen MET-hours per week is approximately equivalent to walking at 4 miles per hour for 150 minutes per week or jogging at 6 miles per hour for 75 minutes per week. ***Weight loss (at least 5% weight loss):*** There are clear, consistent data that a large volume of physical activity is needed for weight loss in the absence of concurrent dietary changes. Physical activity equivalent to 26 kilocalories per kilogram (1,560 MET-minutes) or more per week is needed for weight loss of 5% or greater (Moderate); less amounts of weight loss are seen with smaller amounts of physical activity. This relatively high volume of physical activity is equivalent to walking about 45 minutes per day at 4 miles per hour or about 70 minutes per day at 3 miles per hour, or jogging 22 minutes per day at 6 miles per hour. ***Weight maintenance following weight loss:*** PA equivalent to 30 kilocalories per kilogram per week or more. This is equivalent to walking about 50 minutes per day at about 4 miles per hour or 80 minutes per day at about 3 miles per hour, or jogging for 25 minutes per day at 6 miles per hour (Moderate).

Health Outcome: Energy Balance (continued)
Abdominal obesity: Aerobic physical activity in the range of 13 to 26 kilocalories per kilogram per week results in decreases in total and abdominal adiposity that are consistent with improved metabolic function. Thirteen MET-hours per week is approximately equivalent to walking at 4 miles per hour for 150 minutes per week or jogging at 6 miles per hour for 75 minutes per week. However, larger volumes of physical activity (e.g., 42 kilocalories per kilogram per week) result in decreases in intra-abdominal adipose tissue that are 3 to 4 times that seen with 13 to 26 kilocalories per kilogram per week of physical activity.
What is the evidence on accumulation? (Strength of evidence in parentheses) ***Weight maintenance (less than 3%):*** Accumulation of energy expenditure due to PA is what is important to achieving energy balance* (Strong). Accumulation of PA can be obtained in short multiple bouts or one long bout to meet PA expenditure goals for weight maintenance (Moderate). ***Weight loss (at least 5% weight loss):*** There is evidence that accumulation of PA independent of distribution of PA bouts is what is important for weight loss (Limited); however, it is difficult accumulate large volumes of PA without concentrated bouts. ***Weight maintenance following weight loss:*** There is reasonable evidence that accumulation of PA independent of distribution of bouts is what is important for weight stability following weight loss (Limited); however, it is difficult accumulate large volumes of PA without concentrated bouts. ***Abdominal obesity:*** This has not been tested.
What other unique comments should be made about the evidence of PA with this health outcome? *NOTE: It is important to note that the role of energy intake (diet) must be considered in any discussion of physical activity and weight control. Weight loss in excess of 5% can be achieved with large volumes of physical activity. However, a more predictable weight loss occurs when energy intake is held constant during a physical activity intervention.

Health Outcome: Musculoskeletal Health
Types of studies? ***Bone:*** Type 3a: fractures Type 1, 2a: bone density ***Joint:*** Type 3a: prevention and/or promotion of osteoarthritis (OA) Type 1: improvement of OA, rheumatoid arthritis (RA), and fibromyalgia ***Muscular:*** Type 1: muscle strength

Health Outcome: Musculoskeletal Health (continued)
What is the nature of the association of PA with Musculoskeletal Health? (Strength of evidence in parentheses) ***Bone:*** There is an inverse association of PA with relative risk of hip fracture (Moderate) and vertebral fracture (Weak). Increases in exercise training can increase, or minimize the decrease, in spine and hip bone mineral density (BMD) (Moderate). ***Joint:*** In the absence of a major joint injury, there is no evidence that regular moderate PA promotes the development of OA (Moderate). Participation in low/moderate levels of PA may provide a mild degree of protection against the development of OA (Weak, Limited). Participation in moderate-intensity, low-impact PA has disease-specific benefits (pain, function, quality of life, and mental health) for people with OA, RA, and fibromyalgia (Strong). PA may delay the onset of disability in people with OA (Weak). ***Muscular:*** Increases in exercise training enhance skeletal muscle mass, strength, power, and intrinsic neuromuscular activation (Strong).
What is the effect size? (Strength of evidence in parentheses) ***Bone:*** Risk reduction of hip fracture is 36% to 68% at the highest level of PA (Moderate). The magnitude of effect of PA on BMD is 1% to 2% (Moderate). ***Joint:*** Risk reduction of incident OA for various measures of walking ranges from 22% to 83% (Weak). Among adults with osteoarthritis, pooled effect sizes (ES) for pain relief are small to moderate (ES = 0.25 to 0.52); for function and disability ES are small (function ES = 0.14 to 0.49, disability ES = 0.32 to 0.46) (Strong). ***Muscular:*** The magnitude of the effect of resistance types of PA on muscle mass and function is highly variable and dose-dependent (Strong).
Is there any evidence for an effect of sex, age, race/ethnicity? (Strength of evidence in parentheses) ***Bone:*** There is evidence for a lower relative risk of hip fracture in older women and men; the evidence is more consistent in women (Moderate). Benefits of PA on BMD have been found to occur in premenopausal women, postmenopausal women, and adult men; the evidence is more consistent in women (Moderate). Information on race and ethnic specificity is lacking. ***Joint:*** Female sex and older age are established risk factors for incident OA (Strong), the evidence for race/ethnicity is equivocal (Weak). Male and female adults of any age with OA benefit from both aerobic and resistance exercise (Strong). Women may have a bigger benefit from resistance exercise, likely due to lower baseline muscular strength (Limited).

Health Outcome: Musculoskeletal Health (continued)
Muscular: Benefits are similar in men and women and pervasive across the life span (Strong), although the magnitude of the benefits may be attenuated in old age (Moderate). Information on race and ethnic specificity is lacking.
Is there a dose-response effect? (Strength of evidence in parentheses) ***Bone:*** There is evidence of a dose-response association of PA with hip fracture risk (Moderate). Dose-response effects have not been adequately tested for PA and BMD. ***Joint:*** High-level (elite, professional) athletes competing in high joint-loading sports (e.g., football, soccer, track and field) may have an increased risk of hip/knee OA (Strong). Dose-response effects have not been tested with regard to PA among adults with arthritis. ***Muscular:*** There is a dose-response with greatest gains in muscle mass and muscle strength experienced with higher-intensity protocols (Strong).
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) ***Bone:*** PA of 4 or more hours per week of walking, 2 to 4 hours per week of LTPA, 9 to 14.9 MET hours per week of PA, and and1 hour per week of PA have been associated with a 36% to 41% lower risk in hip fracture risk. Weight-bearing endurance and resistance types of PA (i.e., exercise training) are effective in promoting increases in BMD (moderate-to-vigorous intensity; 3 to 5 days per week; 30 to 60 minutes per session). Walking-only protocols found a benefit on spine BMD (Moderate). ***Joint:*** For adults with arthritis, benefits in pain, function, and disability were noted with programs averaging a total volume of 130 to 150 minutes per week: 30 to 60 minutes per session; 3 to 5 days per week; moderate intensity; low-impact (Strong). Both aerobic and muscle strengthening activities improve joint function and reduce pain. ***Muscular:*** Progressive, high-intensity (60% to 80% of 1 repetition maximum [1RM]) muscle-strengthening activities can preserve or increase skeletal muscle mass, strength, power, and intrinsic neuromuscular activation (Strong).

