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The State of the Summer: a Review of Child Summer Weight Gain and Efforts to Prevent It

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Abstract

Purpose of Review—Accumulating evidence shows that children in the USA gain weight more rapidly during the summer, when school is not in session. This narrative review spanning 2007 to 2017 summarizes efforts to characterize the problem, identify key determinants, and intervene to prevent excess summer weight gain.

Recent Findings—Summer weight gain remains a concern for elementary-age youth. Few studies have examined its determinants, but unfavorable summertime shifts in diet, physical activity, sedentary time, screen media use, and sleep have been reported. Increased structure is thought to protect against summer weight gain. Interventions to support physical activity and nutrition during the summer show promise, though large-scale impact on weight outcomes remains to be seen.

Summary—Supporting health behaviors during the summer remains a priority for obesity prevention researchers, practitioners, and policymakers. Strategies to expand access to structured programs and reach beyond such programs to improve behaviors at home are of particular importance.

Keywords

Child obesity; Summer weight gain; Out of school time; Seasonal weight gain

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Compliance with Ethical Standards

Human and Animal Rights and Informed Consent All reported studies/experiments with animal or human subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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Introduction

Obesity currently affects more than 18% of children in the USA, and despite coordinated national efforts to address the issue, rates have continued to rise since the turn of the millennium [1]. Children with obesity are at increased risk for a range of short- and long-term metabolic, cardiovascular, respiratory, and psychosocial consequences and premature mortality [2–4]. There is an urgent need for effective programs and policies to prevent child obesity and thereby reduce its toll on quality and length of life.

In an effort to reach a large number of children, significant emphasis has been placed on improving the school environment [5]. Over the past decade, progress includes improvements to the nutritional profile of school meals and regulation of competitive foods sold at school [6], expansion of programs that increase availability of high-quality fruits and vegetables [7, 8], and implementation of school-based obesity prevention programs designed to help children move more, eat better, and develop skills to support healthy choices [9].

Far less emphasis has been placed on the out-of-school environment. For most American children, the longest span of time spent away from school is during the summer break, which typically spans from June to August and comprises over 20% of the year [10]. A growing body of evidence shows that summer break promotes obesity to a greater extent than the school year [11•, 12•]. These findings have important implications for the effectiveness of school-year obesity prevention efforts and overall progress toward reversing the obesity epidemic. Further, there is evidence that black and Hispanic [13] and overweight youth [13, 14]—children already at increased risk for obesity—are more susceptible to excess summer weight gain than their peers. It appears that summer break may amplify health disparities just as it has been shown to amplify disparities in academic progress [15].

Little is known about the primary causes of excess summer weight gain or the role of demographic and socioeconomic factors, but as the issue gains attention, more researchers have begun to explore its determinants. Establishing evidence-based targets for intervention can help pinpoint program and policy efforts, address a potential cause of health disparities, and ensure that children return to school no less healthy than when they left for summer break.

This narrative review summarizes the research on summer weight gain among school children in the USA, its potential determinants, and early efforts to intervene. Because summer weight gain is a relatively new area of focus in child obesity prevention, we have described key papers published from 2007 to 2017. The review concludes with a summary of gaps in knowledge and suggests priorities for researchers and practitioners who wish to work toward a healthier summer break for all children.

Summer Weight Gain Among Schoolchildren in the USA

The first major study of summer weight gain among American children was published by von Hippel and colleagues in 2007 [13]. The researchers analyzed height and weight data from 5380 children in the Early Childhood Longitudinal Study, Kindergarten (ECLS-K) Cohort 1998–1999, a nationally representative sample. On average, BMI gain was more than

two times greater during the summer between kindergarten and first grade than during either school year. In addition, black and Hispanic children and those who were already overweight were disproportionately affected. The authors noted that although schools have absorbed substantial blame for the rise of child obesity in the USA, they may, in fact, have a protective effect against child obesity compared to the summer, particularly for children who are overweight upon entering kindergarten.

Moreno and colleagues extended these findings with a 5-year longitudinal study of summer weight change in 3588 kindergarteners in Southeast Texas [14]. On average, participants lost weight while school was in session and gained weight during the summer. Overweight and obese children's BMI z-scores increased to a greater extent than their healthy-weight peers during the summer. Interestingly, the BMI z-scores of overweight and obese children decreased during the school year, further supporting the notion that school has a protective effect for this population relative to summer. In contrast to the von Hippel study, no significant difference in summer weight gain by race/ethnicity was observed.

A follow-up analysis of 7599 ethnically diverse students published by Moreno and colleagues in 2015 showed that the magnitude of summer weight gain was greatest in the summer after first grade, and though the pattern of accelerated summer weight gain persisted, it decreased in magnitude as children approached fifth grade [16•]. Another analysis of these data showed that children were more likely to transition to a higher weight category during the summer months than the school year [17]. These findings emphasize the importance of intervening to prevent summer weight gain in the early elementary years.

In 2016, von Hippel and Workman conducted an updated nationally representative analysis of seasonal weight change [18••]. Once again, the researchers used ECLS-K data, this time from the 2010–2011 cohort, which provided a sample of 13,006 children tracked from the start of kindergarten through the start of second grade. In alignment with previous ECLS-K findings [13], BMI increased more rapidly during the summers than the school years. On average, summer weight gain surpassed school-year weight gain by 0.04 kg/m^2 per month. The prevalence of overweight and obesity only increased during the summer periods, never during the school year [18••]. Variability of BMI growth was three times greater in the summer compared to the school year, suggesting that the school year has a more consistent effect on BMI than summer. In contrast to the earlier nationally representative analysis of summer weight gain [13], this study did not reveal significant differences in summer weight gain by race/ethnicity, sex, maternal education or employment, or family income. However, the overall magnitude of summer weight gain was similar across both studies.

