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ORIGINAL ARTICLES

EVIDENCE BASED PHYSICAL ACTIVITY FOR SCHOOL-AGE YOUTH

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Objectives To review the effects of physical activity on health and behavior outcomes and develop evidence-based recommendations for physical activity in youth.

Study design A systematic literature review identified 850 articles; additional papers were identified by the expert panelists. Articles in the identified outcome areas were reviewed, evaluated and summarized by an expert panelist. The strength of the evidence, conclusions, key issues, and gaps in the evidence were abstracted in a standardized format and presented and discussed by panelists and organizational representatives.

Results Most intervention studies used supervised programs of moderate to vigorous physical activity of 30 to 45 minutes duration 3 to 5 days per week. The panel believed that a greater amount of physical activity would be necessary to achieve similar beneficial effects on health and behavioral outcomes in ordinary daily circumstances (typically intermittent and unsupervised activity).

Conclusion School-age youth should participate daily in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities. *(J Pediatr 2005;146:732-7)*

Recommendations for appropriate amounts of physical activity for the US population, including school-age youth, have been developed by several organizations and agencies.[1] Although recent reviews have summarized the benefits of regular physical activity on the health of youth and its potential for reducing the incidence of chronic diseases that are manifested in adulthood,[2-5] a more systematic approach is indicated. This report presents results of a systematic evaluation of evidence dealing with the effects of regular physical activity on several health and behavioral outcomes in US school-age youth, with the goal of developing a recommendation for the amount of physical activity deemed appropriate to yield beneficial health and behavioral outcomes.

See editorial, p 719.

METHOD

Under a contract with the Divisions of Nutrition and Physical Activity and Adolescent and School Health of the Centers for Disease Control and Prevention and the Constella Group, an expert panel was convened to review and evaluate available evidence on the influence of physical activity on several health and behavioral outcomes in youth aged 6 to 18 years. The co-chairs of the panel selected panelists on the basis of expertise in specific areas: adiposity, cardiovascular health (lipids and lipoproteins, blood pressure, the metabolic syndrome, type 2 diabetes mellitus, cardiovascular reactivity, heart rate variability, inflammation, and cardiovascular fitness), asthma, several domains of mental health (self-concept, anxiety, depression), academic achievement, injury associated with physical activity, and musculoskeletal health (bone mineral, muscular strength, and endurance). The epidemiology and tracking of physical activity and overweight in youth

HDL-C	High-density lipoprotein cholesterol level	MS	Metabolic syndrome
LDL-C	Low-density lipoprotein cholesterol level		

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were also reviewed because of their public health implications, but are not included in this report.

Literature Search

Databases (PubMed, ERIC, PsycINFO, 1980 to the present) were searched for publications in English that were related to physical activity and specific outcomes in youth. Approximately 1220 abstracts were reviewed, and >850 articles were provided to the respective panelists. Articles not identified in the bibliographic searches were added by several panelists.

Evaluation of Articles

The panelists systematically evaluated and abstracted relevant articles for each outcome. This information was abstracted for each report: complete citation, study design, characteristics of the study population, measure of physical activity, statistical analyses, outcome measures, main findings, and evidence for dose-response effects. The co-chairs and panelists developed conceptual definitions and inclusion and exclusion criteria for each of the outcomes. On the basis of the review of reports, each expert provided a summary of the evidence for strength (strong [>60% of studies reviewed], moderate [30%-59% of studies], weak [<30% of studies]) and direction (positive, null, negative) of physical activity effects on each health and behavioral outcome.

Meeting Format

A meeting of the panel and representatives of major organizations and agencies with interests in physical activity and health of youth was convened in January 2004. The 2-day meeting was designed and convened for maximum input from the expert panelists and individuals representing the invited organizations and agencies (Appendix). Panel members gave presentations summarizing the evidence for an assigned outcome; each presentation was followed by an open discussion. The process of developing physical activity recommendations was then discussed among all participants. Subsequently, the co-chairs and panelists met to develop a recommendation for physical activity for school-age youth in the context of the strength of evidence available for each health and behavioral objective.

RESULTS

Evidence pertaining to the influence of physical activity on each health and behavior outcome in youth is summarized in Table I; available online at http://www.us.elsevierhealth.com/jpeds.

