PART F. CHAPTER 7. YOUTH

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INTRODUCTION

The *2008 Physical Activity Guidelines for Americans* included a physical activity recommendation for children and adolescents, ages 6 to 17 years.[1] That guideline was based on the conclusion in the *Physical Activity Guidelines Advisory Committee Report, 2008* that strong evidence demonstrated that, in children and adolescents, higher levels of physical activity are associated with multiple beneficial health outcomes, including cardiorespiratory and muscular fitness, bone health, and maintenance of healthy weight status.[2] The 2018 Physical Activity Guidelines Advisory Committee, in establishing the parameters of its work, opted to examine new evidence addressing the relationships between physical activity and health outcomes in school-aged youth. In addition, the Subcommittee considered two issues that were not examined by the 2008 Committee: 1) the association between physical activity and health outcomes in children younger than age 6 years, and 2) the association between sedentary behavior and health outcomes in children and adolescents.

REVIEW OF THE SCIENCE

Overview of Questions Addressed

This chapter addresses three major questions and related subquestions:

1. In children younger than age 6 years, is physical activity related to health outcomes?
    a) What is the relationship between physical activity and adiposity or weight status?
    b) What is the relationship between physical activity and bone health?
    c) What is the relationship between physical activity and cardiometabolic health?
    d) Are there dose-response relationships? If so, what are the shapes of those relationships?
    e) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

2. In children and adolescents, is physical activity related to health outcomes?
    a) What is the relationship between physical activity and cardiorespiratory and muscular fitness?
    b) What is the relationship between physical activity and adiposity or weight status? Does physical activity prevent or reduce the risk of excessive increases in adiposity or weight status?
    c) What is the relationship between physical activity and cardiometabolic health?
    d) What is the relationship between physical activity and bone health?
    e) Are there dose-response relationships? If so, what are the shapes of those relationships?
    f) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

3. In children and adolescents, is sedentary behavior related to health outcomes?
    a) What is the relationship between sedentary behavior and cardiometabolic health?
    b) What is the relationship between sedentary behavior and adiposity or weight status?
    c) What is the relationship between sedentary behavior and bone health?
    d) Are there dose-response relationships? If so, what are the shapes of those relationships?
    e) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

Data Sources and Process Used to Answer Questions

In considering the evidence linking physical activity to health outcomes in school-aged youth, the Subcommittee based its review on systematic reviews and meta-analyses that had examined longitudinal studies of the relationships between physical activity and the following health outcomes: cardiorespiratory and muscular fitness, adiposity or weight status, bone health, and cardiometabolic health. In most cases, the systematic reviews and meta-analyses included primary research articles published since 2006. Many of those studies had employed objective, device-based measures of physical activity.

In the past decade, a substantial volume of research has examined physical activity and its relationship to health factors in children younger than age 6 years. Accordingly, the Subcommittee opted to examine this relationship initially including only systematic reviews and meta-analyses. However, the reviews provided insufficient information, so the Subcommittee conducted a de novo search of the primary research literature. Only studies using longitudinal designs were included, and the following three indicators of health were considered: adiposity or weight status, bone health, and cardiometabolic health. Almost all of the relevant studies focused on children ages 3 to 5 years.

In addition, over the past decade researchers and professionals in multiple fields have expressed concern regarding the potential impact of high levels of sedentary behavior on children's health. Accordingly, the Subcommittee opted to examine the evidence regarding the relationship between sedentary behavior and selected health outcomes. That examination relied on systematic reviews and meta-analyses, several of which have summarized studies with longitudinal designs. For bone health, the review of evidence focused on the primary research literature.

Question 1. In children younger than age 6 years, is physical activity related to health outcomes?

a) What is the relationship between physical activity and adiposity or weight status?
b) What is the relationship between physical activity and bone health?
c) What is the relationship between physical activity and cardiometabolic health?
d) Are there dose-response relationships? If so, what are the shapes of those relationships?
e) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

Source of evidence: Original research studies

Conclusion Statements

Strong evidence demonstrates that higher amounts of physical activity are associated with more favorable indicators of bone health and with reduced risk for excessive increases in body weight and adiposity in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Subquestions

Strong evidence demonstrates that higher amounts of physical activity are associated with a reduced risk of excessive increases in body weight and adiposity in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Strong evidence demonstrates that higher amounts of physical activity are associated with favorable indicators of bone health in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Insufficient evidence is available to determine the effects of physical activity on cardiometabolic risk factors in children under 6 years of age. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine the dose-response relationship between physical activity and health effects in children younger than 6 years of age. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine whether the relationship between physical activity and health effects in children younger than 6 years of age is moderated by age, sex, race/ethnicity, weight status, or socioeconomic status. **PAGAC Grade: Not assignable.**

Review of the Evidence

Evidence on the Overall Relationship

The conclusion that higher amounts of physical activity are associated with beneficial health outcomes in children younger than 6 years of age was based on the conclusions for two subquestions. Specifically, it was concluded that strong evidence demonstrated that higher amounts of physical activity are associated with favorable indicators of bone health and reduced risk of excessive increases in body weight and adiposity in children ages 3 to 6 years. The evidence supporting these conclusions is summarized below.