These findings were mirrored in a large study of older elementary school students in Massachusetts. Researchers compared school year and summer weight change in a sample of 769 socioeconomically and ethnically diverse third and fourth graders and found that on average, BMI increased more rapidly in the summer than during the school year [Tanskey L, Goldberg J, Chui K, Must A, Sacheck J. 2017. Excess summer weight gain in a low-income, ethnically diverse sample of elementary school children in Massachusetts. In review.]. The magnitude of this difference (gains of 0.046 kg/m^2 more per month during the summer) was nearly identical to that observed in the most recent ECLS-K analysis [18••]. The findings

affirm that summer weight gain does remain a concern as children approach middle school. Notably, no significant differences were observed by race/ethnicity or baseline weight status.

Only one study [19] has specifically assessed seasonal weight change among middle school students, and it contrasts with findings from younger populations. Daratha and colleagues found that in a predominantly white population of 865 middle school students in the Pacific Northwest, summer was associated with beneficial changes in BMI compared to the school year [19]. Given the ethnic homogeneity of this study, further research in ethnically diverse populations is needed to clarify whether summer weight gain is a concern for middle school students.

Studies assessing seasonal weight change among high-risk groups have yielded mixed results. A 2014 study by Rodriguez and colleagues assessed seasonal differences in BMI z-score and percent body fat in a sample of 119 low-income, Hispanic youth ages 8 to 12 years old [20]. The school year appeared to have a protective effect for overweight children, whose BMI z-scores decreased during that interval but not during the summer. However, among girls, percent body fat increased significantly over both the school year and the summer. And while both boys and girls improved their aerobic endurance during the school year, progress stagnated over the summer. Overall, these findings suggest that low-income, Hispanic youth may benefit from the school environment and that efforts to sustain these benefits over the summer are needed.

Two published studies describe summer weight change in American Indian children, an at-risk population with a high prevalence of overweight and obesity [21, 22]. A study of summer weight change in third to eighth graders in Wyoming showed greater summertime gains in BMI among overweight and obese children, but these results were not statistically significant when analyzed as BMI z-scores [21]. A second study of 440 kindergartens through first graders in South Dakota [22] detected no excess weight gain during the summer, finding instead that children's BMI z-scores increased more rapidly in first grade than during the previous summer. It is important to note that youth in both studies lived on American Indian reservations, an environment which likely has a unique impact on child weight status and therefore may not generalize to the broader US population.

In 2014, two narrative review articles on summer weight gain were published, each underscoring the importance of the issue and the need for more research [11•, 12•]. One placed particular emphasis on the potential for the detrimental effects of summer to exacerbate health disparities in the USA [12•], and both highlighted the adverse effect summer break can have for children who are already overweight or obese. Both reviews emphasized the need for additional research investigating the extent to which this trend occurs and importantly, the need to explore key contributing factors.

Loss of School-Year Intervention Effects over the Summer

Excess summer weight gain has important implications for the long-term effectiveness of school-year obesity prevention programs. The potential for summer to negate school-year progress was especially apparent in Shape Up Somerville, a community-based participatory intervention implemented from 2002 to 2005 to prevent obesity among children in

Somerville, MA [23]. The intervention featured modifications to the home, community, and before-, during-, and after-school environments to increase children's opportunities for PA and promote healthy dietary choices. After 1 year, the mean BMI z-score of children in Somerville had decreased in comparison to children in control communities [23]. In the second year, when the responsibility of administering SUS was shifted to the community, participants' BMI z-scores once again decreased compared to controls, and the intervention decreased the prevalence of overweight and obesity [24]. However, the 2-year analysis showed a spike in BMI z-scores over the summer, when the intervention dose was less intense. A similar trend was observed for children in the control communities [24]. These findings illustrate the impact the summer break can have on the long-term effectiveness of school-year obesity prevention interventions.

Several studies focused on physical activity promotion have observed loss of intervention effects over the summer break. Researchers implementing a school-based PA intervention in a small group of obese middle school students in Wisconsin saw school year improvements in body fat percentage, cardiovascular fitness, and fasting insulin, but these changes were lost during the summer [25]. Similar summer "washout" effects were observed in larger studies evaluating the FitKid after-school obesity prevention program for third to fifth grade students in the Southeastern United States [26, 27]. These findings emphasize how the summer break can negate progress achieved in school-year fitness programs.

Potential Determinants of Summer Weight Gain

The specific determinants of excess summer weight gain are poorly understood, though they are assumed to be rooted in positive energy balance during the summer months. In their 2014 review, Baranowski and colleagues present a conceptual model of the factors believed to promote excess summer weight gain [11•]. The model centers on energy imbalance as the primary cause of child adiposity. Diet, physical activity, screen media use, and sleep are illustrated as determinants of energy balance. Season (defined throughout as summer vs. school year) is hypothesized to ultimately affect child adiposity by influencing the determinants of energy balance.

With this model as a guide, we present research examining the relationship between season and diet, physical activity and sedentary time, screen media use, and sleep. We also explore lack of structure as a potential driver of excess summer weight gain, as it is a key difference between the school year and the summer and has been identified as a likely cause of excess summer weight gain [11•, 12•, 13, 28].