Normal Weight, Overweight, and Obesity

Much of the evidence dealing with adiposity and cardiovascular outcomes is based on subjects classified as overweight or obese. Current criteria are based on age- and sex-specific cut-points of the body mass index (BMI, kg/m^2). In the context of national US surveys, a BMI >85th and <95th percentile is defined as "risk of overweight," and a BMI ≥95th percentile is defined as overweight. The labels "overweight" and "obesity," respectively, are often used in the literature. A BMI >5th and ≤85th percentile is considered normal weight.

Criteria for overweight and obesity, however, varied among studies considered (eg, weight >20% of that expected for height [relative weight], estimated percent fat >25% in boys and >30% in girls, triceps skinfold >85th age- and sex-specific percentiles, and BMI >85th, >90th, or >95th age- and sex-specific percentiles). Subjects who were normal weight had weight, percent fat, skinfold thickness, or BMI below the cut-points. Designation of subjects as overweight/obese or normal weight was accepted as described in the respective reports.

Adiposity

Cross-sectional and longitudinal observational studies suggest that youth of both sexes who participate in relatively high levels of physical activity have less adiposity than less active youth.[6-17] Experimental studies of overweight boys and girls involved in systematic physical activity interventions provide more specific information about the influence of physical activity on adiposity. Programs of moderately intense exercise 30 to 60 minutes in duration, 3 to 7 days per week lead to a reduction in total body and visceral adiposity in overweight children and adolescents.[18-20] However, such programs do not influence the percentage of body fat in normal weight children and adolescents.[20-24] Limited evidence indicates that more intensive and longer sessions (>80 minutes/day) are more successful in reducing percentage fatness in normal weight boys and girls.[6,25] The results suggest that relatively greater amounts of vigorous physical activity may be needed to have a beneficial effect on adiposity in normal weight youth.

Cardiovascular Health

Many indicators of cardiovascular health cluster with overweight and adiposity, and this should be noted in evaluating potential effects of physical activity.

Metabolic syndrome. Many studies view the metabolic syndrome (MS) as a clustering of risk factors. A proposed definition of the MS for adolescents is based on abdominal obesity (waist circumference >90th percentile), triglycerides (≥110 mg/dL), blood pressure (>90th percentiles for age, sex, height), fasting glucose (≥110 mg/dL), and reduced high-density lipoprotein cholesterol level (HDL-C; ≤40 mg/dL).[26] Few studies have evaluated the impact of physical activity on the MS in youth.

Obese adolescent boys with the MS have lower exercise performance (exercise duration with a multistage treadmill protocol) than obese boys without the MS.[27] Adolescents with type 2 diabetes mellitus, in addition to being obese, report no or very little habitual physical activity.[28] In overweight children, exercise successfully reduced triglyceride and insulin levels in a randomized trial,[29] wheras a 40-minute program of

moderate to vigorous physical activity 3 times/week improved some aspects of the MS (triglyceride level, insulin level, adiposity).[30] Several studies show improvement in elements of the MS in association with physical activity in obese and non-obese youth,[31-36] but the amount of activity necessary to prevent or treat the MS is not specified.

Lipids and lipoproteins. Relationships between physical activity and total cholesterol, HDL-C, low-density lipoprotein cholesterol (LDL-C), and triglyceride levels are generally weak in observational studies. The results suggest a beneficial effect of physical activity on HDL-C and triglyceride levels, but no consistent effect on total cholesterol or LDL-C levels.[10,14,17,24,30,36-49] Two studies, however, indicate a null effect of physical activity on lipid and lipoprotein levels.[50,51] The latter more likely applies to youth who entered a study with relatively normal values. Results of studies relating lipid and lipoprotein levels to cardiovascular (aerobic) fitness are inconsistent and do not indicate a significant association.[20,52-57] Intervention studies, including clinical or school-based trials (randomized and non-randomized), show a weak beneficial effect on HDL-C and triglyceride levels, but not on total cholesterol or LDL-C levels.[25,58-60] School-based interventions have not been effective in improving lipid and lipoprotein levels.[34,61]

Allowing for variation in the available data, it appears that a minimum of 40 minutes of activity per day, 5 days per week for 4 months is required to achieve improvement in lipid and lipoprotein levels, primarily increased HDL-C and decreased triglyceride levels. This implies the need for a sustained amount of moderate to vigorous physical activity on a regular basis to induce and maintain the beneficial effect. The role of weight loss in mediating the effect of activity on lipid and lipoprotein levels has not been studied in youth.