Health Outcome: Musculoskeletal Health (continued)
What is the evidence on accumulation? (Strength of evidence in parentheses) ***Bone:*** The effects of accumulation have not been tested in humans. ***Joint:*** One study of fibromyalgia patients supports equal benefits (improved function, well-being, disease activity) for 2 15-minute sessions per day and 1 30-minute session per day of moderate-intensity, low-impact aerobic exercise (Limited). ***Muscular:*** The effects of accumulation have not been tested in humans.
What other unique comments should be made about the evidence of PA with this health outcome? ***Bone:*** Individual RCTs support basic science findings that intensity of loading forces is a key determinant of the skeletal response. Studies of laboratory animals also suggest that multiple, short bouts of PA should have more favorable effects on bone than a single, longer bout of PA. ***Joint:*** Joint injuries and excess body mass are more important risk factors for incident OA than sports/PA participation (Consistent, Strong). ***Muscular:*** Endurance types of PA do not increase muscle mass, but may attenuate the rate of loss with aging and preserve function (Moderate).

Health Outcome: Functional Health
Types of studies? ***Functional Health:*** Type 3a, Type 1 ***Falls:*** Type 1
What is the nature of the association of PA with Functional Health? (Strength of evidence in parentheses) ***Functional Health:*** There is observational evidence that mid-life and older adults who participate in regular PA have reduced risk of moderate/severe functional limitations and role limitations (Moderate to Strong). In older adults with existing functional limitations, there is fairly consistent evidence that regular PA is safe and has a beneficial effect on functional ability (Moderate); however, there is currently little or no experimental evidence in older adults with functional limitations that PA maintains role ability or prevents disability.

Health Outcome: Functional Health (continued)
Falls: In older adults at risk for falls, there is consistent evidence that regular PA is safe and reduces risk of falls (Strong).
What is the effect size? (Strength of evidence in parentheses) ***Functional Health:*** There is about a 30% risk reduction for the prevention or delay in function and/or role limitations with PA (Moderate to Strong). It is difficult to ascertain an effect size for the maintenance/improvements in functional ability due to the variety of outcomes measured. ***Falls:*** Older adults who participate in regular PA have about a 30% lower risk of falls (Strong).
Is there any evidence for an effect of sex, age, race/ethnicity? (Strength of evidence in parentheses) The association exists for both men and women with respect to preventing and maintaining or improving functional health and reducing risk of falls (Strong). The association exists for preventing functional limitations in middle-aged and older adults (Strong); the association for maintaining or improving functional heath is seen in older adults aged 65 years and older (Moderate); the association with falls reduction is seen in older adults at increased risk for falls (Strong). There is limited evidence to show an association exists for different race/ethnic groups for all outcomes (Weak).
Is there a dose-response effect? (Strength of evidence in parentheses) ***Functional Health:*** There appears to be a dose-response effect for PA in preventing or delaying function and/or role limitations, with greatest risk reduction seen with the highest levels of PA (Moderate). It is unclear whether there is a dose-response effect for PA in maintaining or improving functional ability, as this has not been tested. ***Falls:*** It is unclear whether there is a dose-response effect for PA in the reduction of falls in older adults, as this has not been tested.
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) ***Prevention:*** The most evidence of a dose response exists for walking activities (Strong); it is not possible at this point to ascertain dose of PA due to the nature of the study designs. ***Maintenance/Improvement:*** Evidence exists for exercise programs that include periods of 30 to 90 minutes of moderate-to-vigorous PA, 3 to 5 days per week, in which most of this time is devoted to aerobic and muscle-strengthening activities (with a smaller amount of time spent on other forms of activity, such as flexibility) (Moderate). When it was possible to determine the amount of time spent just on aerobic activity, studies usually varied from 60 minutes per week to 150 minutes per week (Moderate).

Health Outcome: Functional Health (continued)
Falls: Evidence exists for exercise programs that include 3 times per week of balance and moderate-intensity strengthening activities at 30 minutes per session, with additional encouragement to participate in moderate-intensity walking activities 2 or more times per week for 30 minutes a session (Strong). Evidence also exists for tai chi exercises (Moderate). It was difficult to ascertain an optimal PA pattern for tai chi. Tai chi studies ranged from 1 hour per week to 3 hours or more per week (Limited).
What is the evidence around accumulation? No evidence is available.
What other unique comments should be made about the evidence of PA with this health outcome? Relative intensity is important to consider, as fitness levels are very low in many older adults. It is important to increase exercise intensity and volume slowly to reduce adverse events, especially injuries.

Health Outcome: Cancer
Types of studies? Type 3a – extensive
What is the nature of the association of PA with Cancer? There is a clear inverse association between PA and prevention of breast and colon cancer. Strength of evidence: Strong
What is the effect size? There is about a 30% lower risk for colon cancer and about a 20% lower risk for breast cancer. Strength of evidence: Strong
Is there any evidence for an effect of sex, age, race/ethnicity? This association exists for both men and women for colon cancer, as well as for adults of different ages. There is reasonable evidence to show an association exists for different race/ethnic groups. Strength of evidence: Sex = Strong, Age = Strong, Race/Ethnicity = Reasonable
Is there a dose-response effect? There is a dose-response association between PA and the development of breast/colon cancer, but the shape of the curve is unclear. Strength of evidence: Reasonable
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) Data indicate at least 30 to 60 minutes per day of moderate-to-vigorous PA is needed to see significantly lower risks (Reasonable). Data are primarily for aerobic LTPA (Strong).

Health Outcome: Cancer (continued)
What is the evidence on accumulation? (Strength of evidence in parentheses) There is no information on accumulation of PA and cancer. However, the LTPA carried out by subjects in observational studies likely is accumulated from different activities of various, but unknown, duration (Limited).
What other unique comments should be made about the evidence of PA with this health outcome? (Strength of evidence in parentheses) There is a small body of Type 1 evidence for an association between improved quality of life and fitness in breast cancer survivors (Strong). There is growing evidence of a reduced risk of cancers of the endometrium and lung with increased physical activity (Reasonable).

