Preventive Medicine 95 (2017) S17–S27

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Using cost-effectiveness analysis to prioritize policy and programmatic approaches to physical activity promotion and obesity prevention in childhood

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ARTICLE INFO

Article history:
Received 28 April 2016
Received in revised form 17 October 2016
Accepted 18 October 2016
Available online 20 October 2016

Keywords:
Physical activity
Cost effectiveness analysis
Youth
Afterschool
School
Childcare
Economic analysis
Obesity

ABSTRACT

Participation in recommended levels of physical activity promotes a healthy body weight and reduced chronic disease risk. To inform investment in prevention initiatives, we simulate the national implementation, impact on physical activity and childhood obesity and associated cost-effectiveness (versus the status quo) of six recommended strategies that can be applied throughout childhood to increase physical activity in US school, afterschool and childcare settings. In 2016, the Childhood Obesity Intervention Cost Effectiveness Study (CHOICES) systematic review process identified six interventions for study. A microsimulation model estimated intervention outcomes 2015–2025 including changes in mean MET-hours/day, intervention reach and cost per person, cost per MET-hour change, ten-year net costs to society and cases of childhood obesity prevented. First year reach of the interventions ranged from 90,000 youth attending a Healthy Afterschool Program to 31.3 million youth reached by Active School Day policies. Mean MET-hour/day/person increases ranged from 0.05 MET-hour/day/person for Active PE and Healthy Afterschool to 1.29 MET-hour/day/person for the implementation of New Afterschool Programs. Cost per MET-hour change ranged from cost saving to $3.14. Approximately 2500 to 110,000 cases of children with obesity could be prevented depending on the intervention implemented. All of the six interventions are estimated to increase physical activity levels among children and adolescents in the US population and prevent cases of childhood obesity. Results do not include other impacts of increased physical activity, including cognitive and behavioral effects. Decision-makers can use these methods to inform prioritization of physical activity promotion and obesity prevention on policy agendas.

1. Introduction

Participation in recommended levels of physical activity promotes a healthy body weight and reduced chronic disease risk (U.S. Department of Health and Human Services, 2008). National guidelines recommend that children and adolescents engage in 60 min of moderate to vigorous physical activity (MVPA) each day and suggest the importance of strategies to promote activity in school and early care settings (U.S. Department of Health and Human Services, 2008; U.S. Department of Health and Human Services, 2012). Many children do not meet the recommended physical activity (PA) levels (Troiano et al., 2008) and consume excess empty calories (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). As children enter adolescence, PA opportunities at school decline dramatically (Lee et al., 2007), and overall levels of daily PA drop as well (Troiano et al., 2008). The Institute of Medicine recommends that schools take a "whole-of-school approach" to provide students with 60 daily minutes of physical activity, at least half of which should occur during the school day (Institute of Medicine, 2013). For U.S. policymakers facing constrained societal resources, existing research provides limited guidance in how to prioritize implementation of policies based on their cost, effectiveness, population impact and feasibility (Babey et al., 2014; Wu et al., 2011; Dietz and Gortmaker, 2016).

1.1. Within-school approaches to promoting physical activity

Key components of a school-based approach to promote physical activity include high quality physical education (PE) and opportunities for physical activity during the school day through recess (Institute of

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http://dx.doi.org/10.1016/j.ypmed.2016.10.017
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Medicine, 2013; Centers for Disease Control and Prevention, 2015; National Association for Sport and Physical Education, 2008; American Academy of Pediatrics Council On School Health, 2013). High-quality curricular PE during which students spend at least half of class time engaged in MVPA is recommended (Institute of Medicine, 2013). However, less than one-quarter of students are provided with the recommended amount of PE (Turner et al., 2012). Recess, regularly scheduled periods for unstructured active play, is offered by nearly all elementary schools (Turner et al., 2012), and elementary school children typically spend more time in recess than PE classes each week (Robert Wood Johnson Foundation, 2007). However, schools often lack optimal levels of resources (e.g., supervision, play facilities, equipment) that encourage physical activity among children (National Association for Sport and Physical Education, 2006). On average, children spend <50% of both PE (Nader, 2003; McKenzie et al., 1996; Sallis et al., 1997; UCLA Center to Eliminate Health Disparities and Samuels and Associates, 2007) and recess (Stratton, 2000) time engaged in MVPA.