Blood pressure. Little evidence supports the efficacy of or need for exercise training to reduce blood pressure in normotensive youth. A meta-analysis[62] and comprehensive review[63] indicate no clear association between physical activity and reduction of blood pressure in normotensive youth. Limited studies of youth with systemic hypertension show a beneficial effect of aerobic activity programs of 12 to 32 weeks duration on blood pressure[64-66] Strength training after an aerobic intervention prevents the return of blood pressure to pre-intervention levels in hypertensive adolescents.[67] However, an 8-week strength training program by itself has no influence on blood pressure in hypertensive youth.[68] Overall, data suggest that a physical activity intervention with a duration (at least 30 minutes), frequency (3 times/week), and intensity sufficient to improve aerobic fitness (approximately 80% of maximal heart rate) can be in reducing blood pressure in youth with mild essential hypertension. Continued physical activity is necessary to maintain the beneficial effect.

Other cardiovascular variables. Studies of physical activity in relation to hemostasis (fibrinogen),[30,69-73] inflammation (high sensitivity C-reactive protein),[72,74,75] and endothelial function[76-78] are inconclusive, but experimental studies indicate a beneficial effect of activity on cardiovascular autonomic tone.[56,79]

Cardiovascular fitness (aerobic fitness). Correlational studies indicate low-to-moderate positive relationships between physical activity and maximal and submaximal indicators of aerobic fitness. Comparisons of habitually active and less-active children and adolescents show better levels of aerobic fitness in the former.[15,80-97] Experimental training studies with youth 8 years and older indicate improvements in aerobic fitness.[21,24,34,58,61,64,98-109] Successful programs ordinarily involve continuous vigorous activity (eg, 80% of maximal heart rate) for >30 minutes at least 3 days per week.[110,111] Change with systematic training averages approximately 10% (3-4 mL/kg/min).

Asthma

Comparisons of population-based and convenience samples of youth with asthma give inconsistent results. Physical activity levels are higher,[112,113] lower,[114] or not different[112,115-117] in asthmatic compared with non-asthmatic youth. However, higher levels of activity are associated with greater reporting of asthma[115] or related symptoms (eg, whistling, wheezing[116]) in asthmatic youth. Some,[117-119] but not all,[120-122] studies indicate lower levels of aerobic and anaerobic fitness in youth with asthma. Risk of developing asthma may be associated with overweight in boys[123] and girls.[124] Controlled aerobic programs (2-3 sessions/week for at least 6 weeks)[125-128] result in improved aerobic and anaerobic fitness in youth with asthma, but are not associated with systematic improvements in pulmonary function[126,128,129] or exercise-induced bronchoconstriction.[126-128]

Mental Health

Indicators of mental health in youth were delimited to anxiety, depression, and self-concept. There are too few studies of physical activity and other important aspects of mental health, such as perceived stress,[130-132] emotional distress,[133-134] and perceived vigor or exhaustion.[133,135] Moreover, the dearth of prospective population cohort studies[136,137] and randomized controlled trials[138] limits conclusions about causality in results that are derived mainly from cross-sectional and quasi-experimental studies.

Anxiety and depression. Cross-sectional studies suggest weak positive associations between physical activity and lower scores on scales of anxiety[132,139-141] and depression symptoms,[130,132,141-147] whereas quasi-experimental studies show strong positive influences of physical activity and improvement on measures of anxiety[132,135] and depression symptoms.[132,135,148-150] The influence of physical activity on anxiety and depression symptoms varies with mode of activity.

Self-concept. Self-concept refers to the perception of self, whereas self-esteem refers to the value placed on one's

self-concept. Self-concept comprises several domains—academic and non-academic, social and emotional, and physical (sport competence, strength or endurance, appearance). The structure of self-concept changes with age and becomes more clearly differentiated in the transition into puberty and during adolescence. Cross-sectional studies suggest a moderately positive association between physical activity and physical self-concept, but weak positive associations between physical activity and global, social, and academic self-concept.[133,139,140,143,145,151-162] Quasi-experimental studies[135,149,150,163-188] indicate strong positive effects of physical activity on physical (sport competence) and global self-concept and weaker positive effects on social and academic self-concept. The influence of physical activity on self-concept may be mediated by mode of activity, with beneficial effects associated with aerobics, aerobics combined with strength/flexibility activities, dance, perceptual-motor, and cognitive behavioral modifications to augment physical activity. Although sport activities are positively associated with global self-concept, they have the potential for negative influence. Coaching and teaching styles are particularly relevant to the self-concept in organized sport[189] and physical education.[190]