Health Outcome: Mental Health
Types of studies? Type 1, 2a, 3a and 3b
What is the nature of the association of PA with Mental Health? There is clear evidence that PA reduces risk of depression and cognitive decline in adults and older adults. There is some evidence that PA improves sleep. There is limited evidence that PA reduces distress/well-being and anxiety. Strength of evidence: Depression and cognitive health = Strong; Sleep = Moderate; Distress/well-being and Anxiety = Limited
What is the effect size? There is about a 20% to 30% lower risk for depression, distress/well-being, and dementia. Strength of evidence: Strong
Is there any evidence for an effect of sex, age, race/ethnicity? Risk reduction has been observed for men and women of all ages, but few studies have directly compared results according to sex or age. Racial/ethnic minority groups have been underrepresented in most studies, but limited results from prospective cohort studies suggest that risk reduction among blacks and Hispanic/Latinos is similar to that among whites. Strength of evidence: Limited
Is there a dose-response effect? (Strength of evidence in parentheses) Reasonable evidence indicates a dose-response effect between PA and mental health. Moderate and high levels of physical activity are similarly associated with lower risk of depression and distress/well-being, compared to low levels of physical activity exposure, which is nonetheless more protective than inactivity or very low levels of physical activity (Moderate). There is insufficient evidence to determine whether there are dose-response relations with physical activity for anxiety, cognitive health, and sleep (Limited).

Health Outcome: Mental Health (continued)
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? Most evidence comes from PA programs of 3 to 5 days per week, 30 to 60 minutes per session and moderate to vigorous intensity. Most evidence comes from aerobic and multi-modal interventions (usually aerobic plus muscle strengthening activities). Only a few studies have manipulated and compared features of physical activity and their effects on mental health. Aerobic or resistance, and their combination, have positive effects. However, the minimal or optimal type or amount of exercise for mental health is not yet known Strength of evidence: Limited to Moderate
What is the evidence on accumulation? Mental health outcomes have not differed when physical activity was continuous or intermittent in nature, but studies have not directly compared single versus multiple sessions of similar amounts of physical activity in controlled studies. Hence, there is insufficient evidence to determine whether physical activity can be accumulated to achieve mental health benefits. Strength of evidence: Limited
What other unique comments should be made about the evidence of PA with this health outcome? Positive findings from initial studies suggest that physical activity and exercise might reduce the onset, progression, or adverse impact of central nervous system disorders other than dementia that contribute to disability and mortality risk, such as multiple sclerosis and Parkinson's disease. Benefits of physical activity may also extend to other aspects of mental health that are important contributors to overall quality of life, such as self-esteem and feelings of energy/fatigue. Sufficient evidence exists to encourage more study in these areas, but presently not enough studies are available to draw conclusions about how the effects of physical activity or exercise may differ according to types of people or types and amounts of physical activity.

Health Outcome: Youth
Types of studies? ***Physical Fitness***: Type 1, 2a, 2b, 3a, 3b: Cardiorespiratory Type 2b: Muscular Strength ***Body Mass and Composition***: Type 1, 2b, 3a, 3b ***Cardiovascular and Metabolic Health***: Type 1, 2b, 3a, 3b ***Bone Health***: Type 1, 3a ***Mental Health:*** Type 1, 2b, 3a, 3b: Depression Type 1, 3b: Anxiety

Health Outcome: Youth (continued)
What is the nature of the association of PA with health for Youth? (Strength of evidence in parentheses) ***Physical Fitness***: There is a clear, positive association between PA and cardiorespiratory fitness and muscular strength (Strong). ***Body Composition***: There is a clear, positive association between PA and favorable body composition (Strong). ***Cardiovascular and Metabolic Health***: There is a clear, positive association between PA and cardiovascular and metabolic health (Strong). ***Bone Health***: There is a clear, positive association between PA and bone health (Strong). ***Mental Health:*** There appears to be an association between PA and reduced symptoms of depression (Moderate), anxiety (Weak), and higher self esteem (Limited).
Is there a dose-response effect? ***Cardiovascular and Metabolic Health***: There appears to be a dose-response relationship; however, the precise pattern of this relationship has not been determined. ***Other Outcomes***: Either evidence is insufficient or the varying methodologies and insufficient numbers of intervention trials preclude inferences about dose-response patterns for the remainder of the outcomes. Dose-response studies are needed.
Is there any evidence for an effect of sex, age, race/ethnicity? (Strength of evidence in parentheses) ***Physical Fitness***: The association between PA and cardiorespiratory fitness and muscle strength exists for both boys and girls, as well as in children and adolescents (Strong). The research is not adequate to draw conclusions about race/ethnicity. ***Body Composition***: The research is not adequate to draw conclusions about age, biological maturity, and race/ethnicity for body mass and composition. ***Cardiovascular and Metabolic Health***: Very little is known about the effects of sex, age, biological maturity, and race/ethnicity on the relationship of PA to cardiovascular and metabolic health.

Health Outcome: Youth (continued)
Bone Health: This association exists for both boys and girls, and is influenced by age and developmental status (Strong). The window of opportunity appears to be in puberty and pre-menarchal years (Moderate). The research is not adequate to draw conclusions about race/ethnicity. ***Mental Health***: The research is not adequate to draw conclusions about sex, age, maturity, and race/ethnicity on the relationship of PA to mental health.
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? ***Overall Conclusion***: Important health and fitness benefits can be expected by most children and youth who participate daily in 60 or more minutes of moderate-to-vigorous physical activity (Strong). ***Physical Fitness***: Vigorous aerobic activity 3 or more days per week significantly improves cardiorespiratory fitness. Resistance training 2 or 3 days per week significantly improves muscular strength. ***Body Composition***: Reductions in overall adiposity and visceral adiposity with exposure to regular moderate-to-vigorous PA 3 to 5 days per week for 30 to 60 minutes have been observed. ***Cardiovascular and Metabolic Health:*** Vigorous aerobic activity 3 or more days per week significantly improves cardiovascular and metabolic health. ***Bone Health***: Targeted weight-loading activities that simultaneously influence muscular strength, done 3 or more days per week, significantly improve bone mineral content and density.
What other unique comments should be made about the evidence of PA with this health outcome? ***Overall Conclusions***: It is important to minimize the potential risks of overtraining and injuries. A wide-range of developmentally appropriate activities for children should be chosen.