Diet—Research comparing differences in children's school year and summer dietary patterns is limited. One of the first investigations of the summer diet and physical activity landscape took place in the SASSY (the Summer Activity Study of Somerville Youth) pilot study [28]. Parents completed a one-time food frequency questionnaire to describe their child's summer dietary patterns. While there were no school-year comparison data available, children's summertime diets showed room for improvement. Fruit and vegetable consumption was low while chips, ice cream, baked goods, and sugar-sweetened beverages (SSBs) were regularly consumed during the summer.

An analysis of 2003–2008 National Health and Nutrition Examination Survey (NHANES) data further supports the hypothesis that children's dietary patterns are poorer in the summer [29•]. Comparing dietary data from 1st through 12th graders surveyed during the school year with those surveyed during the summer, researchers observed lower intakes of non-starchy vegetables and higher intakes of added sugar, primarily from sugar-sweetened beverages, during the summer. There was no significant difference in caloric intake by season. However, different children from different geographic regions were surveyed at each time point.

A within-subject comparison of the summer and school year dietary patterns of 103 third and fourth graders in Massachusetts showed that on average, children consumed about a half serving less of vegetables each day in the summer compared to the school year [Tanskey L, Goldberg J, Chui K, Must A, Sacheck J. 2017. A comparison of school year and summer diet and physical activity patterns in elementary school students in Massachusetts. In review.]. Surprisingly, children also consumed fewer servings of salty snacks and sweets in the summer than the school year. No significant difference was observed in fruit or sugar-sweetened beverage consumption. Because the diet screener used in this study did not assess total diet, further research is needed to assess seasonal differences in overall diet and energy intake.

It is reasonable to expect that the school environment promotes better dietary patterns for most children. The National School Lunch Program (NSLP) provides nutritionally balanced meals for over 30 million children each day, approximately two-thirds of whom receive lunch free or at a reduced price [30]. There is evidence that children who participate in the NSLP have better nutritional profiles than non-participants [31, 32]. Through the Healthy, Hunger-Free Kids Act, national guidelines now regulate the nutritional quality of competitive foods sold in schools [33]. As a result, children have more limited access to SSBs, sweets, and energy-dense snack foods during the school day, whereas no similar policy governs the summer.

Food insecurity, which tends to increase in households with children during the summer [34], further complicates the summer nutrition landscape. The USDA's Summer Food Service Program (SFSP) offers free meals to children throughout the summer break, but the program is not widely utilized. In 2016, the SFSP served an average of 2.8 million children per day [35], compared to the 30.4 million children served each day during the school year [36]. Further, the USDA estimates that only one in six children eligible for free or reduced-price meals participates in the SFSP [37]. It is worth noting that the current summer meal patterns set by USDA are not as stringent as the school-year standards in terms of energy and nutrient content [38]. Evaluation of the SFSP and its effects on child weight status is needed; findings would have important implications for how to best attenuate summer weight gain.

Physical Activity and Sedentary Behavior—There is a large body of evidence spanning multiple countries to show that children's physical activity (PA) patterns vary by season and that children tend to be more active during warmer months than colder months [39]. The available evidence is more limited when looking only at studies that have assessed

PA using accelerometers, a direct measure. A review article by Rich and colleagues found that European children were more physically active in summer than winter [40]. However, of the accelerometer studies conducted in the USA [41–43], only one reported higher child PA levels during the summer [41], and all of these studies involved preschool children.

More recent studies have attempted to characterize seasonal differences in PA using accelerometers, and the findings are mixed. The previously mentioned within-subject analysis conducted in Massachusetts also included a school year and summer comparison of child physical activity [Tanskey L, Goldberg J, Chui K, Must A, Sacheck J. 2017. A comparison of school year and summer diet and physical activity patterns in elementary school students in Massachusetts. In review.]. Accelerometer data from 98 participants showed that on average, children were less physically active in the summer, engaging in 12.8 fewer minutes per day of moderate-to-vigorous physical activity and 26.5 more minutes per day of sedentary activity. Waterproof accelerometers were not used in this study, so aquatic activity was not captured, and summertime PA is likely underestimated in a portion of these children. However, the higher rates of sedentary time observed in summer affirm that interventions are needed to increase movement and decrease inactivity over the summer break. These findings align with a study of 9–11 year-olds in rural Minnesota, which also found unfavorable shifts in PA engagement over the course of the summer, though no school-year comparison was available [44]. Conversely, NHANES data show that children surveyed in summer engaged in about five more minutes of MVPA than children surveyed in the school year [29•]. More accelerometer-based research is needed to characterize summer and school year differences in PA and sedentary behavior among youth in the USA.

Studies using self-reported data also show mixed findings. In the SASSY study [28], parents of second and third graders reported the amount of time children spent in various settings and activity intensity in each setting. This information was translated into a weighted activity score, and the researchers found that children spent a substantial portion of their summer engaging in sedentary and light activity. Children who spent more time in a structured camp setting had a higher activity index than children who spent most of their time in parent care. A repeated cross-sectional comparison of 406 5- to 18-year-olds in Louisiana showed that children surveyed in the summer break reported higher levels of physical activity engagement than those surveyed in the school year [45]. Weather and local climate are also likely to play a role in summertime PA. It remains to be determined whether summer PA patterns differ substantially by geographic region, and how factors such as extreme summer heat influence PA engagement and sedentary time. Though the current findings regarding summer PA engagement are mixed, promotion of PA throughout the whole year remains a priority [46].