Academic Performance

Indicators of academic performance include grade point average, scores on standardized tests, and grades in specific courses; measures of concentration, memory, and classroom behaviors are indirect estimates. The addition of physical education to the curriculum results in small positive gains in academic performance.[191-193] The quasi-experimental data also suggest that allocating more curricular time to programs of physical activity does not negatively affect academic achievement, even when time allocated to other subjects is reduced.[194] Some results also suggest a relative increase in academic performance per unit of time.[194,195] Cross-sectional observations show a positive association between academic performance and physical activity[142,196-199] and physical fitness.[200] Physical activity has a positive influence on concentration and memory[201-209] and on classroom behavior.[194] Mechanistic studies of cognitive function also suggest a positive effect of physical activity on intellectual performance.[210]

Injuries

Children and adolescents incur injury in physical activities associated with recreation, free play, organized and unorganized sport, and physical education. Most data are case series based on convenience samples from emergency departments or sports medicine clinics. Other data are from accident reports, insurance records, interviews, and retrospective questionnaires. Variation in definition of injury, inadequate exposure data, and lack of description of the population at risk limits the value of much of the published research in drawing valid conclusions about the risks of injury to children and adolescents associated with a given physical activity.[211] Descriptive longitudinal studies of injury in several high school sports are an exception.[212,213] These studies have a known denominator, relatively accurate exposure data, immediate access to treatment by an athletic trainer, and a well-designed data collection system.

Although limited, information on injuries related to physical education classes suggests that the injury rate is nearly 0 during 20-minute sessions held 3 times/week,[214-217] whereas the prevalence of injury in a supervised after school program is low, 0.0016 per student hour.[218]

Musculoskeletal Health and Fitness

Muscular strength and endurance. Although muscular strength and endurance were not among the primary health outcomes initially examined, panel members recommended inclusion because they are important components of physical fitness. Correlational studies and cross-sectional comparisons give equivocal results relating physical activity to indicators of muscular strength and endurance,[81,94,219-225] but longitudinal studies of adolescents indicate a positive influence of habitual physical activity on upper body muscular endurance.[81,220,223] Experimental studies of resistance training 2 or 3 times per week (with a day of rest between training sessions) show improvements in muscular strength and endurance during childhood and adolescence.[226-241] Most studies focus on pre-adolescent children, and strength gains are not associated with muscular hypertrophy.[230,232,237,241] Muscular hypertrophy in association with gains in strength with resistance training occurs in adolescent boys,[242] but data for adolescents of both sexes are limited.

Bone mineral. The tensile and compressive forces associated with muscular contractions during weight-bearing activities and specialized exercises such as strength/resistance training have a favorable influence on skeletal tissue. Case studies,[243,244] correlational studies,[245-252] retrospective studies of activity in childhood in relation to bone mass in adulthood,[253-259] comparisons of habitually active and inactive children and adolescents,[260-266] and comparisons of elite young athletes with less active youth[267-281] indicate a beneficial effect of physical activity on skeletal health. The osteogenic influence of physical activity is generally site-specific and related to local mechanical strains. The benefits are reflected in bone mineral content, bone mineral density, and bone mineral apparent density. Prospective studies of children with varying levels of current or past physical activity,[282-287] and experimental studies give similar results in pre-pubertal boys and in girls who were either prepubertal[215,257,288-292] or in the early stages of puberty.[216,293-295] The experimental studies generally involve programs of 10 to 60 minutes duration of moderate to high-strain activity (impact, weight bearing) for 2 to 3 or more days per week. The benefits are not as clearly established for adolescents[214,295,296] in later stages of puberty (primarily girls).