Health Outcome: Understudied Populations
Types of studies? Type 1, 2a, 2b
What is the nature of the association of PA with health for people with disabilities? Consistency of evidence supports the use of PA to improve key health outcomes in people with physical and cognitive disabilities. Strength of evidence: ***Physical Disability***: The strongest evidence is found under the categories of cardiorespiratory, musculoskeletal, and mental health. ***Cognitive Disability***: The strongest evidence is found under the categories of functional health and mental health.
What is the effect size? N/A Level of evidence was based on number of significant trials reporting positive outcomes. Definition of strength of evidence: ***Strong***: At least 75% of reviewed trials significant. ***Moderate***: 50% to 74% of reviewed trials significant. ***Limited***: Up to 49% of reviewed trials significant. Strength of evidence: ***Physical Disability***: Strong for cardiorespiratory health, musculoskeletal health, and mental health; Moderate for functional health. ***Cognitive Disability***: Strong for functional health and mental health; Moderate for cardiorespiratory health, musculoskeletal health, and healthy weight and metabolic health.
Is there any evidence for an effect of sex, age, race/ethnicity? No
Is there a dose-response effect? No direct data on dose response are available.
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? (Strength of evidence in parentheses) The majority of the studies included exercise doses typically used in studies with the general population: Intensity: 50% or more of heart rate reserve or VO_{2peak} (Strong) Frequency: 3 to 5 days per week (Strong) Duration: 30 to 60 minutes (Strong)

Health Outcome: Understudied Populations (continued)
What is the evidence on accumulation? No direct data are available on multiple bouts versus one long bout.
What other unique comments should be made about the evidence of PA for people with disabilities? PA is relatively safe and effective for people with disabilities and can improve several key health outcomes. Very few serious adverse events have been reported (1.15% exercise versus 0.60% for controls).

Health Outcome: Adverse Events
Types of studies? Types: 1, 3a, 4
What is the nature of the association of PA with Adverse Events? (Strength of evidence in parentheses) The risk of musculoskeletal injuries is lower for non-contact (e.g., walking) and limited contact (e.g., baseball) activities than for contact (e.g., basketball) and collision (e.g., football) activities (Strong). The usual dose of regular physical activity is directly related to the risk of musculoskeletal injury (Strong) and inversely related to the risk of sudden adverse cardiac events (Strong). The risk of musculoskeletal injuries and sudden cardiac adverse events is directly related to the size of the difference between the usual dose of activity and the new or momentary dose of activity (Strong). The most consistently reported risk factor for musculoskeletal injuries (Strong) and sudden cardiac adverse events (Strong) is inactivity and low fitness.
Is there any evidence for an effect of sex, age, race/ethnicity? Older people are more susceptible to activity-related musculoskeletal injuries (Weak). Females are more likely than males to suffer musculoskeletal injuries, but the difference appears to be due to lower fitness (Weak). Differences in the risk of musculoskeletal injuries among different race/ethnicity groups do not appear to be marked but have been infrequently studied (Weak).
What is an effective PA dose regarding mode, duration, intensity, and frequency that is supported by the evidence? A series of small increases in activity each followed by a period of adaptation will cause fewer adverse events than will larger or more frequent increases in activity (Weak). The incidence of adverse events caused by moderate-intensity physical activity appears to be low (Weak).

Health Outcome: Adverse Events (continued)
What other unique comments should be made about the evidence of PA and Adverse Events? The benefits of regular physical activity far outweigh the risks of adverse events for outcomes that encompass a broad spectrum of medical maladies such as all-cause mortality (Strong), functional health (Moderate), and medical expenditures (Strong). Appropriate clothing, gear, and equipment, as well as a safe environment, reduce the risk of adverse events.

Integrating the Evidence: Questions and Answers About the Health Benefits of Physical Activity

After it summarized the evidence linking physical activity to a variety of health outcomes and populations, the PAGAC's next step was to integrate this evidence in the following questions and responses. Because the primary charge to the PAGAC was to review the scientific evidence to inform the development of public health physical activity guidelines and policy for Americans, the questions and answers primarily focus on major outcomes and on issues involving dose response, particularly the minimum amount, intensity, duration, and frequency associated with health benefits, as well as whether additional health benefits are observed at higher levels of physical activity.

Overall Benefits of Physical Activity

Q-1. Does existing evidence indicate that people who are habitually physically active have better health and a lower risk of developing a variety of chronic diseases than do inactive people?

R-1. Yes. Very strong scientific evidence based on a wide range of well-conducted studies shows that physically active people have higher levels of health-related fitness and a lower risk profile for developing a number of disabling medical conditions than do people who are inactive. In **children and youth** major benefits supported by strong evidence include enhanced cardiorespiratory and muscular fitness, cardiovascular and metabolic health biomarkers, bone health, body mass and composition. Less strong evidence supports selected measures of mental health. In **adults and older adults** strong evidence demonstrates that, compared to less active counterparts, more active men and women have lower rates of all-cause mortality, coronary heart disease, high blood pressure, stroke, type 2 diabetes, metabolic syndrome, colon cancer, breast cancer, and depression. Strong evidence also supports the conclusion that, compared to less active people, physically active adults and older adults exhibit a higher level of cardiorespiratory and muscular fitness, have a healthier body mass and composition, and a biomarker profile that is more favorable for the preventing cardiovascular disease and type 2 diabetes and enhancing bone health. Modest

evidence indicates that physically active adults and older adults have better quality sleep and health-related quality of life. For **older adults**, strong evidence indicates that being physically active is associated with higher levels of functional health, a lower risk of falling, and better cognitive function.

Time course for benefits. Strong evidence indicates that increases in cardiorespiratory and muscular fitness and improvements in various biomarkers that appear in the causal pathways between increased activity and favorable clinical outcomes and in some clinical outcomes, such as a decrease in depression, frequently occur in weeks or a few months in response to a sustained increase in moderate- to vigorous-intensity activity. The time course for a decrease in occurrence of various chronic disease clinical outcomes has not been established but appears to require longer exposure to an increased level of activity.

Q-2. What does the evidence indicate about dose of physical activity that is most likely to provide many of the benefits indicated in R-1?