Evidence on Specific Factors

Body weight and adiposity: The conclusion that higher levels of physical activity are associated with reduced risk for excessive increases in body weight and adiposity was based primarily on the findings of 14 studies.[3-16] All these studies used prospective observational study designs, and they employed device-based measures of physical activity. Twelve of the 14 studies found negative associations between physical activity and weight and/or adiposity measured at follow-up.[3-10, 12-15] Although the evidence indicated a benefit of greater amounts of physical activity, it was not sufficient to identify a particular dose of physical activity that was needed to provide benefits.

Bone health: The Subcommittee's conclusion regarding the positive effects of physical activity on measures of bone health in children younger than age 6 years was supported by the findings of 10 research articles based on four separate studies.[17-26] These included a mix of randomized controlled trials and prospective observational studies. All the studies used state-of-the-art bone imaging procedures. Several types of physical activity were found to be associated with bone health, including gymnastics and other bone-strengthening activities, such as jumping and hopping. Total physical activity as assessed by accelerometry also was found to be positively associated with measures of bone health.

The evidence was not sufficient to identify a particular dose of physical activity that was needed to produce benefits, however.

Cardiometabolic health: Very few studies have examined the relationship between physical activity and indicators of cardiometabolic health in children younger than age 6 years.[9, 27, 28] Accordingly, this subquestion was graded as Not Assignable.

Dose-response: Few studies of physical activity and health in children younger than age 6 years have been designed in a manner that allows examination of dose-response relationships. Therefore, this subquestion was graded as Not Assignable.

Demographic factors and weight status: The studies on physical activity and health in children younger than age 6 years have rarely been designed in a manner that provided for examination of the potential modifying effects of demographic characteristics, such as sex, age, race/ethnicity, weight status, and socioeconomic status. Accordingly, this subquestion was graded as Not Assignable.

For additional details on this body of evidence, visit: https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx for the Evidence Portfolio.

Comparing 2018 Findings with the 2008 Scientific Report

The 2008 Scientific Report included the overall conclusion that "physical activity provides important health benefits for children and adolescents".[2] The scientific literature that was cited as supporting that conclusion was limited to studies on children ages 5 to 19 years. This age range was selected because the scientific literature at that time included few studies on children younger than age 6 years. However, in the intervening decade, a substantial amount of research has focused on physical activity and its relationship with health in children younger than 6 years, particularly those ages 3 to 5 years. Accordingly, this literature was systematically reviewed, and it supports the conclusions presented above. These conclusions, by focusing on the early childhood developmental period, extend the scope of the 2018 Committee's work to an age range younger than that addressed by the 2008 Scientific Report.

Public Health Impact

Approximately 13 million children, representing more than 4 percent of the U.S. population, are younger than age 6 years. The evidence summarized above demonstrates that higher amounts of physical activity are associated with better health indicators in this age group. It is noteworthy that the beneficial effects were documented for adiposity and bone health, two health characteristics that are known to track into later life.[29, 30] Accordingly, efforts aimed at enabling and encouraging young children to be more physically active, especially activities facilitating bone health and avoidance of excessive weight gain, would be expected to have a positive impact on the future health of the nation. As noted above, the existing literature demonstrates that higher doses of physical activity, as compared with lower doses, provide important health benefits in children ages 3 to 5 years. However, that literature does not provide extensive information on dose-response relationships, nor does it suggest a dose range that would serve as a suitable public health target. In lieu of more direct evidence on dose-response relationships, the Subcommittee concluded that important public health benefits would result if children, who fall below the median level for device-based measured total physical activity, increased their activity to at least that median. Descriptive epidemiologic studies, using device-based measures of physical activity, have observed that the median time spent in light-, moderate-, or vigorous-intensity physical activity approximates three hours per day in children ages three to five years.[31] Further, because bone-strengthening and muscle-strengthening activities provide important benefits to bone health, the Subcommittee concludes that these young children would benefit from regular participation in activities like gymnastics that involve jumping, leaping, and landing.