DISCUSSION

Discussions of the benefits of physical activity for youth are often framed in the context of the future health status of

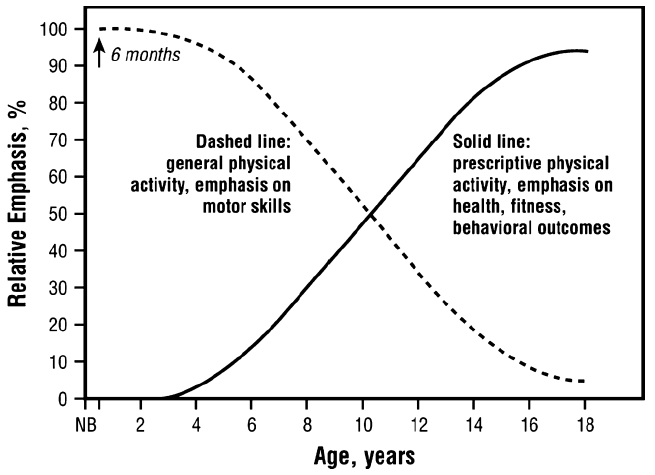

Figure. Changing emphasis of physical activity during childhood and adolescence. The figure is modified after R. M. Malina. Fitness and performance: adult health and the culture of youth, new paradigms? In: R. J. Park and M. H. Eckert, editors. New possibilities, new paradigms? (American Academy of Physical Education Papers No. 24). Champaign, IL: Human Kinetics Publishers; 1991. p. 30-8.

the individual. It is also important to consider physical activity as it relates to the multiple demands of childhood and adolescence associated with physical growth, biological maturation, and behavioral development. These processes vary considerably among individuals, occur simultaneously and interact, and provide the backdrop against which youth evaluate their own status among peers, especially during adolescence. This backdrop has implications for many decisions youth make, including those about physical activity.

Evidence-based data are strong for beneficial effects of physical activity on musculoskeletal health, several components of cardiovascular health, adiposity in overweight youth, and blood pressure in mildly hypertensive adolescents. Evidence is adequate to make informed judgments about the beneficial effects of physical activity on lipid and lipoprotein levels and adiposity in normal weight children and adolescents, blood pressure in normotensive youth, other cardiovascular variables, self-concept, anxiety, and depression symptoms, and academic performance. A definition of the MS for youth is not yet firmly established. However, the association between the MS and adiposity, lipid and lipoprotein levels, and blood pressure suggests that regulation of overweight through physical activity may have a beneficial effect on components of the syndrome.

Recommendations

School-age youth should participate every day in 60 minutes or more of moderate to vigorous physical activity that is enjoyable and developmentally appropriate. Interventional studies indicate specific amounts of physical activity necessary for beneficial changes in the skeletal health, aerobic fitness, and muscular strength and endurance of youth, and in adiposity in youth who are overweight (Table). Activity protocols varied somewhat among studies, but most used programs of continuous moderate to vigorous activities for 30 to 45 minutes duration for 3 to 5 days per week. It is reasonable, however, to expect that the amount of physical activity necessary to achieve similar or greater beneficial effects in the context of ordinary daily activities, which are typically intermittent, would be substantially more than indicated in controlled experimental conditions. This is generally consistent with rationale for prior recommendations.[4] Moreover, allowing for inter- and intra-individual differences in physical activity and in response to physical activity among free-living children and adolescents, 60 minutes or more of moderate to vigorous physical activity on a daily basis is consistent with desired health and behavioral outcomes.

Physical activities of children and adolescents vary with age, type of exercise, and setting. Physical activity begins in infancy with pushing up, turning, crawling, and eventually walking, and it progresses to more complex activities as neuromuscular control develops. Basic movement patterns develop during preschool ages and are the foundation for a wide range of physical activities at later ages. With growth, maturation, and experience, basic movements are integrated and coordinated into more specialized and complex movement skills that characterize the free play, games, sports, and other activities of school-age youth. Guided instruction and supervised practice, specifically by qualified teachers, coaches, and others who work with children, are important in learning movement skills. Types and contexts of activities are variable and change with age during childhood and adolescence. Activities of children aged 6 to 9 years are largely anaerobic (as in non-sustained activities or games such as "tag"), and they help the child learn basic and more specialized motor skills. As youth move into the pubertal transition (about age 10-14 years, earlier in girls than in boys), these skills are incorporated into a variety of individual and group activities and many organized sports. Mature structure and function are approached or attained in late adolescence (age 15-18 years), so that physical activity programs can be more structured.