R-2. Current science, inter-individual differences in the biological responses to specific activity regimens and the wide variety of benefits provided by being physically active do not allow a single, highly precise answer to this question. However, as a starting place for overall public health benefit, data from a large number of studies evaluating a wide variety of benefits in diverse populations generally support 30 to 60 minutes per day of moderate- to vigorous-intensity physical activity on 5 or more days of the week. For a number of benefits, such as lower risk for all-cause mortality, coronary heart disease, stroke, hypertension, and type 2 diabetes in adults and older adults, lower risk is consistently observed at 2.5 hours per week (equivalent to 30 minutes per day, 5 days per week) of moderate- to vigorous-intensity activity. The amount of moderate- to vigorous-intensity activity most consistently associated with significantly lower rates of colon and breast cancer and the prevention of unhealthy weight gain or significant weight loss by physical activity alone is in the range of 3 to 5 hours per week.

By converting the intensity and duration of various aerobic activities into MET-minutes or MET-hours (intensity in METs x duration), it is possible to combine activities of different types and intensities into a single measure of amount of activity. For many studies, the amount of moderate- and vigorous-intensity activity associated with significantly lower rates of disease or improvements in biomarkers and fitness is in the range of 500 to 1,000 MET-minutes per week. An adult can achieve a target of 500 MET-minutes per week by walking at about 3.0 miles per hour for approximately 150 minutes per week (7.5 miles), walking faster at 4.0 miles per hour for 100 minutes (6.6 miles) or jogging or running at 6 miles per hour for about 50 minutes per week (5.0 miles). To achieve 1,000 MET-minutes per week, these amounts of activity would need to be doubled. These MET-minutes per week targets also can be achieved by performing various combinations of activities of

different intensities and durations (See Table D.3 in ***Part D: Background*** and its accompanying text for more details).

Very limited data are available on dose response in children and youth, but strong evidence indicates that better fitness and health outcomes are observed when 60 minutes of moderate- to vigorous-intensities activity of various types is accumulated throughout the day.

Q-3. Is there evidence that performing more than 30 minutes per day of moderate- to vigorous-intensity activity on most days confers greater health benefits for some health outcomes?

R-3. Yes. For a variety of health and fitness outcomes, including chronic disease prevention, improvement of various disease biomarkers and the maintenance of a healthy weight, reasonably strong evidence demonstrates that amounts of moderate-to vigorous-intensity activity that exceed 150 minutes per week are associated with greater health benefits. However, in a number of studies where such a dose response is observed in preventing chronic disease or reducting all-cause mortality, the relation appears to be curvilinear. This means that the absolute increase in benefits becomes less and less for any given increase in the amount of physical activity. An example of a curvilinear dose-response relation between the relative risk of all-cause mortality and the amount of moderate-to-vigorous physical activity in hours per week is displayed in Figure G1.3 (***Part G. Section 1: All-Cause Mortality).*** As stated in that chapter, "On average, compared to less than 0.5 hours per week of moderate-to-vigorous physical activity, engaging in approximately 1.5 hours per week in such activity is associated with about a 20% reduction in risk of all-cause mortality during follow-up. Additional amounts of physical activity are associated with additional reductions, but at smaller magnitudes, such that approximately 5.5 hours per week is required to observe a further 20% reduction in risk (i.e., approximately 7.0 hours per week is associated with approximately 40% reduction in risk compared with less than 0.5 hours per week)." A somewhat similar curvilinear relation appears to exist between amounts of moderate to vigorous activity and risk of coronary heart disease. The added value of higher amounts of activity for helping maintain a healthy body weight is discussed in the responses to Questions 15 to 17.

Q-4. For people who are physically inactive or unfit, does current science support the concept that some activity is better than none?

R-4. PAGAC members spent substantial time considering this question and concluded that for otherwise healthy sedentary individuals, some physical activity is better than none. The least active in the population generally have the highest risk for various negative health consequences and the most to gain from becoming more active. Increasing evidence suggests that performing activity in amounts of no more than about 1 hour per week at an intensity that is moderate relative to the person's capacity will provide small increases in cardiorespiratory and muscular fitness. In

some studies, this amount of activity is associated with lower risk of all-cause mortality and the incidence of coronary heart disease. At this lower amount and intensity of activity, the benefits usually are less than that observed with greater amounts of activity, and studies are much less consistent about the nature and magnitude of these benefits. Nevertheless, the dose-response curves for the major health benefits clearly indicate an inverse relation between the dose of activity and rate of disease. Although the minimum amount of activity needed to produce a benefit cannot be stated with certainty, nothing would suggest a threshold below which there are no benefits. Therefore, for inactive adults any increase appears better than none. To achieve benefits for various health outcomes equivalent to those achieved by their more active peers, very inactive adults will need to progress gradually to higher amounts and intensities of activity.

Q-5. If physical activity is performed at a vigorous intensity, are the health outcomes greater than what has been observed with moderate-intensity activity?

R-5. Yes. For some favorable health and fitness outcomes strong evidence indicates that an increase in intensity is associated with greater improvements compared to those observed with moderate-intensity activity. For example, when a similar amount of activity is performed per session, such as walking 3 miles per day, participants who walk faster have a greater increase in cardiorespirtaory fitness than those who walk more slowly. One problem in interpreting data that compares the benefits of moderate versus vigorous activity in many observational and experimental studies is that along with a difference in intensity between study groups, the amount or volume of activity performed also differs. For example, if participants in two groups are physically active 30 minutes per day 5 days per week, but one group walks at 3 miles per hour and the other jogs at 6 miles per hour, both the intensity and the amount of activity performed will be different between the two groups. In this case it is not possible to tell for sure whether differences in health or fitness outcomes between the 2 groups are due to the difference in the intensity or the amount of activity performed, or both. It is important to recognize that the rate of energy expenditure goes up quite rapidly with increases in intensity for some types of activity, such as going from walking to jogging or running.

As people consider increasing their physical activity to high doses of vigorous-intensity activity with the primary goal of achieving favorable health outcomes, they need to be aware that such increases may accelerate the injury rate disproportionate to the benefits accrued. This appears to be especially true for people who have been inactive for extended periods and who then rapidly increase the amount and/or intensity of activity they perform.

Q-6. Is there evidence that the frequency of physical activity sessions influences health and fitness outcomes independent of the amount of activity performed?

R-6. Very limited published research has systematically evaluated health or fitness benefits in response to different frequencies of activity sessions per week when the amount of activity is held reasonably constant. In experimental studies, comparisons have been made between 2 versus 3 or more sessions per week for both aerobic and resistance activity, but the amount of activity performed increased as the number of sessions increased so it is not possible to separate out the effects of increasing the session frequency from the effects of increasing the amount. Most of the data from prospective cohort studies with outcomes of all-cause mortality or chronic disease morbidity and mortality do not provide information about frequency of activity independent of intensity and amount, but the very limited data available indicate that when activity amount is controlled for, the effect of session frequency is not significant.