Question 2. In children and adolescents, is physical activity related to health outcomes?

a) What is the relationship between physical activity and cardiorespiratory and muscular fitness?
b) What is the relationship between physical activity and adiposity or weight status? Does physical activity prevent or reduce the risk of excessive increases in adiposity or weight?
c) What is the relationship between physical activity and cardiometabolic health?
d) What is the relationship between physical activity and bone health?
e) Are there dose-response relationships? If so, what are the shapes of those relationships?
f) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

Sources of evidence: Systematic reviews, meta-analyses

Conclusion Statements

Strong evidence demonstrates that, in children and adolescents, higher amounts of physical activity are associated with more favorable status for multiple health indicators, including cardiorespiratory and muscular fitness, bone health, and weight status or adiposity. **PAGAC Grade: Strong.**

Moderate evidence indicates that physical activity is positively associated with cardiometabolic health in children and adolescents. **PAGAC Grade: Moderate.**

Subquestions

Strong evidence demonstrates that increased moderate-to-vigorous physical activity increases cardiorespiratory fitness and that increased resistance exercise increases muscular fitness in children and adolescents. **PAGAC Grade: Strong.**

Strong evidence demonstrates that higher levels of physical activity are associated with smaller increases in weight and adiposity during childhood and adolescence. **PAGAC Grade: Strong.**

Moderate evidence indicates that physical activity is positively associated with cardiometabolic health in children and adolescents in general; the evidence is strong for plasma triglycerides and insulin. **PAGAC Grade: Moderate.**

Strong evidence demonstrates that children and youth who are more physically active than their peers have higher bone mass, improved bone structure, and greater bone strength. **PAGAC Grade: Strong**.

Insufficient evidence is available to determine the dose-response relationship between physical activity and health effects during childhood and adolescence. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine whether the relationship between physical activity and health effects in youth is moderated by age, sex, race/ethnicity, weight status or socioeconomic status. **PAGAC Grade: Not assignable.**

Review of the Evidence

The conclusion that higher amounts of physical activity are associated with beneficial health outcomes in youth was based on the conclusions for four subquestions. Specifically, the Subcommittee concluded that strong evidence demonstrates that higher amounts of physical activity are associated with increased cardiorespiratory and muscular fitness, smaller age-related increases in body weight and adiposity, and higher bone mass, improved bone structure, and greater bone strength. Moderate evidence indicated that physical activity is positively associated with indicators of cardiometabolic health. The evidence supporting these conclusions is summarized below. It is important to note that, in most cases, the evidence available to address this question was based on a review of research on children ages 6 years and above. However, relevant research on children younger than 6 years, when available, was also considered.

Cardiorespiratory and Muscular Fitness

Six meta-analyses,[32-37] and nine systematic reviews[38-46] were identified that examined the association between physical activity and cardiorespiratory fitness. Two reviews[40, 45] included muscular fitness outcomes.

Overall, the reviews included publications from inception of the database through 2016. Reviews were focused on the impact of a variety of physical activity intervention or program types on cardiorespiratory fitness outcomes, including afterschool programs,[32] school-based interventions,[41-43] exercise training or aerobic exercise programs,[33-37, 40, 45] active transportation,[39] and exergaming[38, 44, 46]; two reviews[37, 40] included interventions from any setting. Reviews focused on interventions among children and adolescents ages 2 to 18 years; most studies focused on children and adolescents between the ages of 6 and 18 years.

Evidence on the Overall Relationship

All identified reviews concluded that physical activity positively affects measures of cardiorespiratory fitness. The strongest evidence for the impact of physical activity on cardiorespiratory fitness was for organized group-based programs that included specific exercise prescriptions among youth. A meta-analysis of afterschool interventions that included a component designed to promote physical activity identified a pooled effect size from six relevant studies of 0.16 (range -0.23 to 0.86; 95% confidence interval (CI): 0.01-0.30).[32] Systematic reviews did not provide effect sizes but were consistent with findings that school-based interventions were effective for increasing fitness.[41-43] Organized exercise training programs were more effective for improving fitness levels than were general physical activity programs; effect size 4.19 (95% CI: 3.68-4.70) vs. 3.34 (95% CI: 2.08-4.60).[33] Supervised exercise training studies yielded 7 percent to 8 percent increases in VO_2max.[34-36]

A single review identified associations between active transportation and health outcomes across 68 studies, 10 of which included fitness outcomes.[39] Active transportation through cycling was clearly linked with improvements in cardiorespiratory fitness. The association between walking and fitness was less apparent, perhaps because of the lower intensity level of walking compared with cycling.

Three reviews evaluated the impact of exergaming on fitness levels.[38, 44, 46] Findings were mixed, with about half of included studies finding a positive impact of exergaming on some measure of fitness and the other half finding non-significant or null effects; no studies identified a negative impact of exergaming on fitness. Importantly, exergaming appears to be a feasible and acceptable strategy for increasing light-intensity physical activity. Exergaming also appears to be feasible for increasing participation in physical activity at the lower limit of the moderate-intensity range. However, the included reviews did not provide sufficient evidence that the level of energy expended during exergaming is sufficient for increasing measures of cardiorespiratory fitness.