Recommended priorities for physical activities during childhood and adolescence relative to the development of skills and to behavioral, health, and fitness benefits are schematically illustrated in the Figure. During the preschool and early school ages, general movement activities develop movement patterns and skills (dashed line in Figure). As these basic movements become established and skills improve, health, fitness, and behavioral components of physical activities increase in importance (solid line in Figure). Health-related activities include those that emphasize cardiovascular and muscular endurance and muscular strength and those that involve weight bearing. The setting of physical activity is especially important in achieving positive behavioral outcomes. Although there is less emphasis on the development of motor skills during adolescence, refinement of those skills is important and new movement skills can be learned and can contribute to a physically active lifestyle.

Activities are generally classified as low, moderate, and vigorous intensity on the basis of METs (metabolic

equivalents for specific activities on the basis of the ratio of activity to resting energy expenditure). Tables of MET values for a variety of activities based largely on measurements in adults are available.[297] Because exercise energy expenditure per unit of body mass is higher in children and adolescents than in adults,[298] these MET values have limitations. Nevertheless, moderate-to-vigorous activities require about 5 to 8 METs,[4] and such intensity is needed to derive most health benefits. Brisk walking, bicycling, and active outdoor playing ordinarily reach this criterion.

The recommended 60 minutes or more of physical activity can be achieved in a cumulative manner in school during physical education, recess, intramural sports, and before and after school programs. In this regard, the Centers for Disease Control recommends daily quality physical education from kindergarten through grade 12. Both physical education and recess afford opportunities to achieve the daily physical activity goal without any evidence of compromising academic performance. Opportunities to influence youth participation in physical activities are readily available at home and school, as well as in community and health care settings.

Physical inactivity is a strong contributor to overweight. Sedentary activities such as excessive television viewing, computer use, video games, and telephone conversations should be discouraged. Reducing sedentary behaviors to <2 hours per day is important to increasing physical activity and to health.

The decline in physical activity during adolescence is of special concern.[299-301] Data from several European countries highlight the importance of involvement in community-based sport clubs during adolescence as an important predictor of physical activity in adolescence.[302-306] Restoration of intramural sport programs and expansion of the school day for such programs in middle and high schools may provide opportunities for all students to be physically active.

For youth who have been physically inactive, an incremental approach to the 60-minute goal is recommended. Increasing activity by 10% per week, an approach used in athletic training, appears to be acceptable and achievable. Attempting to achieve too much too rapidly is often counterproductive and may lead to injury.

Risk of overweight[307] and sedentary behavior[308] are increasingly evident in children aged 2 to 5 years, which has implications for subsequent ages. It is important to promote physical activity and limit the amount of physical inactivity beginning with the preschool child. The family unit, the pediatric community, day care centers, and preschools are important contributors to encouraging healthy behaviors. Children live at home and receive their health care in a variety of settings, including a pediatrician or family practitioner's office, clinics, and public health facilities. The child's health care providers should routinely screen for overweight and inactivity and counsel parents and other care givers about the health risks of overweight and the health benefits of physical activity, not only for the child, but also for the parents. At home, in day care, and in preschool, children should be regularly encouraged to be active and to explore. The amount of time that they are restrained from being active should be minimized. Two recent sets of guidelines for the promotion of physical activity among youth are excellent sources of information on this topic.[309,310] Physicians are important in this process and should be strong advocates of a physically active lifestyle for youth at home and in schools and communities.

CONCLUSIONS

Increasing the level of habitual moderate- to vigorous-intensity physical activity in youth is a health promotion and a disease-prevention strategy. Sedentary youngsters should progress toward the recommended level of physical activity gradually. The recommendations are consistent with presently available scientific evidence and are also in general accord with recommendations promoted by governmental agencies[4,311,312] and professional organizations.[3,313,314]

APPENDIX

American Cancer Society; American Academy of Kinesiology and Physical Education; American Diabetes Association; American Heart Association; American College of Sports Medicine; American Academy of Pediatrics; Centers for Disease Control and Prevention, National Association for Sport and Physical Education; National Cancer Institute; National Heart, Lung and Blood Institute; National Institute of Arthritis and Musculoskeletal and Skin Diseases; National Institute of Child Health and Human Development; National Institute of Diabetes and Digestive and Kidney Diseases; National Center for Health Statistics; Robert Wood Johnson Foundation; US Department of Agriculture; US Department of Health and Human Services, Office of Public Health Science; and the US Department of Health and Human Services, Office of Disease Prevention and Health Promotion, President's Council on Physical Fitness and Sports.

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