1.2. Promoting activity outside of school hours

Offering PA opportunities in afterschool programs may help children achieve the recommended daily PA not achieved during school hours. About 10.2 million children (18%) participate in after school programs, and many (45%) are from low-income households (Afterschool Alliance, 2013). However, there is considerable unmet demand for afterschool programs in the U.S. In 2014, an estimated 19.4 million children not enrolled in a program would be if one were available, with affordability of afterschool programs and transportation identified as key obstacles (Afterschool Alliance, 2013). Parents in low-income households are more likely to report a lack of available programs. Also, despite research showing the benefits of increased PA opportunities in afterschool programs (Salcedo Aguilar et al., 2010; DeRenne et al., 2008; Madsen et al., 2009; Martinez Vizcaino et al., 2008; Weintraub et al., 2008; Madsen et al., 2013; Kaestner and Xu, 2007; Kaestner and Xin, 2010; Lubans and Morgan, 2008), only five states require afterschool programs to provide a minimum amount of time for MVPA and state policies mandating adoption of national guidelines are lacking (Beets et al., 2010; After School Network, 2013).

1.3. Physical activity in early childhood education settings

The early care and education (ECE) setting can have a profound influence on young children's PA. ECE programs serve 64.3% of 3–5 year olds in the U.S. who attend for about 30 h per week (Snyder and Dillow, 2013). Almost 50% of the between-child variation in PA is associated with the ECE center a child attends (Pate et al., 2004; Finn et al., 2002). Few programs train staff in appropriate strategies to encourage young children to be physically active (Gooze et al., 2010; Whitaker et al., 2009; Trost et al., 2009) and few ECE programs allot 60 min daily for PA (McWilliams et al., 2009), resulting in children spending very little of their ECE time—as little as 3%— in MVPA (Pate et al., 2004; Pate et al., 2008; Sugiyama et al., 2012; Reilly et al., 2006; Cardon and De Bourdeaudhuij, 2008).

Research has documented effective strategies to promote physical activity in schools, afterschool programs, and early education settings. To inform investment in prevention initiatives, we simulate the national implementation, impact on physical activity and childhood obesity and associated cost-effectiveness (versus the status quo) of six recommended strategies that can be applied throughout childhood.

2. Methods

2.1. Economic evaluation approach

We used the Childhood Obesity Intervention Cost Effectiveness Study (CHOICES) systematic review process to identify the six interventions with substantial evidence for effectiveness in various settings and age groups. The CHOICES evaluation process is modeled after the Australian Assessing Cost-Effectiveness approach (Carter et al., 2009; Carter et al., 2008) and includes a structured process of engaging a group of national stakeholders in selection of intervention strategies, consultation regarding evidence for effectiveness, potential to reduce obesity, and discussion of implementation and equity issues (Gortmaker et al., 2015a, 2015b; Long et al., 2015; Sonneville et al., 2015; Wright et al., 2015; Barrett et al., 2015).

We used an individual level microsimulation model of the population in the United States to project outcomes of the national implementation of each intervention using U.S. population, mortality, and health care cost data from 2015 to 2025; the model has been described in detail elsewhere (Gortmaker et al., 2015a). Briefly, the model uses data from several national data systems including the Census Bureau, American Community Survey, National Survey of Children's Health, National Health and Nutrition Examination Surveys and the Behavioral Risk Factor Surveillance System. The microsimulation modeling strategy allows researchers to model heterogeneity of individual differences, including exposure to an intervention. In order to assess impact on body mass index (BMI), we compiled longitudinal weight and height data from multiple national longitudinal studies. We conducted probabilistic sensitivity analysis to account for uncertainty in underlying model inputs to calculate 95% uncertainty intervals (UI) using 1000 Monte Carlo iterations for a simulated population of one million individuals scaled to the national population (Carter et al., 2009).