When many adults with sedentary occupations reach the range of 500 to 1,000 MET-minutes per week of leisure-time physical activity (LTPA), it is very likely that this activity is the result of multiple sessions performed during the week. Experimental studies that show significant improvements in health-related outcomes typically feature session frequencies ranging between 3 and 5 times per week. Also, as the response to the Question 7 demonstrates, a growing, but still limited, body of evidence indicates that multiple short bouts (10 or more minutes) per day of aerobic activity produces improvements in cardiorespiratory fitness and selected cardiovascular disease (CVD) biomarkers similar to that obtained with a single bout of equal total duration and intensity.

Overall, one interpretation of the existing data is that for health and fitness benefits, the frequency of activity is much less important than the amount or intensity. Many experimental studies since 1995 have demonstrated beneficial effects of 120 to 150 minutes per week of moderate- or vigorous-intensity activity usually performed during 3 to 5 sessions per week, so we know that this frequency of activity is effective. Only limited data are available comparing the benefits from just one or two sessions per week with multiple sessions spread throughout the week with activity amount and intensity held constant. Again, while very limited data are available from direct comparisons, the rate of certain types of adverse events (e.g., joint irritation, muscle soreness) may be lower when performing a similar amount and intensity of activity but during more sessions per week.

Q-7. Is there evidence that physical activity can be accumulated throughout the day for some health and fitness outcomes?

R-7. The concept of accumulation refers to performing multiple short bouts of physical activity throughout the day. Some scientific evidence of moderate strength suggests that accumulating 30 or more minutes per day of moderate- to vigorous-intensity

aerobic activity throughout the day in bouts of 10 minutes or longer produces improvements in cardiorespiratory fitness. Limited data indicate that accumulated short bouts improve selected CVD biomarkers in a manner generally similar to that observed when activity of a similar amount and intensity is performed in a single bout of 30 or more minutes. These experimental studies have primarily evaluated the effects of multiple short bouts of 8 to 10 minutes duration versus longer bouts of 30 to 40 minutes and have not provided data on numerous shorter bouts (e.g., 30 1-minute bouts per day). Data on the effects of accumulating activity involving multiple short bouts for the prevention of major clinical outcomes, such as all-cause mortality, CVD, diabetes, and selected cancers, are very limited because of the type of data collected from questionnaires used in most prospective observational studies. Using data from these questionnaires, it has not been possible to precisely differentiate between activities conducted in a single, long bout versus those conducted in multiple, short bouts over the day. Prospective cohort studies with clinical outcomes have tended to present their data according to categories of the total amount of activity performed, and this total amount is likely to be accumulated from different activities of varying, but unknown durations and frequencies, over the course of the day.

Q-8. Is there evidence that performing bouts of walking as a frequent routine is associated with positive health effects?

R-8. Yes. Strong evidence shows that a regimen of brisk walking provides a number of health and fitness benefits for adults and older adults. For example, women in the United States who walk 2 to 3 hours per week have a significantly lower risk of all-cause mortality and cardiovascular disease than do women who report no or very little walking. Also, for people walking for equivalent amounts of time, a faster pace is associated with a lower risk of cardiovascular disease, type 2 diabetes, and all-cause mortality. Strong evidence also shows that frequent bouts of walking increase cardiorespiratory fitness, especially in people who have been performing little activity on a regular basis. Limited to moderate evidence suggests that walking helps to maintain bone density and reduce fractures over time, especially in women, and helps to maintain joint health and functional ability in adults and older adults.

Q-9. What does the scientific evidence indicate about the pattern of physical activity that is most likely to produce the fewest adverse medical events while providing health benefits?

R-9. Much of the research that addresses this question has evaluated the risk of musculoskeletal injuries or sudden cardiac death during vigorous physical activity (e.g., jogging, running, competitive sports, military training) with few well-conducted studies evaluating the risk during moderate-intensity activity intended primarily to improve health. 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, which are already popular in the United States, are activities with the lowest injury rates. Risk of musculoskeletal injury during activity increases with the total volume of activity (e.g., MET-hours per week). Intensity, frequency, and duration of activity all contribute to the risk of musculoskeletal injuries but their relative contributions are unknown. For sudden cardiac adverse events, intensity appears to be more important than frequency or duration. The limited data that do exist for medical risks during moderate-intensity activity indicate that the risks are very low for activities like walking and that the health benefits from such activity outweigh the risk.

Q-10. What does the scientific evidence say about actions that can be taken to reduce the risk of injury during physical activity?

R-10. Research with a variety of populations and methods indicates that injuries are more likely when people are more physically active than usual. The key point to remember, however, is that when individuals do more activity than usual, 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. Although the safest method of increasing one's physical activity has not been empirically established, 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, has a low risk of musculoskeletal injury and no known risk of sudden severe cardiac events.

For people with stable activity habits, risk of injury is directly related to the total volume of activity performed. Other things being equal, people who are very physically active are more likely to incur an activity-related injury than people who are active to a lesser degree. Some evidence suggests, however, that even though more active people are more likely to incur a physical activity-related injury they may suffer fewer overall injuries because they are less likely to be injured in other settings such as at work or around the home.

Q-11. Is there evidence regarding who should see a physician or have a medical examination before increasing the amount or intensity of physical activity they perform?

R-11. The protective value of a medical consultation for persons with or without chronic diseases who are interested in increasing their physical activity level is not established. No evidence is available to indicate that people who consult with their medical provider receive more benefits and suffer fewer adverse events than people who do not. 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.

Q-12. What are the major health benefits provided by an increase in aerobic (endurance) activity?

R-12. Aerobic activity of moderate to vigorous intensity performed on a regular basis results in improvements in cardiorespiratory fitness (VO_{2max}) with an increase in the capacity and efficiency of the cardiorespiratory system to transport oxygen to skeletal muscles and for muscles to use this oxygen. This increase in cardiorespiratory fitness has a strong inverse association with risk of all-cause mortality and a variety of chronic diseases. The evidence is strong that aerobic activity has favorable effects on various biomarkers for CVD and type 2 diabetes (e.g., atherogenic lipoprotein profile, blood pressure, insulin sensitivity) in adults and older adults with and without these diseases. Much of the physical activity associated with lower risk for all-cause mortality, coronary heart disease, stroke, hypertension, breast and colon cancer, and depression in many of the prospective observational studies published since 1995 has been moderate- to vigorous-intensity aerobic activity. For most people, performing aerobic activity that requires the rhythmic use of large muscles and the movement of the body mass against gravity (e.g., walking, jogging, cycling, climbing stairs, dancing) is the most effective way to increase the rate of energy expenditure and better achieve energy balance. For many of the benefits linked to preventing various chronic diseases, aerobic activity performed at moderate to vigorous intensity in the range of 500 to 1,000 MET-minutes per week is associated with a significantly lower risk.