Two systematic reviews specifically looked at musculoskeletal fitness, both of which generally concluded that studies including a muscle strengthening component had a positive impact on muscular fitness.[40, 45] Although effect sizes were not provided within the systematic reviews, results of positive outcomes for muscle-strengthening activity on at least one measure of muscular fitness were consistent.

All identified reviews concluded that physical activity positively affected at least one measure of cardiorespiratory fitness. Organized group-based programs were typically implemented on 3 or more days per week for 30 to 60 minutes, at 50 percent to 90 percent VO_2max or heart rate (HR) max. The evidence for the impact of active transportation and exergaming is less clear.

Two identified reviews concluded that two or more sessions of muscle-strengthening activity weekly was effective for improving measures of muscular fitness. Specific detail on session duration, intensity, and types of exercise was not readily apparent in the information provided.

Dose-response: The studies reviewed were not able to establish dose-response relationships for these modes of exercise and physical activity.

Evidence on Specific Factors

Demographic factors and weight status: The reviews typically focused solely on the impact of physical activity on cardiorespiratory fitness and did not specifically explore subgroup analyses or effect modifiers. Several of the studies included in the reviews focused on children with overweight or obesity. These studies generally concluded that physical activity positively affects cardiorespiratory and muscular fitness outcomes, regardless of weight status. The reviews did not provide comparisons between children with normal weight and those with overweight or obesity.

Cardiometabolic Health

Nine articles including one systematic review[47] and eight meta-analyses[33-36, 48-51] were identified that examined the association between physical activity and cardiometabolic health in children and adolescents. Three of the meta-analyses were exclusively concerned with the effects of physical activity among children and adolescents with overweight or obesity.[36, 49, 50]

Five out of five meta-analyses that analyzed the association between physical activity and plasma triglycerides reported a significant, beneficial effect.[33, 34, 36, 48, 49] Three[33, 36, 51] out of four meta-analyses[33, 36, 48, 51] that analyzed the association between physical activity and plasma insulin reported a significant, beneficial effect. The results for high density lipoprotein (HDL)-cholesterol and blood pressure were not as strong, but were suggestive of a potential benefit from physical activity. Three[33, 48, 49] out of six[33-36, 48, 49] meta-analyses reported a significant, beneficial effect of physical activity on HDL-cholesterol, two[48, 50] out of three[36, 48, 50] meta-analyses reported a significant benefit for systolic blood pressure, while one[50] out of three[36, 48, 50] meta-analyses reported a significant benefit for diastolic blood pressure.

Dose-response: Although the individual studies reviewed in the meta-analyses varied with respect to intervention duration and exercise intensity, they provided insufficient evidence to make any conclusions about dose-response associations. In general, most studies on the effects of physical activity on cardiometabolic risk factors in children were not designed to test a specific risk factor. Rather, specific risk factors were measured as one of the outcomes among many others. Thus, the children may not have had elevated levels of each risk factor at baseline, making it difficult to determine the true effects of physical activity among high-risk children (e.g., those with high blood pressure, insulin resistance).

Demographic factors and weight status: Given that only systematic reviews and meta-analyses were included in this review, limited information is available on the effects of age, sex race/ethnicity, or socioeconomic status on the association between physical activity and cardiometabolic risk factors in children. Two meta-analyses reported that the effects in children with overweight and obesity were greater than in normal weight children for reductions in triglycerides[34] and markers of insulin resistance.[51]

Body Weight and/or Adiposity

The Subcommittee identified a substantial number of systematic reviews and meta-analyses summarizing the scientific literature on the relationship between physical activity and weight status and/or adiposity. However, most of those articles focused on studies in which multiple exposures, often both physical activity and diet, were considered in ways that did not allow determining the independent association of physical activity with weight-related outcomes. Ten articles did focus on studies that considered the independent association of physical activity with weight-related outcomes, and these included systematic reviews[52-56] and meta-analyses[35, 48, 57-59] examining studies with both experimental and prospective, observational study designs. When the conclusions of those articles were considered, the collective findings were deemed to be inconsistent and the evidence linking physical activity to better weight status and/or adiposity was considered to be of moderate strength. However, the consideration of evidence progressed to a third stage that involved considering only the five reviews that focused on studies using prospective, observational study designs.[53-56, 59] The decision to focus on those reviews was based on the belief that prospective, observational study designs are particularly appropriate for an outcome such as adiposity. Observation of differential effects of physical activity doses (e.g., higher vs. lower) may require exposure for periods that are practical in observational studies but longer than feasible in experimental trials. When that subset of five reviews was considered, consistent evidence of an inverse association between physical activity and indicators of weight status and/or adiposity was found.