2.2. Intervention and health care cost calculations

We modeled the impact of national implementation of each intervention using the best available data for population eligibility, intervention impact, and implementation cost. Details for each intervention are provided in the Appendices A-G. Further specifics on CHOICES costing protocols following standard guidelines (Gold et al., 1996; Drummond et al., 2005) are available elsewhere (Gortmaker et al., 2015a). All costs were calculated in 2014 dollars and future costs were discounted at 3% annually (Siegel et al., 1996). For each intervention, researchers estimated the incremental costs of national implementation of the intervention by 1) identifying key activities and resources necessary for each activity, 2) measuring the quantity of resources needed to implement (per person, per state or nationally), and 3) valuing those resources in monetary terms. We used a fringe rate of 45.56% based on data from the U.S. Bureau of Labor Statistics on the proportion of total compensation due to wages and amortized capital costs over the useful life (Bureau of Labor Statistics, 2014). We used a modified societal perspective (Siegel et al., 1996), accounting for all costs of the implementation of the intervention, regardless of payer, except the time of the participant in the intervention. Based on a published analysis of data from the 2001–2003 Medical Expenditure Panel survey (Finkelstein and Trogdon, 2008), annual incremental health care costs among children with obesity were estimated to be $220 for children 6–19 years. For adults, annual incremental health care costs increased with age and ranged from $240 at age 20 to $2147 for ages 74 years and older. Health care cost savings were estimated based on the estimated (lower) annual obesity prevalence due to the intervention. Net costs of the intervention were calculated by summing the cost of implementing the intervention and the health care cost savings due to the intervention over the period 2015–2025. Further details are available elsewhere (Gortmaker et al., 2015a).

2.3. Intervention effectiveness estimates

CHOICES project stakeholders and researchers systematically reviewed and prioritized intervention selection based on evidence for effectiveness of physical activity interventions within several settings consistent with the GRADE approach used in the Cochrane Collaboration

(Guyatt et al., 2008; The Cochrane Colllaboration, 2011). A total of 25,378 articles were reviewed, with 109 abstracted and 19 experimental studies were used in estimating effectiveness; details of systematic reviews are provided in the appendices. In all but one case (New Afterschool), intervention effect estimates used for modeling changes in physical activity were derived from objective assessments of changes in MVPA or physical activity intensity. We used a standard conversion from change in MVPA to BMI (Active PE, Active Recess, Active School Day) derived from published literature, or where available, we used objectively measured changes in BMI associated with the intervention (New Afterschool and Hip Hop to Health) (Table 2).

To convert changes in daily minutes of MVPA or vigorous physical activity (VPA) into MET-hours, a metric that incorporates physical activity intensity and duration, we used thresholds of 4 METs for moderate activity and 6 METs for vigorous activity (Trost et al., 2011). Each additional minute spent in MVPA was assigned an incremental increase of 4 METs. Each additional minute spent in VPA was assigned an incremental increase of 2 METs. We converted minutes at a particular activity level to MET-hours by dividing by 60 min/h and multiplying by the MET increase to estimate the daily changes in mean minutes of MVPA per day and mean change in MET-hours per day.

2.4. Outcomes

Primary short-term metrics include estimated additional minutes of MVPA per day and change in MET-hours per day. Other outcomes included intervention cost per person, cost per MET-hour change and cost per BMI unit reduction, and health care cost reductions due to changes in obesity cases. We also modeled the net cost of the intervention over the period 2015–2025 and reductions in BMI associated with implementation to determine the cases of childhood obesity in 2025 prevented by each intervention if implemented at the national level. We assume that effects on BMI are maintained over the period of follow-up (2015–2025).

The interventions discussed here include:

1) **Active Physical Education** (Active PE) is a state-level policy requiring that 50% of time during physical education class be of moderate-to-vigorous activity intensity in classes for children enrolled in public elementary and middle schools in grades K-8 (Appendix A). We assume that the active PE intervention requires state level coordination and monitoring, training for physical education instructors annually, portable equipment and other physical education materials, and school principal training to improve teacher performance through evaluation. We assume that all states without a current comparable physical education policy will adopt and implement all of the intervention activities.
2) **Active Recess** is a district-level, voluntary program increasing physical activity through different strategies including structured physical activities, the installation of playground markings, and/or the provision of portable play equipment implemented at recess, during the school day, within public elementary schools for children grades K-5 (Appendix B). The active recess intervention requires initial and ongoing training for teachers and recess monitors to implement structured play activities. Schools opt to provide portable play equipment and/ or install playground markings in play spaces. We assume that 90% of elementary schools do not currently use active recess strategies and that 50% of these schools adopt and implement the voluntary program. Volunteers install playground markings and schools purchase and replace portable play equipment as necessary. We assume at least one trained monitor per 200 children is present on the playground and that schools implement at least one strategy.
3) **Active School Day** is a district-level policy requiring schools to provide opportunities for at least 150 min of physical activity for children in public elementary and middle schools during the school day via strategies that include active PE and active recess, classroom activity breaks, or other evidence-based strategies (Appendix C). Implementation requires the coordination between the school district and School Wellness Champions to promote physical activity and policy implementation. We assume an annual training for the physical education teachers, School Wellness Champions, and recess monitors in implementing districts. Schools purchase portable play equipment as necessary. We assume that 90% of public elementary and middle schools do not have an active school day policy and that 100% of these schools adopt and implement the intervention.
4) **Healthy Afterschool** is a state policy that establishes a voluntary recognition program for state-administered 21st Century Community Learning Center Afterschool Programs (CCLC) serving children 5–11 years of age (Appendix D). State agencies oversee the recognition and monitoring systems and establish a website. A state trainer facilitates learning collaboratives for afterschool program staff, during which staff receive training on policy and environmental strategies to promote healthy eating and physical activity through improved program practices. Educational materials, incentives, and Continuing Education Units are provided for participants. We assume that 20% of eligible programs will voluntarily participate.
5) **New Afterschool Programs** assumes Title I federal funding is made available to state departments of education to provide children 5–11 years of age with afterschool programs that offer daily 2-h supervised sessions that include physical activity (80 min), academic enrichment activities, homework assistance, and a snack at no cost to families following the FitKid model (Appendix E). New afterschool program staff and coordinators would attend a multi-day training. Programs would provide a snack meeting USDA standards, transportation for 50% of attending children from the school-based program to their home, and relevant program materials. We assume that all children whose parents or guardians would like them to be in an afterschool program and are not currently enrolled in afterschool and attend schools eligible for school-wide Title I status would participate (12%) (Table 1). Federal, state, and district level personnel collaborate in coordination of the afterschool programs and programs are staffed with classroom teachers and para-professionals, with custodial support for each day of programming to enable use of program space. We consider the cost of child care by parents, relatives, and non-relatives in the absence of afterschool programming to be a cost offset owing to the more efficient use of labor in afterschool programs (due to the greater child to caregiver ratio) when compared with other options.
6) **Hip Hop to Health, Jr.** assumes a regulatory policy establishing a mandatory structured physical activity promotion training requirement for licensed ECE programs. State-level child care licensing staff provide oversight and monitoring and state coordinators provide trainings for ECE program staff in implementation of Hip Hop to Health, Jr. to meet this requirement (Appendix F). Resources for implementing the Hip Hop to Health, Jr. program include portable equipment, curricular materials, and specialized CDs and handouts. We assume that all states without an existing licensing requirement for staff training in providing structured physical activity will adopt and implement this training requirement.

Further details on each of the interventions, assumptions on intervention uptake and population reached, effect and key activities included in costing are presented in Tables 1-3 and Appendices.

3. Results

The estimated national reach for each intervention in the first year varies widely and ranges from 90,000 youth attending a designated healthy afterschool program to >31.3 million youth reached by Active School Day policies (Table 4). The limited reach of the Healthy Afterschool program is primarily due to the small proportion of all US children served by existing federally funded, state administered 21st CCLC afterschool programs (Afterschool Alliance, 2015) and the

Table 1
Estimated reach of interventions for six childhood obesity prevention interventions in the United States, 2015–2025.

	Intervention					
	Active PE	Active recess	Active school day	Healthy afterschool	New afterschool	Hip hop to health, Jr.
Population target	Ages 5–14	Ages 5–11	Ages 5–14	Ages 5–11	Ages 5–11	Ages 3–5
Enrolled/ participating	Public school students grades K-8 100% grades 1–8 and 77% kindergarten enrolled full day (Child Trends, 2015) 96% receiving PE (Office of the New York State Comptroller, 2008; Health Impact Assessment Group, UCLA School of Public Health, 2007)	Public school students grades K-5	Public school students grades K-8 100% grades 1–8 and 77% kindergarten enrolled full day (Child Trends, 2015)	2.1% of children ages 5–11 attend 21st Century Learning afterschool programs (Afterschool Alliance, 2015; Afterschool Alliance, 2014)	Attend schools with school wide Title I status	41.2% of children attend a licensed ECE program (National Association for Regulatory Administration, 2013)
Without policy or Program[a]	All states but TX, AZ, OK, & DC (Carlson et al., 2013; Levi et al., 2009)	90% of schools without active recess strategy (Lounsbery et al., 2011)	88% of grade K-5 and 91% of grade 6–8 students without current policy specifying 150 physical activity minutes per week (Child Trends, 2015)	All states but CA[c]	12% of all elementary school age children attend schools with school wide Title I status and do not participate in afterschool programming but would if it were available (Afterschool Alliance, 2014; Keaton, 2012	All states without an existing licensing requirement for staff training in promoting structured physical activity (all states) [c]
Adopting policy or Program[a]	100% of states without a policy[b]	50% of eligible schools adopt active recess strategies[b]	100% of districts adopt policy[b]	19.6% of eligible programs voluntarily adopt standards(Assembly Committee on Appropriations, 2014)	100% of eligible schools adopt the program[b]	100% of states without policy[b]
Implementation of policy or Program[a]	71% of trained PE teachers implement the policy (Hoelscher et al., 2004; McKenzie et al., 2003)	100% among schools adopting[b]	100% among districts adopting[b]	100% among programs adopting[b]	100% among programs adopting[b]	73% of trained programs implement the curriculum (Ward et al., 2008)