Q-13. What are the major health benefits provided by resistance or muscle-strengthening activity?

R-13. Strong evidence exists in youth, adults and older adults that muscle-strengthening exercises that load skeletal muscle and bone increase muscle mass, strength, and quality and increase bone mineral density. Evidence is moderate that muscle-strengthening exercises improve functional ability in older adults and lead to improvements in muscle strength, joint pain, stiffness, and functional ability in adults with osteoarthritis. In combination with balance training, muscle-strengthening exercises reduce risk of falls in older adults at risk for falls (this evidence is discussed in more detail in Question 22). Resistance exercise can help maintain lean body mass during a program of weight loss, but by itself results in little weight loss.

Most of the evidence supports a resistance activity program with the following characteristics: progressive muscle strengthening exercises that target all major muscle groups performed on 2 or more days per week. To enhance muscle strength, 8 to 12 repetitions of each exercise should be performed to volitional fatigue. One set is effective; however, limited evidence suggests that 2 or 3 sets may be more effective.

Q-14. What is the evidence that flexibility activities provide health benefits?

R-14. Flexibility is an important element of overall fitness. However, the evidence that flexibility exercises by themselves confer health benefits is very limited. Most well-designed exercise interventions in youth, adults, and older adults include a brief flexibility routine as part of the intervention and often as the control condition, thus preventing the assessment of the relative benefits of flexibility training alone. Some evidence indicates that balanced exercise interventions that include flexibility activities reduce the risk of injuries.

Energy Balance

Q-15. What is the amount of physical activity that is necessary for weight stability over the long term?

R-15. The optimal amount of physical activity needed for weight maintenance (defined as less than 3% change in weight) over the long-term is unclear. However, the evidence is clear that physical activity provides benefit for weight stability. A great deal of inter-individual variability exists with physical activity and weight stability, and many persons may need more than 150 minutes of moderate-intensity activity per week to maintain weight. Data from recent well-designed randomized controlled trials lasting up to 12 months indicate that aerobic physical activity performed to achieve a volume of 13 to 26 MET-hours per week is associated with approximately a 1% to 3% weight loss (i.e., an amount generally considered to represent weight stability). Thirteen MET-hours per week is approximately equivalent to walking at 4 miles per hour for 150 minutes per week or jogging at 6 miles per hour for 75 minutes per week.

Q-16. What is the evidence for the amount of physical activity that is necessary for weight loss in adults?

R-16. A wide range of studies provides evidence of a dose-response relation between physical activity and weight loss. Clear, consistent data show that a large volume of physical activity is needed for weight loss in the absence of concurrent dietary changes. The physical activity equivalent of 26 kilocalories per kilogram of body weight (1,560 MET-minutes) or more per week is needed for weight loss of 5% or greater. Smaller amounts of weight loss are seen with smaller amounts of physical activity (as noted in R-15). This relatively high volume of physical activity is equivalent to walking about 45 minutes per day at 4 miles per hour or about 70 minutes per day at 3 miles per hour, or jogging 22 minutes per day at 6 miles per hour.

The role of energy intake (diet) must be considered in any discussion of weight control. When calorie intake is carefully controlled at a baseline level, the magnitude of any weight loss is what would be expected given the increase in energy

expenditure of the person's physical activity. However, in situations in which people's dietary intake is not controlled, the amount of weight loss due to the increase in physical activity is not commensurate to what would be expected. Therefore, for most people to achieve substantial weight loss (i.e., more than 5% decrease in body weight), a dietary intervention also is needed. The dietary intervention could include either maintenance of baseline caloric intake, or a reduction in caloric intake to accompany the physical activity intervention. The magnitude of change in weight due to physical activity is additive to that associated with caloric restriction.

Q-17. Is there evidence that physical activity provides benefit for weight maintenance in adults who have previously lost substantial body weight?

R-17. The scientific evidence for the effectiveness of physical activity alone in preventing weight regain following significant weight loss is limited. Available data indicate that to prevent substantial weight regain over 6 months or longer, many adults need to exercise in the range of 60 minutes of walking or 30 minutes of jogging daily (approximately 4.4 kilocalories per kilogram per day of activity energy expenditure). The literature generally supports the concept that "more is better" for long-term weight maintenance following weight loss. Further, the evidence indicates that individuals who are successful at long-term weight maintenance appear to limit caloric intake in addition to maintaining physical activity.

Q-18. For people who are overweight or obese is there evidence that physical activity provides health benefits irrespective of assisting with energy balance?

R-18. Yes. Strong evidence shows that physically active adults who are overweight or obese experience a variety of health benefits that are generally similar to those observed in people of optimal body weight (BMI = 18.5-24.9). These benefits include lower rates of all-cause mortality, coronary heart disease, hypertension, stroke, type 2 diabetes, colon cancer, and breast cancer. At least some of these benefits appear to be independent of a loss in body weight, while in some cases weight loss in conjunction with an increase in physical activity results in even greater benefits. Because of the health benefits of physical activity that are independent of body weight classification, adults of all sizes and shapes gain health and fitness benefits by being habitually physically active.

Youth

Q-19. What does the evidence indicate about the major physical fitness and health benefits of physical activity in children and youth?

R-19. Strong evidence demonstrates that the physical fitness and health status of children and youth is substantially enhanced by frequent physical activity. Compared to inactive young people, physically active children and youth have higher levels of

cardiorespiratory endurance and muscular strength and well documented health benefits include lower body fatness, more favorable cardiovascular and metabolic disease risk profiles, enhanced bone health, and reduced symptoms of anxiety and depression. These conclusions are based on the results of observational studies in which higher levels of physical activity were found to be associated with favorable health parameters as well as experimental studies in which exercise treatments caused improvements in physical fitness and various health-related factors.

Q-20. What does the evidence indicate about the dose of physical activity that is most likely to provide health benefits for children and youth?

R-20. Few studies have provided data on the dose response for various health and fitness outcomes in children and youth. However, substantial data indicate that important health and fitness benefits can be expected to accrue to most children and youth who participate daily in 60 or more minutes of moderate to vigorous physical activity. Also, the Committee concluded that certain specific types of physical activity should be included in an overall physical activity pattern in order for children and youth to gain comprehensive health benefits. These include regular participation in each of the following types of physical activity on 3 or more days per week: resistance exercise to enhance muscular strength in the large muscle groups of the trunk and limbs, vigorous aerobic exercise to improve cardiorespiratory fitness and cardiovascular and metabolic disease risk factors, and weight-loading activities to promote bone health.