Screen Media Use—Screen time, including time spent watching television, playing video games, and using a computer or tablet, is another factor likely to promote summer weight gain. Screen media use has been linked to child and adolescent obesity [47–49]. It not only contributes to sedentary time and displaces PA, but it is also associated with poor diet quality and sleep disruptions [50–52]. Exposure to food marketing through media channels is also likely to affect food preferences and attitudes [53–55]. Wang and colleagues assessed seasonal differences in screen time using NHANES data and found that children surveyed in

the summer watched 18 more minutes of television than children surveyed in the school year [29•]. The aforementioned cross-sectional study of youth in Louisiana also showed higher levels of screen time in the summer compared to the school year, though this finding was attenuated when adjusting for weather [45]. Qualitative research also suggests that children engage in more screen time during the summer. Interviews conducted with 28 parents of third and fourth graders in Massachusetts showed that screen time is more strictly limited in the school year to ensure children complete homework [Tanskey L, Goldberg J, Chui K, Must A, Sacheck J. 2017. Summer weight change among elementary school children in Eastern Massachusetts: a mixed methods study. Manuscript in progress. In review.]. Parents said that screen time rules tend to be much more relaxed when school is not in session. Continued research is needed characterize screen use in the summer, particularly now that screens are increasingly portable and accessible to children.

Sleep—There is considerable evidence linking short sleep duration to obesity in children [56]. Insufficient sleep is thought to promote obesity by altering hormones such as leptin, growth hormone, and stress hormones and impacting appetite, insulin response, and energy expenditure [56]. There is some evidence from New Zealand that children get less sleep in the summer than during the school year [57], though research exploring it as a potential contributor to summer weight gain is limited. Qualitative research with parents of third and fourth graders in Massachusetts indicates that bedtimes tend to be more loosely enforced during the summer than the school year, unless children attend a structured program [Tanskey L, Goldberg J, Chui K, Must A, Sacheck J. 2017. Summer weight change among elementary school children in Eastern Massachusetts: a mixed methods study. Manuscript in progress. In review.]. A study of urban minority girls showed that only about half of participants slept for the recommended 9 h per night during summer [58]. Additional research objectively measuring and comparing sleep in the school year and summer is critical for understanding its role in summer weight gain.

Structure—One notable difference about the summer is the relative lack of structure governing children's days compared to the school year. Researchers have hypothesized that this lack of structure is a driving force behind excess summer weight gain [11•, 12•, 13, 28]. Recently, Brazendale and colleagues formalized this theory with the creation of the Structured Days Hypothesis (SDH) [59•]. The SDH posits that children are less likely to engage in obesogenic behaviors on days with structured, scheduled activities such as school days. Conversely, children are more likely to engage in obesogenic behaviors on days without formal structure, such as summer or weekend days. Because the data comparing school year and summertime obesity-related behaviors are limited, Brazendale and colleagues argue that weekend days provide a reasonable proxy of summer days with regard to structure and that exploration of weekday versus weekend differences in behavior can shed light on the causes of excess summer weight gain. Their analysis of 190 studies comparing weekday and weekend behavior showed that, over-whelmingly, the health behaviors of school-age children were less favorable on weekends. These findings were consistent and compelling across each domain examined: physical activity, sedentary and screen time, sleep, and diet. The authors further hypothesize that the concentration of unstructured days in the summer compounds obesity risk beyond what children experience

on weekends during the school year. More research is needed to understand how closely weekend days mimic summer days, but the SDH provides a strong framework to guide summertime obesity prevention efforts in the interim.

A study of adolescents from a low-income area in Southern Texas further supports the idea that structure, or lack thereof, plays an important role in excess summer weight gain. Students who attended summer school were protected against the excess weight gain and losses in fitness observed in non-participants, even though the program did not specifically promote nutrition or physical activity [60]. Expanding access to structured programs, regardless of their focus on diet and PA, may help attenuate excess summer weight gain.

Efforts to Prevent Summer Weight Gain

Because excess summer weight gain is a relatively newly recognized problem, few interventions have set out to specifically address it. One of the most comprehensive interventions to prevent summer weight gain is Camp NERF (Nutrition Education Recreation and Fitness), an 8-week, theory-based program for at-risk, urban elementary school children and their families in Ohio [61]. Camp NERF is designed to be delivered at USDA summer meal sites to promote nutrition, physical activity, and mental health. In an effort to reinforce program messaging beyond the intervention setting, the Camp NERF program also targets caregivers and youth mentors. A program evaluation is planned and will assess impact on child diet, PA, mental health, social support, body composition, and blood pressure, as well as several caregiver and youth mentor outcomes. The findings will shed light on the effectiveness of multi-component summer interventions, the potential for partnerships with summer meal sites, and the value of engaging parents and youth mentors.

Several other interventions show promise in promoting health behaviors in the camp setting. A large intervention to expand, extend, and enhance opportunities for PA in summer day camps increased the percentage of children attaining 60 min of physical activity each day at camp by more than 10% [62]. The Healthy Lifestyle Fitness Camp, a free summer day camp in Fresno, CA, for overweight and obese youth, provided 3 h of daily moderate physical activity, healthy snacks, and nutrition education [63]. The 6-week program resulted in favorable changes in waist-to-height ratio compared to a control group, and these changes were sustained for at least 2 months post-intervention [63]. Girls in the Game, a Chicago-based summer camp for low-income, ethnic minority girls, shows promise as a way to promote physical activity, healthy eating, and leadership skills in a high-risk population [64]. An evaluation of 46 participants showed increases in overall daily PA and MVPA and substantial decreases in sedentary time, though favorable changes in BMI z-score were not observed [64]. Providing camp staff with competency-based professional development, designed to foster skill building as opposed to rote knowledge, can also support healthy eating and physical activity in summer day camps [62, 65]. Recent studies show that there is room for improvement in the nutritional quality of foods served in camp and brought by campers [66, 67], so efforts to improve the camp food environment are particularly important.