Dose-response: The aforementioned five reviews, while concluding that higher amounts of physical activity provided beneficial body weight and adiposity outcomes, did not describe dose-response relationships.[53-55, 59] One review concluded that higher intensity physical activity provided greater benefit than less intense physical activity.[54]

Demographic factors and weight status: The five systematic reviews focusing on prospective observational studies gave limited attention to demographic effect modifiers. One review concluded that the protective effect of physical activity on weight-related outcomes was evident in both sexes.[54] This protective effect was reported in reviews focusing on both children of preschool age[55, 56] as well as older children and adolescents.[53, 54]

Bone Health

The Subcommittee identified five meta-analyses[48, 57, 60-62] and five systematic reviews.[41, 63-66] Reviews included all publications through 2016 and focused on studies among children and adolescents ages 3 to 18 years; most studies focused on children and adolescents ages 8 to 15 years, i.e., the peri-pubertal years. Intervention studies were primarily school-based. The volume of the exercise within interventions varied among the studies. However, almost all interventions included high-impact, dynamic, short duration exercise, such as hopping, skipping, jumping, and tumbling. Only two reviews considered observational studies.[65, 66] Results from the observational studies were consistent with results from the intervention studies. All reviews (systematic and meta-analyses) concluded that in youth, physical activity is positively associated with bone mass accrual and/or bone structure.

The greatest amount of evidence for the effect of physical activity on bone strength was for bone mass outcomes. In their meta-analysis, Specker et al[60] examined 22 trials (15 were randomized) and noted that the difference in annual increase in bone mass between intervention and control groups was 0.8 percent (95% CI: 0.3-1.3) for total body; 1.5 percent (95% CI: 0.5-2.5) for femoral neck; and 1.7 percent (95% CI: 0.4-3.1) for spine. Weaver et al[66] identified 38 reports of randomized controlled trials or clinical trials where exercise was used as an intervention to increase bone mass outcomes. Thirty of these reports (84%) reported statistically significant differences between exercise and control groups, ranging from approximately 1 percent to 6 percent over 6 months for total body, femoral neck, and spine. Nineteen prospective longitudinal reports were also examined in the Weaver et al[66] review. Of these, 17 reports (89%) indicated that the most active youth had significantly more bone mass when compared to less active peers.

In addition to its association with bone mass, physical activity is associated with bone structure. This is important because the skeleton needs to be strong to bear loads, but at the same time light for energy-efficient movement. Of the systematic reviews, Tan et al[65] and Weaver et al[66] included specific critiques of studies addressing bone structure. In Tan et al,[65] 14 intervention studies and 23 observational studies (cross-sectional and longitudinal) were examined. Studies with strong design scores showed the greatest effect in structural outcomes between intervention and control groups (3% to 4% difference). None of the studies showed negative associations between physical activity and bone structure. Weaver et al[66] examined 18 reports and noted that 8 showed positive, significant effects of exercise on bone structure outcomes. However, of the 10 reports that indicated no significant differences between exercise and control groups, 6 reports were from the same study, which did not intervene with high-impact, dynamic, short duration exercise. Weaver et al[66] also identified eight prospective observational studies; all eight studies found significant differences in bone structure favoring the most active cohort members when compared to the least active.

Dose-response: Almost exclusively, intervention studies that reported positive outcomes used targeted, high-impact exercise with ground reaction forces at least three times body weight for approximately 6 months. Examples of physical activities that typically include this magnitude of ground reaction forces include volleyball, basketball, martial arts, and gymnastics. The duration and frequency of the interventions varied greatly, ranging from 2 to 12 sessions per week and 1 to 60 minutes per session.[65, 66] However, the reviewed trials were not designed to examine dose-response and no trial included multiple arms of exercise using different loading conditions. Therefore, dose-response is not conclusively known. Limited evidence supports the osteogenic effect of resistance training and other muscle-strengthening physical activity.[66] However, dose-response information is not available.

Demographic factors and weight status: The effect of physical activity on bone strength appears greatest around puberty, indicating that maturity is an effect modifier. However, very few studies focused on post-pubertal youth or pre-school children. Males and females benefit similarly from physical activity (though bone structural changes may be different between males and females). Recent reports suggest that when compared to peers of the same body weight and sex, youth with obesity have weaker bones, indicating that weight status may be an effect modifier.[66] Few studies have included children from diverse racial/ethnic groups or addressed socioeconomic status, so their effect on modifying the relationship between physical activity and bone strength is not known.

For additional details on this body of evidence, visit: https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx for the Evidence Portfolio.