PE, physical education; ECE, early care and education.
[a] All values presented are means estimated using 1000 model iterations based on evidence from studies as described in Appendices.
[b] Values are based on assumptions (uniformly used across all similar types of interventions based on intervention description of either a mandatory policy (100%) or voluntary program adoption (50%).
[c] Data derived from author review of state policy or regulation.

Table 2
Estimated[a] effect of interventions on physical activity, Kcals and body mass index change for six childhood obesity prevention interventions in the United States, 2015–2025.

	Intervention					
	Active PE[b]	Active recess[c]	Active school day	Healthy afterschool	New afterschool	Hip hop to health, Jr.
Change in physical activity	6.26 percentage point increase in % PE class time spent in MVPA (Lonsdale et al., 2013)	13.4 percentage point increase in % MVPA during recess (Stratton, 2000; Huberty et al., 2013; Janssen et al., 2013; Kelly et al., 2012; Ridgers et al., 2010; Stratton and Mullan, 2005; Verstraete et al., 2006; Yıldırım et al., 2014; Blaes et al., 2013)	3.9 min per school day increase in MVPA (Cradock et al., 2014)	3.2 min per day increase in VPA during afterschool programming (Cradock et al., 2016)	0.32 h per day increase in MVPA (Howe et al., 2010)	7.43 min per day increase in MVPA (Fitzgibbon et al., 2011)
Change in kcal	N/A	N/A	N/A	1.53 kcal/min reduction per minute change in VPA 47 kcal reduction in snack consumed per day attending afterschool programs (Lee, 2013)	N/A *Estimate of intervention impact directly on BMI incorporates changes in kcal consumption due to snack provision during program time	N/A *Estimate of intervention impact on BMI also incorporates possible changes in child energy intake attributable to intervention
Change in weight/BMI	0.02 BMI reduction per 1-min change in MVPA per day (Kriemler et al., 2010) [d]	0.02 BMI reduction per 1-min change in MVPA per day (Kriemler et al., 2010) [d]	0.02 BMI reduction per 1-min change in MVPA per day (Kriemler et al., 2010) [d]	1 kg change in weight per 46 kcal/day change in energy balance (range 38–56 kcal/day per kg based on age and sex) (Hall et al., 2013) [e]	0.33 BMI reduction directly due to the intervention (Howe et al., 2010; Barbeau et al., 2007; Yin et al., 2005; Hillman et al., 2014)	0.13 BMI reduction directly due to the intervention (Kong et al., 2016)

PE, physical education; MVPA, moderate to vigorous physical activity; VPA, vigorous physical activity; N/A, not applicable; BMI, body mass index.
[a] All values presented are means estimated using 1000 model iterations based on evidence from studies as described in Appendices.
[b] At baseline 94.2 weekly minutes of PE for elementary school students and 149.5 for middle school students (Turner et al., 2010; Johnston et al., 2014).
[c] At baseline 19.4 daily minutes of recess (Carlson et al., 2013).
[d] Change in total MVPA on school days was assumed to equal the change in MVPA during school (Long et al., 2013; Baggett et al., 2010; Goodman et al., 2011; Dale et al., 2000; Morgan et al., 2007). Average daily change in MVPA was calculated by multiplying change on school days by 180 school days/365.25 calendar days per year.
[e] Children attend afterschool programming on average for 32 weeks per year and 5 days per week, out of 365.25 calendar days per year.

Table 3
Estimated intervention costs (US $ millions) over 10 years[a] for six childhood obesity prevention interventions in the United States, 2015–2025.