However, only a fraction of children attend camp during the summer, and many camps are only attended for 1–2 weeks. Interventions that extend beyond the camp environment are

critical, especially if children in unstructured settings are at higher risk for summer weight gain. Communication campaigns and community partnerships show promise to reach a larger audience. As an extension of the national VERB physical activity campaign, researchers implemented a VERB Summer Scorecard intervention in Lexington, KY, that successfully increased PA among tween girls [68]. Participants were given a Summer Scorecard on which they could track PA engagement both at home and in community venues such as roller rinks and swimming pools. PA was incentivized with water bottles, Frisbees, beach towels, and chances to win a bike or YMCA membership. The authors also emphasized the potential for schools to promote summer programs and provide a venue for children and families to be active. A Belgian intervention in which traffic was blocked off at specific intervals during the summer to create “Play Streets” substantially increased children’s MVPA and decreased sedentary time [69]. This approach could be adapted to create safe play spaces for urban children in the USA. It is important to identify other strategies to reach youth who do not attend structured programs. Many existing summer health initiatives focus on increasing PA. Increasing the emphasis on nutrition in such programs may further enhance their effectiveness in preventing summer weight gain.

Summer can be characterized as a time when most children have increased exposure to the home environment. Therefore, interventions to improve the home food environment, promote PA, reduce sedentary and screen time, and engage families can play an important role in preventing summer weight gain. Evidence shows that although home-based interventions can reduce sedentary behavior and increase fruit and vegetable consumption, they have not shown beneficial effects on BMI, BMI z-score, or prevalence of overweight and obesity [70]. Few studies have attempted to intervene upon the home environment, and more work is needed to find successful approaches. Efforts to reduce screen time are particularly important given that US youth spend more than 4 h per day using electronic media such as television, computers, mobile devices, and video games [71].

Moreno and colleagues recently published a protocol paper describing plans to conduct a systematic review and meta-analysis of summer interventions to influence BMI and weight-related behaviors [72•]. This review will systematically synthesize efforts to prevent summer weight gain and favorably shift diet, PA, sedentary behavior, screen media use, and sleep. The findings from this review can help identify the most promising strategies for summer obesity prevention, which may then be applied by researchers, practitioners, and policymakers.

Priorities for Research and Practice

As our understanding of summer weight gain grows, more opportunities for impactful research emerge. Few studies have examined seasonal weight change among adolescents, particularly minorities and those from lower-income families. The relationship between household income and summer weight gain has not been clearly defined and likely has important implications for summer health. To our knowledge, no study has explored differences in summer weight gain between rural, suburban, and urban settings. This is a critical area for exploration because evidence shows that rural youth tend to be at significantly higher risk of obesity [73]. Further research is also needed to isolate the key

determinants of summer weight gain, and large, within-subjects analyses can provide much needed information to guide interventions. Of particular importance are studies that objectively measure seasonal differences in physical activity, sedentary time, and sleep and studies that more comprehensively assess diet. To our knowledge, none of the existing studies on summer weight gain have examined the role of community-level factors such as the built environment. Exploration of these factors may reveal ways to effectively intervene and support healthy behaviors on a broader scale.

In an effort to leverage existing, successful obesity prevention programs, it may be beneficial to examine how school-year programs can be extended into the summer. Expanding programs with which children and families are already familiar may be more efficient and effective than developing new programs for the summer. Because structure is hypothesized to benefit youth during the school break, increasing access to structured programs is a priority. Summer camps can be cost-prohibitive for lower-income families, so low-cost or free options are critically needed. A 2016 article from USDA's Team Nutrition emphasizes opportunities to provide nutrition education and physical activity engagement at USDA summer meal sites and highlights free resources for nutrition educators [74]. Given the previously articulated problem of summer learning loss, there is a need for programs that provide a free, healthy meal (through the SFSP), opportunities for structured PA, and academic support. Such programs can help address not only the behavioral risk factors for obesity, but social determinants of health and well-being.

Developing interventions to improve health behaviors at home is a major challenge, but success in this domain can benefit children throughout the entire year. Finding ways to engage caregivers is notoriously difficult, and more work is needed to determine how best to reach and support caregivers so they can reinforce healthy behaviors at home.

Conclusions

Recent studies confirm that excess summer weight gain remains a persistent problem in the USA and stands in the way of meaningful progress to reduce rates of overweight and obesity. While researchers have identified likely determinants of excess summer weight gain —poor diet, physical in-activity, increased sedentary and screen time, inadequate sleep, and lack of structure—additional research is needed to understand how these factors interact and to clarify opportunities for intervention. Early efforts to prevent summer weight gain show promise, but many are focused on summer day camps, which reach only a fraction of youth. Expanding access to structured summer programs, ensuring a health-promoting environment in those programs, and identifying ways to reach children who do not attend summer programs remain priorities.