Comparing 2018 Findings with the 2008 Scientific Report

The findings and conclusions of this report regarding the associations between physical activity and health in youth are consistent with the findings reported in the 2008 Scientific Report.[2] However, the scientific evidence supporting the conclusions in this report is substantially more robust than was the case in 2008. The evidence has been strengthened by marked increases in the quantity and quality of research on physical activity and two key health indicators, weight status and/or adiposity and bone health. Further, the evidence has been strengthened by the publication of numerous systematic reviews and meta-analyses on topics related to the impact of physical activity on health outcomes in children and adolescents.

The 2008 Scientific Report[2] informed a recommendation that was included in the 2008 Physical Activity Guidelines for Americans. That recommendation called for children and adolescents ages 6 to 17 to do 60 minutes or more of moderate-to-vigorous physical activity per day. It was further recommended that, within the 60 minutes of daily physical activity, children and adolescents should engage in muscle-strengthening, bone-strengthening, and vigorous intensity physical activities at least three days per week.[1] As noted above, the Subcommittee's conclusions are consistent with the conclusions of the 2008 Scientific Report. Accordingly, these conclusions and the evidence summaries supporting the conclusions are consistent with the physical activity recommendation for children and adolescents as included in 2008 Physical Activity Guidelines for Americans.

Public Health Impact

A substantial percentage of U.S. children and youth do not meet the current federal physical activity guideline.[67] That guideline calls for daily participation in 60 or more minutes of moderate-to-vigorous physical activity as well as regular engagement in vigorous physical activity, muscle-strengthening exercise, and bone-strengthening activities. The conclusion that strong evidence demonstrates that higher amounts of physical activity are associated with better status on multiple health indicators during childhood and adolescence points to the important public health benefits that would be associated with increasing the percentage of young persons in the United States who meet physical activity guidelines. The evidence is strong that these health benefits would accrue to children and adolescents during their developmental years. Further, current evidence suggests that it is likely that many of those health benefits would carry forward into adulthood.

Question 3. In children and adolescents, is sedentary behavior related to health outcomes?

a) What is the relationship between sedentary behavior and cardiometabolic health?
b) What is the relationship between sedentary behavior and adiposity or weight status?
c) What is the relationship between sedentary behavior and bone health?
d) Are there dose-response relationships? If so, what are the shapes of those relationships?
e) Do the relationships vary by age, sex, race/ethnicity, weight status, or socioeconomic status?

Sources of evidence: Systematic reviews, meta-analyses, original research articles

Conclusion Statements

Limited evidence suggests that greater time spent in sedentary behavior is related to poorer health outcomes in children and adolescents. **PAGAC Grade: Limited.**

Subquestions

Limited evidence suggests that greater time spent in sedentary behavior is related to poorer cardiometabolic health; the evidence is somewhat stronger for television viewing or screen time than for total sedentary time. **PAGAC Grade: Limited.**

Limited evidence suggests that greater time spent in sedentary behavior is related to higher weight status or adiposity in children and adolescents; the evidence is somewhat stronger for television viewing or screen time than for total sedentary time. **PAGAC Grade: Limited.**

Limited evidence suggests that sedentary behavior is not related to bone health in children and adolescents. **PAGAC Grade: Limited.**

Insufficient evidence is available to determine whether a dose-response relationship exists between greater time spent in sedentary behavior and poorer health outcomes in children and adolescents. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine whether the relationship between sedentary behavior and health outcomes in youth is moderated by age, sex, race/ethnicity, or socioeconomic status. **PAGAC Grade: Not assignable.**

Review of the Evidence

Evidence Related to the Overall Question

The conclusion that there is limited evidence that greater time spent in sedentary behavior is related to poorer health outcomes in children and adolescents was based on the conclusions for three subquestions. Specifically, it was concluded that limited evidence demonstrated that greater time spent in sedentary behavior is associated with lower cardiometabolic health and less favorable weight status or adiposity, and limited evidence of no relationship between sedentary behavior and bone health. The evidence supporting these conclusions is summarized below. For Question 3, the Subcommittee relied on systematic reviews and meta-analyses, while a search was conducted for original research articles to address bone health.

Evidence Related to Specific Factors

Cardiometabolic risk factors: The Subcommittee obtained evidence on the relationship between sedentary time and cardiometabolic risk factors from systematic reviews and meta-analyses. The literature search identified 12 systematic reviews and meta-analyses that potentially addressed this question. After review of these articles, it was determined that four articles[68-71] were best suited to answer the question. The systematic review by Chinapaw et al[68] found insufficient evidence for a longitudinal association between sedentary behavior and blood pressure or blood lipids in children and adolescents. Tremblay et al[69] reported that increased screen time was related to increased risk factors in children and adolescents. However, this conclusion was based on nine cross-sectional studies and only two longitudinal studies. Likewise, in an update of the evidence from Tremblay et al,[69] Carson et al[70] reported that results varied across different risk factors, but TV or screen time was more closely related to risk factors than accelerometer-derived estimates of sedentary behavior. This conclusion was based on 25 cross-sectional studies and 6 longitudinal studies. Finally, Cliff et al[71] reported that 8 out of 28 studies found a significant association between sedentary behavior and cardiometabolic outcomes in children and adolescents. In general, the limited evidence from longitudinal studies suggests a positive association between sedentary time and cardiometabolic risk factors in children and adolescents, with somewhat stronger results for TV viewing or screen time as the exposure.