Cost category	Active PE	Active recess	Active school day	Healthy afterschool	New afterschool	Hip hop to health, Jr.
Coordination	<1% of costs: $3.82 State PE coordinator for coordination & monitoring	NA	83% of costs: $12,800 District staff time for coordination and development and purchasing of materials	41% of costs: $21.0 Regulation communications, compliance monitoring, and website maintenance	15% of costs: $4700 Federal, state, district and transportation coordinators	1% of costs: $11.4 Compliance review during site visits
Training	29% of costs: $272 PE teacher, principal, and facilitator time; training materials; and travel	64% of costs: $406 Teacher, recess monitor, and facilitator time and travel	2% of costs: $285 PE, recess, and movement breaks training costs, including substitute teachers, training materials, and travel	8% of costs: $3.92 Train-the-trainer and learning community costs, including facilitator and program staff time, materials and incentives, and travel	3% of costs:$925 Group leader, program site director, food service director, and facilitator time	58% of costs: $624 Program staff, program administrator, and facilitator time and travel
Materials & equipment	70% of costs: $654 Active PE curricula & materials	36% of costs: $229 Portable equipment & playground marking materials	2% of costs: $380 Active PE and movement breaks curricula & equipment and policy implementation guidance materials	NA	1% of costs: $425 Intervention curriculum, handbook, and physical activity equipment	41% of costs: $446 Hip hop to health, Jr. materials package
Implementation	NA	NA	13% of costs: $1640 Wellness champion stipend and PE instructional coach time	51% of costs: $25.8 Changing individual snacks to meet requirements	80% of costs: $26,400 Transportation, snacks, and personnel for program operations	NA
Cost offsets (cost savings)	NA	NA	NA	NA	−$78,700 Time of caregivers (parents, relatives and non-relatives) who would have otherwise been providing care for children in the absence of afterschool programming	NA
Total cost including offsets	$930	$635	$15,100	$50.7	−$46,200	$ 1080

PE, physical education; NA, not applicable. Total Cost including Offsets may not reflect the sum of individual Cost Category costs due to rounding.
[a] All values presented are means estimated using 1000 model iterations (rounded to three significant digits) based on evidence from studies as described in Appendices. Additional details in Appendix A through G.

Table 4
Estimated short-term and ten-year cost-effectiveness and economic outcomes for six childhood obesity prevention interventions in the United States, 2015–2025.

Intervention	Short-term outcome metrics[a]					Ten-year outcome metrics[b]		
	First year population reached, millions	Mean change in MET-hour per day per person (UI)	Average annual cost per person reached (UI)	Cost per MET-hour per day change (UI)[c]	Cost per BMI unit change per person (UI)	Health care cost savings US $ millions (UI)[e]	Net cost US $ millions (UI)	Cases of childhood obesity prevented in 2025[f] (UI)
Sector: School								
Active PE	21.7	0.05 (0.01, 0.12)	$4.29 ($3.53, $5.49)	$0.23 ($0.10, $1.57)	$818 ($536, $2780)	$35.4 ($4.66, $53.6)	$894 ($841, $1094)	13,652 (154, 21,330)
Active recess	11.3	0.09 (0.01, 0.27)	$5.64 ($3.21, $8.03)	$0.16 ($0.05, $1.76)	$541 ($236, $2470)	$41.7 ($8.25, $61.1)	$594 ($315, $869)	24688 (5115, 36458)
Active school day	31.3	0.13 (0.06, 0.19)	$48.48 ($48.06, $48.92)	$1.05 ($0.68, $2.32)	$2825 ($2467, $5591)	$171 ($79.8, $203)	$14,982 ($14,872, $15,110)	73,589 (35,709, 89,126)
Sector: Afterschool								
Healthy afterschool	0.09	0.05 (0.03, 0.07)	$53.87 ($41.16, $91.82)	$3.14 ($1.97, $6.42)	$367 ($237, $717)	$4.01 ($1.67, $7.01)	$46.7 ($31.7, $68.1)[b]	2558 (951, 4786)[b]
New afterschool programs	3.3	1.29 (1.11, 1.47)	-$1423 (−$1696, −$530)	Cost-saving[d]	Cost-saving[d]	$185 ($98.9, $277)	-$46,435 (−$56,165, −$15,004)[b]	109,973 (58,558, 168,455)[b]
Sector: Early care and education								
Hip hop to health, Jr.	4.8	0.50 (0.10, 0.88)	$22.64 ($22.15, $23.13)	$0.13 ($0.07, $0.54)	$361 ($-2031, $3454)	$67.2 (−$63.2, $179)	$1014 ($900, $1143)[b]	93,065 (−88,279, 248,174)[b]