References

Papers of particular interest, published recently, have been highlighted as:

• Of importance

•• Of outstanding importance

1. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015–2016. NCHS Data Brief. 2017;(288):1–8.
2. Yanovski JA. Pediatric obesity. An introduction. Appetite. 2015;93: 3–12. 10.1016/j.appet.2015.03.028. [PubMed: 25836737]
3. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes. 2011;35(7):891–8. 10.1038/ijo.2010.222.
4. Biro FM, Wien M. Childhood obesity and adult morbidities. Am J Clin Nutr. 2010;91(5):1499S–505S. 10.3945/ajcn.2010.28701B. [PubMed: 20335542]
5. Institute of Medicine, The National Academy of Sciences. Accelerating progress in obesity prevention: solving the weight of the nation. Washington, DC, 2012.
6. Public Law 111–296: The healthy, hunger-free kids act of 2010.
7. Olsho LE, Klerman JA, Ritchie L, Wakimoto P, Webb KL, Bartlett S. Increasing child fruit and vegetable intake: findings from the US Department of Agriculture Fresh Fruit and Vegetable Program. J Acad Nutr Diet. 2015;115(8):1283–90. 10.1016/j.jand.2014.12.026. [PubMed: 25746429]
8. Feenstra G, Ohmart J. The evolution of the School Food and Farm to School Movement in the United States: connecting childhood health, farms, and communities. Child Obes. 2012;8(4):280–9. 10.1089/chi.2012.0023. [PubMed: 22867064]
9. Sobol-Goldberg S, Rabinowitz J, Gross R. School-based obesity prevention programs: a meta-analysis of randomized controlled trials. Obesity. 2013;21(12):2422–8. 10.1002/oby.20515. [PubMed: 23794226]
10. Mahoney JL. Adolescent summer care arrangements and risk for obesity the following school year. J Adolesc. 2011;34(4):737–49. 10.1016/j.adolescence.2010.08.010. [PubMed: 20863556]
11. •Baranowski T, O'Connor T, Johnston C, Hughes S, Moreno J, Chen TA, et al. School year versus summer differences in child weight gain: a narrative review. Child Obes. 2014;10(1):18–24. 10.1089/chi.2013.0116. [PubMed: 24367922] A narrative review of summer weight gain featuring a conceptual model of influences on seasonal differences in BMI
12. •Franckle R, Adler R, Davison K. Accelerated weight gain among children during summer versus school year and related racial/ethnic disparities: a systematic review. Prev Chronic Dis. 2014;11:E101 10.5888/pcd11.130355.A systematic review of accelerated summer weight gain covering studies published between 2005 and 2013, with a focus on racial/ethnic disparities
13. von Hippel PT, Powell B, Downey DB, Rowland NJ. The effect of school on overweight in childhood: gain in body mass index during the school year and during summer vacation. Am J Public Health. 2007;97(4):696–702. 10.2105/AJPH.2005.080754. [PubMed: 17329660]
14. Moreno JP, Johnston CA, Woehler D. Changes in weight over the school year and summer vacation: results of a 5-year longitudinal study. J Sch Health. 2013;83(7):473–7. 10.1111/josh.12054. [PubMed: 23782089]
15. Alexander K, Entwisle D, Olson L. Lasting consequences of the summer learning gap. Am Sociol Rev. 2007;72(2):167–80. 10.1177/000312240707200202.
16. •Moreno JP, Johnston CA, Chen TA, O'Connor TA, Hughes SO, Baranowski J, et al. Seasonal variability in weight change during elementary school. Obesity. 2015;23(2):422–8. 10.1002/oby.20977. [PubMed: 25557689] A large longitudinal analysis of data from children in Southeast Texas illustrating a consistent pattern of summer weight gain that diminishes in magnitude over the elementary school years
17. Chen TA, Baranowski T, Moreno JP, O'Connor TM, Hughes SO, Baranowski J, et al. Obesity status transitions across the elementary years: use of Markov chain modelling. Pediatr Obes. 2016;11(2): 88–94. 10.1111/ijpo.12025. [PubMed: 25854860]
18. ••von Hippel PT, Workman J. From kindergarten through second grade, U.S. children's obesity prevalence grows only during summer vacations. Obesity. 2016;24(11):2296–300. 10.1002/oby.21613. [PubMed: 27804271] The most recent nationally representative analysis of summer weight gain, which followed over 18,000 children from kindergarten through second grade
19. Daratha K, Power T, Steele M, Bindler R, Ullrich-French S. Changes in BMI between summer and school months among middle school students. Wash State J Public Health Pract. 2009;2(2): 13–21.