Weight Status or adiposity: Evidence on the relationship between sedentary time and weight status or adiposity was obtained from systematic reviews and meta-analyses. The literature search identified 12 systematic reviews and meta-analyses that potentially addressed this question. After review of these articles by two members of the Subcommittee, it was determined that eight articles[53, 68-74] were best suited to answer the question.

In the most comprehensive review of sedentary behavior and adiposity published to date,[70] which included 162 studies (125 cross-sectional, 32 longitudinal, 5 case-control) the authors reported that there was a positive longitudinal association between TV or screen time and adiposity, but device-based measurements of sedentary time were not associated with adiposity. These results are supported by other systematic reviews that generally reported low levels of evidence for longitudinal associations between sedentary behavior and adiposity in children and adolescents.[53, 68, 69, 71, 73] In a systematic review that focused exclusively on the early years (ages 0 to 4 years),[72] three of four studies in toddlers reported a dose-response association between TV viewing and adiposity and two of five studies in preschoolers demonstrated a significant association. Wu et al[74] conducted a systematic review of interventions to reduce screen time, and reported no significant effect of screen time reduction on body mass index in children, based on evidence from seven studies.

Bone Health: The Subcommittee obtained evidence on the relationship between sedentary time and bone health from primary research. The literature search identified four prospective observational studies,[75-78] with sample sizes varying from 169 to 602 and age ranges from 8 to 20 years. All studies used a device-based measure of sedentary time (i.e., accelerometer). Vaitkeviciute et al[78] and Ivuškāns et al[75] used the same cohort of peri-pubescent boys and showed sedentary time was negatively associated with bone outcomes. However, the method used to construct sedentary time from accelerometry data likely attributed an unknown proportion of sedentary time as non-wear time. One study[77] used a temporal substitution statistical model and, surprisingly, reported that bone outcomes improved when levels of high physical activity intensity were held fixed and sedentary time was statistically exchanged for light-intensity physical activity time. Whereas, Gabel et al[76] reported some negative associations and some positive associations between sedentary time and bone outcomes. Variability in bone outcomes, accelerometry-processing, and statistical approaches may have all contributed to the lack of consensus in results. The literature at this time suggests limited evidence that there is no relationship between sedentary behavior and bone health.

Dose-Response: Few studies of sedentary behavior and health outcomes in children and adolescents have been designed in a manner that allows examination of dose-response relationships. Accordingly, this subquestion was graded as Not Assignable**.**

Demographic Effect Modifiers: The studies on sedentary behavior and health outcomes in children and adolescents have not been designed in a manner that allowed examination of the potential modifying effects of demographic characteristics such as sex, age, race/ethnicity, weight status, and socioeconomic status. Accordingly, this subquestion was graded as Not Assignable**.**

For additional details on this body of evidence, visit: https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx for the Evidence Portfolio.

Public Health Impact

Compelling evidence demonstrates that children and adolescents in the United States spend substantial amounts of time engaged in sedentary behaviors. This evidence comes from surveillance systems using device-based assessment of time spent in sedentary behavior and from surveys documenting time spent in specific behaviors that typically involve little or no physical activity. These behaviors include television viewing and other forms of "screen time," such as use of cell phones, tablets, and other devices for text messaging, playing video games, and other recreational pursuits. These discretionary sedentary behaviors are in addition to time spent reading and studying in school and after school. Analyses of data from NHANES have shown that U.S. children and adolescents spend 6 to 8 hours per day in sedentary behavior and that the majority spend more than 2 hours per day watching television and/or engaged with other types of screens.[79-81]

This information plus evidence that sedentary behavior causes adverse health outcomes in adults (see *Part F. Chapter 2. Sedentary Behaviors* for details) raises the concern that this behavior pattern may exert a negative effect on health among youth. Such an outcome could be the result of either direct effects of the sedentary behaviors, displacement of time spent in more physically active behaviors, or both.[69, 82, 83]

As noted above, currently available scientific evidence linking sedentary behavior to health outcomes in young persons is limited. Likewise, the interactive effects of sedentary behavior and physical activity on health in children and adolescents are not well understood. However, as is also noted above, the evidence linking moderate-to-vigorous physical activity to positive health outcomes is strong, and a substantial portion of children and adolescents is insufficiently physically active.[67] Accordingly, replacing some sedentary behavior with moderate-to-vigorous physical activity would improve the health of American youth.