Older Adults

Q-21. Is there evidence that the target dose for physical activity should differ for older adults?

R-21. Yes. If a person has a low exercise capacity (physical fitness), the intensity and amount of activity needed to achieve many health-related and fitness benefits is less than for someone who has a higher level of activity and fitness. For example, relative improvements in cardiorespiratory endurance and muscle strength produced by an increase in physical activity are more closely associated with the activity intensity relative to the capacity of the individual (e.g., percent of VO_{2max} or one repetition max [1RM]) than to the absolute intensity of the activity (e.g., 6 miles per hour or 100 pounds). Because the exercise capacity of adults tends to decrease as they age, older adults generally have lower exercise capacities than younger persons. Thus, they need a physical activity plan that is of lower absolute intensity and amount (but similar in relative intensity and amount) than is appropriate for more fit people, especially when they have been sedentary and are starting an activity program.

Q-22. What is the evidence that physical activity in older adults can reduce or prevent falls?

R-22. For older adults at risk of falling, strong evidence exists that regular physical activity is safe and reduces falls by about 30%. Most evidence supports a program of exercise with the following characteristics: 3 times per week of balance training and moderate-intensity muscle-strengthening activities for 30 minutes per session and with additional encouragement to participate in moderate-intensity walking activities 2 or more times per week for 30 minutes per session. Some evidence, albeit less consistent, suggests that tai chi exercises also reduces falls. Successful reduction in falls by tai chi interventions resulted from programs conducted from 1 to 3 hours or more per week. No evidence indicates that planned physical activity reduces falls in adults and older adults who are not at risk for falls.

Understudied Populations

Q-23. Is there evidence that physical activity provides health benefits to persons with various disabilities?

R-23. Yes. However, for many physical and cognitive disabilities, scientific evidence for various health and fitness outcomes is still limited due to the lack of research. The goal of the scientific review in persons with disabilities was not to consider exercise as a therapy for disability but to evaluate the evidence that physical activity provides the general health and fitness benefits frequently reported in populations without these disabilities (e.g., improvements in physical fitness, biomarkers for chronic disease, physical independence, health-related quality of life). Moderate to strong evidence indicates that increases in aerobic exercise improve cardiorespiratory fitness in individuals with lower limb loss, multiple sclerosis, stroke, spinal cord injury, and mental illness. Limited data show similar results for people with cerebral palsy, muscular dystrophy, and Alzheimer's disease. Moderate to strong evidence also exists for improvements in walking speed and walking distance in patients with stroke, multiple sclerosis, and intellectual disabilities. Quite strong evidence indicates that resistance exercise training improves muscular strength in persons with such conditions as stroke, multiple sclerosis, cerebral palsy, spinal cord injury, and intellectual disability. Although evidence of benefit is suggestive for such outcomes as flexibility, atherogenic lipids, bone mineral density, and quality of life, the data are still very limited.

For a majority of the studies reviewed involving persons with disabilities, the exercise regimen followed was that currently recommended for the general public — aerobic exercise of 30 to 60 minutes, 3 to 5 days per week at moderate intensity, and resistance training with 1 or 2 sets of 8 to 12 repetitions using appropriate muscle groups 2 to 3 times per week (intensity adjusted for the individual's capacity). Data comparing various doses of exercise in a single study are not available. In the studies

reviewed, participants had to meet study eligibility and, in some cases, had to have a pre-participation medical evaluation, but the medical adverse event rate was low and did not differ between exercise program participants and non-exercise controls.

Q-24. Is there evidence regarding the health benefits as well as risks of physical activity for women during pregnancy and the postpartum period?

R-24. Substantial data from observational studies indicates that moderate-intensity physical activity by generally healthy women during pregnancy increases cardiorespiratory fitness without increasing the risk of low birth weight, preterm delivery, or early pregnancy loss. The results of several studies also indicate that moderate-intensity physical activity does not increase the risk of preeclampsia. Available data from recent observational studies show a favorable association between moderate-intensity activity during early pregnancy and somewhat lower rates of preeclampsia and gestational diabetes mellitus (GDM), although these data are not yet conclusive. For moderate-intensity activity during pregnancy, the scientific evidence is strong that the risks are very low, but the science is less strong in documenting improved health outcomes for the mother or child. The few studies that have been conducted on the risks and benefits of vigorous activity by women who are pregnant provide very limited data that this level of activity is associated with small reductions in birth weight compared to birth weights of infants born to less active women.

Moderate-intensity physical activity during the postpartum period does not appear to adversely affect milk volume or composition or infant growth, and moderately strong evidence suggests that it results in enhanced cardiorespiratory fitness and mood of the mother. Physical activity alone does not produce weight loss except when combined with dietary changes.

Dose-response studies of physical activity and health outcomes for moderate- or vigorous-intensity physical activity during pregnancy or the postpartum period have not been conducted. Most studies evaluating possible benefits have promoted moderate-intensity activity for 120 to 150 minutes per week.

Q-25. Is there evidence that the physical activity dose for improving health and fitness should differ for people depending upon race or ethnicity?

R-25. Since 1995, only a limited number of prospective studies investigating the relation between physical activity and health outcomes have had adequate samples of non-Hispanic white men or women and one or more other race/ethnicities, which would allow a direct comparison of benefits. In the observational cohort studies with all-cause mortality or cause-specific chronic disease morbidity and mortality as the outcome and with sufficient samples sizes and event rates to have reasonable power to detect meaningful difference between race and ethnic groups, no differences have been reported. In prospective observational studies conducted in countries where the majority of the population is other than non-Hispanic white, the generally favorable

relation between higher levels of physical activity and chronic disease events is similar to many of the studies reporting on non-Hispanic white populations. In the few experimental studies where aerobic exercise training was the intervention, no meaningful differences have been reported for changes in cardiorespiratory fitness, body weight, or cardiovascular disease biomarkers when comparing non-Hispanic white and African-American men and women. Thus, based on the currently available scientific evidence, the dose of physical activity that provides various favorable health and fitness outcomes appears to be similar for adults of various races and ethnicities.

Reference List

1. American College of Cardiology, American Heart Association. Methodology manual for ACC/AHA guideline writing committees 2008 [cited 6 A.D. May 23] Available from http://www.americanheart.org/presenter.jhtml?identifier=3039684.