Note: Costs are in 2014 US Dollars; UI, 95% Uncertainty Interval.
[a] Based on published estimate of change in minutes of moderate to vigorous physical activity or physical activity intensity only.
[b] Based on estimate of change in minutes of moderate to vigorous physical activity or physical activity intensity and energy intake, or where available, measured change in Body Mass Index.
[c] Average Annual Intervention Cost per person / (Average annual MET-hour/day ⁎ 365.25 days/year).
[d] It is customary not to report a negative incremental cost-effectiveness ratio (Drummond et al., 2005).
[e] The difference in obesity-related costs between the baseline and intervention scenario.
[f] Cases of obesity prevented is estimated at the end of the period 2015–2025.

proportion of those programs that are assumed to voluntarily participate (Assembly Committee on Appropriations, 2014). Conversely, the majority of children in the US are enrolled in public schools, most of which do not have strong existing policies regarding provision of physical activity during the school day (Chriqui et al., 2013; Centers for Disease Control and Prevention and Bridging the Gap Research Program, 2014), resulting in a larger population reach (Table 4).

The average annual intervention cost per person reached ranged from -$1423 for the New Afterschool Program intervention to $54 for the Active School Day intervention (Table 4). The cost-savings for the New Afterschool Program are primarily due to the cost-offset for caregiver costs borne by families for care during the afterschool hours for children (Table 3) due to the substantial efficiencies from higher child to afterschool staff ratios compared to other care options (Appendix E). For other interventions such as the Active School Day and Healthy Afterschool, total costs are driven by costs for labor and materials (including food in afterschool programs) necessary to implement the intervention (Table 3).

Mean MET-hour/day increases ranged from 0.05 MET-hour/day for Active PE and Healthy Afterschool to 1.29 MET-hour/day for the implementation of the New Afterschool Programs (Table 4). The afterschool sector was host to interventions with a large range in estimated cost per MET-hour/day change, ranging from cost saving (New Afterschool) to $3.14 per MET-hour/day (Healthy Afterschool). The school sector interventions ranged in cost per MET-hour change from $0.16 (Active Recess) to $1.05 (Active School Day). For young children, the Hip Hop to Health, Jr. was estimated to cost $0.13 per MET-hour/day.

All interventions were expected to result in a reduction in cases of childhood obesity in 2025 compared to the base case of no intervention (Table 4). However, the 95% UI for the estimate of the number of cases of childhood obesity prevented by national implementation of Hip Hop to Health, Jr. includes zero. In Healthy Afterschool, New Afterschool, and Hip Hop to Health, Jr., the impact on obesity prevention may also be attributable in part to nutrition education and the provision of healthier foods during program time. Based on our model, the New Afterschool intervention is expected to result in the largest reduction of cases of childhood obesity. It is projected to prevent >109,000 cases of childhood obesity in 2025 and be cost-saving, with a projected net cost over 10 years of -$4.6 billion (95% UI: -$5.6 -$1.5 billion) Note that the bulk of this cost-savings comes primarily from the more efficient use of labor for childcare in the afterschool hours. Other obesity prevention interventions ranged in 10-year net costs from $47 million for Healthy Afterschool programs to $15 billion for Active School day (Table 4).

4. Discussion

All of the six interventions studied have solid evidence for effectiveness in increasing physical activity based on evaluation of experimental studies. They are estimated to increase physical activity levels among children and adolescents in the US population and prevent cases of childhood obesity. These estimates of national implementation of interventions within schools, afterschool programs, and early childhood education settings, key sectors and settings for children and adolescents, include estimates of the expected short-term and 10-year outcomes that can inform prevention strategy implementation. If we are to make significant inroads in reducing the rate of increase in the prevalence of childhood obesity, action must be taken across a variety of sectors and settings.

The ability to systematically estimate the national impact and cost-effectiveness of implementation of physical activity promoting interventions enables our ability to compare within and across sector-specific interventions to inform investment in primary prevention. The average annual cost per person reached for each of these physical activity-promoting interventions implemented nationally would be less than $54.00. Early childhood interventions, though implemented at a higher cost, may increase the likelihood that children enter elementary school at a healthy weight. Findings may help prioritize within sectors when comparable data are available. For example, within the school sector, Active Recess ($0.16 per MET-hour/ day) and Active PE ($0.23 per MET-hour/day) were superior to Active School Day ($1.05 per MET-hour/day) based on a short-term metric of cost-effectiveness. However, Active Recess and Active PE interventions are anticipated to reach smaller total populations of youth each year compared to the Active School Day intervention, which would prevent over 73,000 cases of childhood obesity if implemented nationally.