20. Rodriguez AX, Olvera N, Leung P, O'Connor DP, Smith DW. Association between the summer season and body fatness and aerobic fitness among Hispanic children. J Sch Health. 2014;84(4): 233–8. 10.1111/josh.12141. [PubMed: 24617906]
21. Smith DT, Bartee RT, Dorozynski CM, Carr LJ. Prevalence of overweight and influence of out-of-school seasonal periods on body mass index among American Indian schoolchildren. Prev Chronic Dis. 2009;6(1):A20. [PubMed: 19080026]
22. Zhang J, Himes JH, Hannan PJ, Arcan C, Smyth M, Rock BH, et al. Summer effects on body mass index (BMI) gain and growth patterns of American Indian children from kindergarten to first grade: a prospective study. BMC Public Health. 2011;11:951 10.1186/1471-2458-11-951. [PubMed: 22192795]
23. Economos CD, Hyatt RR, Goldberg JP, Must A, Naumova EN, Collins JJ, et al. A community intervention reduces BMI z-score in children: Shape Up Somerville first year results. Obesity. 2007;15(5):1325–36. 10.1038/oby.2007.155. [PubMed: 17495210]
24. Economos CD, Hyatt RR, Must A, Goldberg JP, Kuder J, Naumova EN, et al. Shape Up Somerville two-year results: a community-based environmental change intervention sustains weight reduction in children. Prev Med. 2013;57(4):322–7. 10.1016/j.ypmed.2013.06.001. [PubMed: 23756187]
25. Carrel AL, Clark RR, Peterson S, Eickhoff J, Allen DB. School-based fitness changes are lost during the summer vacation. Arch Pediatr Adolesc Med. 2007;161(6):561–4. 10.1001/archpedi.161.6.561. [PubMed: 17548760]
26. Gutin B, Yin Z, Johnson M, Barbeau P. Preliminary findings of the effect of a 3-year after-school physical activity intervention on fitness and body fat: the Medical College of Georgia Fitkid Project. Int J Pediatr Obes. 2008;3(Suppl 1):3–9. 10.1080/17477160801896457.
27. Yin Z, Moore JB, Johnson MH, Vernon MM, Gutin B. The impact of a 3-year after-school obesity prevention program in elementary school children. Child Obes. 2012;8(1):60–70. 10.1089/chi.2011.0085. [PubMed: 22799482]
28. Tovar A, Lividini K, Economos CD, Folta S, Goldberg J, Must A. School's out: what are urban children doing? The Summer Activity Study of Somerville Youth (SASSY). BMC Pediatr. 2010;10:16 10.1186/1471-2431-10-16. [PubMed: 20334661]
29. •Wang YC, Vine S, Hsiao A, Rundle A, Goldsmith J. Weight-related behaviors when children are in school versus on summer breaks: does income matter? J Sch Health. 2015;85(7):458–66. 10.1111/josh.12274. [PubMed: 26032276] A cross-sectional analysis of nationally representative data to compare obesity-related behaviors in the school year and summer
30. United States Department of Agriculture Economic Research Service. National school lunch program. 2015 http://www.ers.usda.gov/topics/food-nutrition-assistance/child-nutrition-programs/national-school-lunch-program.aspx Accessed 1 May 2015.
31. Briefel RR, Wilson A, Gleason PM. Consumption of low-nutrient, energy-dense foods and beverages at school, home, and other locations among school lunch participants and nonparticipants. J Am Diet Assoc. 2009;109(2 Suppl):S79–90. 10.1016/j.jada.2008.10.064. [PubMed: 19166676]
32. Au LE, Rosen NJ, Fenton K, Hecht K, Ritchie LD. Eating school lunch is associated with higher diet quality among elementary school students. J Acad Nutr Diet. 2016;116(11):1817–24. 10.1016/j.jand.2016.04.010. [PubMed: 27216647]
33. United States Department of Agriculture Food and Nutrition Service. National School Lunch Program and School Breakfast Program: nutrition standards for all foods sold in school as required by the Healthy, Hunger-Free Kids Act of 2010: interim final rule. Fed Regist 78(125) 2013 https://www.gpo.gov/fdsys/pkg/FR-2013-06-28/pdf/2013-15249.pdf. Accessed 2 Febr 2018.
34. Nord M, Romig K. Hunger in the summer. J Child Poverty. 2006;12(2):141–58. 10.1080/10796120600879582.
35. United States Department of Agriculture, Economic research service. Summer Food Service Program 2017 https://www.ers.usda.gov/topics/food-nutrition-assistance/child-nutrition-programs/summer-food-service-program.aspx Accessed 11 Dec 2017.