NEEDS FOR FUTURE RESEARCH

1. Conduct randomized controlled trials and prospective observational studies to elucidate the dose-response relationships for physical activity and health outcomes, including adiposity, cardiometabolic health, and bone health in children and adolescents at each developmental stage.

   Rationale: Few studies have been designed to directly examine dose-response relationships between physical activity and health outcomes in young persons. This gap constitutes a major limitation in the process of identifying the types and amounts of physical activity needed to produce health benefits at each developmental stage.

2. Undertake randomized controlled trials and prospective observational studies to determine whether the health effects of physical activity during childhood and adolescence differ across groups based on sex, age, maturational status, race/ethnicity, and socioeconomic status.

   Rationale: Few studies have been designed to directly examine the extent to which the health effects of physical activity may differ across demographic subgroups. This gap substantially limits the ability to determine whether the dose of physical activity needed to produce health benefits varies across population sub-groups. Studies aimed at elucidating the extent to which race/ethnicity modifies the effects of physical activity on health outcomes should consider social, cultural, and biological factors that may influence an effect modifying role of race/ethnicity.

3. Conduct experimental and prospective observational studies to examine the health effects of physical activity in children and adolescents with elevated risk status based on adiposity, cardiometabolic health, and bone health.

Rationale: Most children and adolescents fall within the normal, healthy range on key health indicators, and consequently increased physical activity is unlikely to enhance their already normal status. However, children at elevated risk may manifest improved status with increased physical activity. A considerable volume of research has been conducted in children and adolescents with overweight and obesity, but more research is needed with young persons who have elevated cardiometabolic and bone health risk.

4. Examine the effects of novel forms of physical activity, including high intensity interval training and exergaming, on health outcomes in youth. Both experimental and prospective observational studies should be conducted.

   Rationale: Certain forms of physical activity are particularly prevalent among children and adolescents, and more research is needed to determine the extent to which these forms of physical activity affect key health outcomes.

5. Develop valid instruments for measuring physical activity and examine the health effects of physical activity in very young children between birth and 2 years.

   Rationale: In part because of a lack of validated measures of physical activity in very young children, knowledge of the relationship between physical activity and health outcomes in children between birth and age 2 years is very limited.

6. Undertake studies, using longitudinal research designs, to examine the relationship between specific forms of sedentary behavior (e.g., sitting time, screen time) and health outcomes in children and adolescents using both self-report and device-based assessment of sedentary behavior.

   Rationale: Current research on the relationship between sedentary behavior and health is limited by a dearth of studies using device-based measures of time spent in sedentary behavior. Many studies have focused on television viewing as an indicator of sedentary behavior, but television viewing is confounded by exposures other than sedentary time. Research is needed to differentiate between the health effects of time spent sedentary and time spent in specific behaviors that typically include sedentary time.

7. Conduct intervention studies to test the effects of reducing sedentary behavior on health outcomes in children and adolescents.

Rationale: Very few studies have examined the health effects associated with reduction of time spent in sedentary behavior among children and adolescents. The findings of such studies would inform the process of identifying the levels of time spent in sedentary behavior that may be associated with negative health outcomes. Further, these studies would determine the extent to which reduction of time spent in sedentary behavior influences time spent in moderate-to-vigorous and light-intensity physical activity.

8. Examine the interactive effects of sedentary behavior and physical activity of varying intensities on health outcomes in children and youth.

   Rationale: The relationship between physical activity and health outcomes in children and adolescents may be modified by amount of time spent in sedentary behavior. That is, youth who spend large amounts of time in sedentary behavior may require higher levels of physical activity to produce a particular health outcome. Studies should be undertaken to directly examine this issue.

9. Undertake prospective observational studies to examine the effects of physical activity during childhood and adolescence on health outcomes later in life.

   Rationale: Large-scale cohort studies that have followed children into adulthood and have used state-of-the-art measures of physical activity are rare, particularly in the United States. Accordingly, knowledge of the long-term impact of physical activity status early in life on health outcomes later in life is very limited. Further, the findings of such studies could inform development of physical activity guidelines for individuals in transitional periods, such as early adulthood.

10. Determine in children and adolescents the impact of genetic profiles on behavioral and physiological responses to physical activity and on the health effects of physical activity.

    Rationale: Studies in adults have shown that the health effects of physical activity are moderated by genetic profile such that a given dose of physical activity produces widely varying effects on indicators of health. Our knowledge of the relationship between physical activity and health in children and adolescents would be enriched by undertaking similar studies in young persons. Such studies could expand knowledge of how genes and the environment may interact in influencing indicators of health in young persons.

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