It is critical to note these population impacts arise from interventions that vary in their expected cost, and the sectors on which these cost burdens (or offsets) would fall (Appendix G). For example, funding opportunities for New Afterschool Programs for elementary age children, on average, would result in considerable cost savings to society over 10 years, while also preventing some 110,000 cases of childhood obesity. We project the New Afterschool Programs will result in obesity-related health care cost savings of $185 million in ten years. However, the majority of overall cost-savings is due to the cost-offset arising from greater efficiencies in care for children, including time that would otherwise be spent caring for children if the afterschool programs were not in place, a direct cost for families. There are projected 10-year obesity-related health care cost savings associated with each intervention (Table 4). All interventions will require investment in training, infrastructure and equipment to benefit child health. In many cases, intervention implementation costs are assumed to be borne by the school, district, state or program implementing the intervention. Efforts to offset costs to school or district budgets may be needed to foster implementation of these strategies.

4.1. Study limitations and strengths

This information may be useful for decision-making, funding, and state actions for implementation because it can help key stakeholders to understand the value of implementing effective evidence-based programs using estimates of cost, reach, and effect. Using a modified societal perspective on costing of interventions and determining payer may help with implementation and scaling of interventions because it identifies needed areas of alliances and funding support for implementation. Understanding the driving costs of interventions will also inform the development and testing of more efficient strategies for intervention implementation.

Ten-year metrics are based on measured changes using objective measures of physical activity or BMI derived from experimental studies in schools, afterschool programs, and early childhood education settings. This strategy has been employed in some (Wu et al., 2011) but not all (Babey et al., 2014) prior economic analyses of youth physical activity interventions. Furthermore, while there is evidence for success in scaling some similar interventions at the state-level (Hoelscher et al., 2004; McKenzie et al., 2003), none of the interventions modeled have been implemented and evaluated on a national scale. Accuracy of modeled outcomes would depend on actual levels of dissemination and implementation and assume that any effects on BMI experienced during the intervention are neither augmented nor erased in subsequent years. However, unlike prior studies (Babey et al., 2014; Wu et al., 2011), our microsimulation modeling strategy explicitly incorporates known uncertainty in intervention inputs for effect, cost, and reach (Table 1-3 and Appendix A-G).

This study moves beyond the short-term cost effectiveness estimates found in prior studies (Babey et al., 2014; Wu et al., 2011) comparing school-based physical activity interventions among youth by estimating the ten-year population reach, intervention costs and impacts of physical activity promotion interventions on childhood obesity. However, these are conservative estimates of the overall impact of these physical activity interventions as we have focused solely on the health care costs attributed to obesity within a ten-year modeling framework. Physical activity is associated with many other important health benefits separate from obesity prevention (U.S. Department of Health and Human Services, 2008), that are not captured by this modeling framework. While consistent across interventions, this strategy does not account for potential cost-offsets related to morbidity and mortality due to insufficient physical activity, independent of BMI (Schmid et al., 2015), assuming that physical activity gains are maintained in adulthood. While there is little existing evidence for preventive effects of physical activity on health care costs and utilization in childhood (Idler et al., 2015), there is evidence that physical activity patterns (Craigie et al., 2011) and BMI (Freedman et al., 2005; Power et al., 1997) track into adulthood. Physical inactivity is associated with increased health-related costs in adults (Peeters et al., 2014). Thus, using a 10-year modeling horizon does not account for those diseases attributable to physical inactivity that may occur later in life but is a conservative choice based on the increase in uncertainty after many decades of child growth and development.

5. Conclusion

All six interventions studied are estimated to increase physical activity levels among children and adolescents in the US population and prevent cases of childhood obesity. Decision-makers can use these methods to inform prioritization of physical activity promotion and obesity prevention on policy agendas.

Conflict of interest

The authors declare there is no conflict of interest.

Acknowledgment

This work was supported in part by grants from The JPB Foundation, the Robert Wood Johnson Foundation (Grant No. 66284), the Donald and Sue Pritzker Nutrition and Fitness Initiative, and the Centers for Disease Control and Prevention (Grant No. U48/DP001946). This work is solely the responsibility of the authors and does not represent the official views of the Centers for Disease Control and Prevention or any of the other funders.

Appendix A–E. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2016.10.017.

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