36. United States Department of Agriculture Economic research service. National School Lunch Program 2017 https://www.ers.usda.gov/topics/food-nutrition-assistance/child-nutrition-programs/national-school-lunch-program/ Accessed 11 Dec 2017.
37. United States Department of Agriculture. Food and nutrition service. Summer Food Service Program (SFSP) 2017 https://www.fns.usda.gov/sfsp/serving-summer-meals Accessed 11 Dec 2017.
38. Hopkins LC, Gunther C. A historical review of changes in nutrition standards of USDA child meal programs relative to research findings on the nutritional adequacy of program meals and the diet and nutritional health of participants: implications for future research and the Summer Food Service Program. Nutrients. 2015;7(12): 10145–67. 10.3390/nu7125523.
39. Carson V, Spence JC. Seasonal variation in physical activity among children and adolescents: a review. Pediatr Exerc Sci. 2010;22(1): 81–92. [PubMed: 20332542]
40. Rich C, Griffiths LJ, Dezateux C. Seasonal variation in accelerometer-determined sedentary behaviour and physical activity in children: a review. Int J Behav Nutr Phys Act. 2012;9:49 10.1186/1479-5868-9-49. [PubMed: 22546178]
41. Rundle A, Goldstein IF, Mellins RB, Ashby-Thompson M, Hoepner L, Jacobson JS. Physical activity and asthma symptoms among New York City Head Start Children. J Asthma. 2009;46(8): 803–9. [PubMed: 19863284]
42. Finn K, Johannsen N, Specker B. Factors associated with physical activity in preschool children. J Pediatr. 2002;140(1):81–5. 10.1067/mpd.2002.120693. [PubMed: 11815768]
43. Burdette HL, Whitaker RC, Daniels SR. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children. Arch Pediatr Adolesc Med. 2004;158(4):353–7. 10.1001/archpedi.158.4.353. [PubMed: 15066875]
44. McCue M, Marlatt K, Sirard J. Examination of changes in youth diet and physical activity over the summer vacation period. Internet J Allied Health Sci Pract 2013; 11(1).
45. Staiano AE, Broyles ST, Katzmarzyk PT. School term vs. school holiday: associations with children's physical activity, screen-time, diet and sleep. Int J Environ Res Public Health. 2015;12(8):8861–70. 10.3390/ijerph120808861. [PubMed: 26264005]
46. Katzmarzyk PT, Denstel KD, Beals K, Bolling C, Wright C, Crouter SE, et al. Results from the United States of America's 2016 report card on physical activity for children and youth. J Phys Act Health. 2016;13(11 Suppl 2):S307–S13. 10.1123/jpah.2016-0321. [PubMed: 27848726]
47. Falbe J, Rosner B, Willett WC, Sonneville KR, Hu FB, Field AE. Adiposity and different types of screen time. Pediatrics. 2013;132(6):e1497–505. 10.1542/peds.2013-0887.
48. Robinson TN, Banda JA, Hale L, Lu AS, Fleming-Milici F, Calvert SL, et al. Screen media exposure and obesity in children and adolescents. Pediatrics. 2017;140(Suppl 2):S97–S101. 10.1542/peds.2016-1758K. [PubMed: 29093041]
49. Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obesity among children in the United States, 1986–1990. Arch Pediatr Adolesc Med. 1996;150(4):356–62. [PubMed: 8634729]
50. Council on Communications Media, Strasburger VC. Children, adolescents, obesity, and the media. Pediatrics. 2011;128(1):201–8. 10.1542/peds.2011-1066. [PubMed: 21708800]
51. Wiecha JL, Peterson KE, Ludwig DS, Kim J, Sobol A, Gortmaker SL. When children eat what they watch: impact of television viewing on dietary intake in youth. Arch Pediatr Adolesc Med. 2006;160(4):436–42. 10.1001/archpedi.160.4.436. [PubMed: 16585491]
52. Reid Chassiakos YL, Radesky J, Christakis D, Moreno MA, Cross C, et al. Children and adolescents and digital media. Pediatrics. 2016;138(5):e20162593. 10.1542/peds.2016-2593.
53. Harris JL, Bargh JA, Brownell KD. Priming effects of television food advertising on eating behavior. Health Psychol. 2009;28(4): 404–13. 10.1037/a0014399. [PubMed: 19594263]
54. Zimmerman FJ, Bell JF. Associations of television content type and obesity in children. Am J Public Health. 2010;100(2):334–40. 10.2105/AJPH.2008.155119. [PubMed: 20019313]
55. Sadeghirad B, Duhaney T, Motaghipisheh S, Campbell NR, Johnston BC. Influence of unhealthy food and beverage marketing on children's dietary intake and preference: a systematic review and meta-analysis of randomized trials. Obes Rev. 2016;17(10):945–59. 10.1111/obr.12445. [PubMed: 27427474]

56. Chen X, Beydoun MA, Wang Y. Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. Obesity. 2008;16(2):265–74. 10.1038/oby.2007.63. [PubMed: 18239632]
57. Nixon GM, Thompson JM, Han DY, Becroft DM, Clark PM, Robinson E, et al. Short sleep duration in middle childhood: risk factors and consequences. Sleep. 2008;31(1):71–8. [PubMed: 18220080]
58. Bates CR, Bohnert AM, Ward AK, Burdette KA, Kliethermes SA, Welch SB, et al. Sleep is in for summer: patterns of sleep and physical activity in urban minority girls. J Pediatr Psychol. 2016;41(6):692–700. 10.1093/jpepsy/jsw009. [PubMed: 26929098]
59. •Brazendale K, Beets MW, Weaver RG, Pate RR, Turner-McGrievy GM, Kaczynski AT, et al. Understanding differences between summer vs. school obesogenic behaviors of children: the structured days hypothesis. Int J Behav Nutr Phys Act. 2017;14(1):100 10.1186/s12966-017-0555-2. [PubMed: 28747186] A comparison of obesogenic behaviors on structured school days and unstructured weekend days to test the hypothesis that structure protects against summer weight gain
60. Park KS, Lee MG. Effects of summer school participation and psychosocial outcomes on changes in body composition and physical fitness during summer break. J Exerc Nutr Biochem. 2015;19(2):81–90. 10.5717/jenb.2015.15052005.
61. Hopkins LC, Fristad M, Goodway JD, Eneli I, Holloman C, Kennel JA, et al. Camp NERF: methods of a theory-based nutrition education recreation and fitness program aimed at preventing unhealthy weight gain in underserved elementary children during summer months. BMC Public Health. 2016;16(1):1122 10.1186/s12889-016-3765-7. [PubMed: 27784290]
62. Weaver RG, Brazendale K, Chandler JL, Turner-McGrievy GM, Moore JB, Huberty JL, et al. First year physical activity findings from turn up the HEAT (Healthy Eating and Activity Time) in summer day camps. PLoS One. 2017;12(3):e0173791. 10.1371/journal.pone.0173791.
63. George GL, Schneider C, Kaiser L. Healthy lifestyle fitness camp: a summer approach to prevent obesity in low-income youth. J Nutr Educ Behav. 2016;48(3):208–12 e1. 10.1016/j.jneb.2015.12.010. [PubMed: 26965098]
64. Bohnert AM, Ward AK, Burdette KA, Silton RL, Dugas LR. Active summers matter: evaluation of a community-based summertime program targeting obesogenic behaviors of low-income, ethnic minority girls. New Dir Youth Dev. 2014;2014(143):133–50. 10.1002/yd.20107. [PubMed: 25530244]
65. Weaver RG, Beets MW, Turner-McGrievy G, Webster CA, Moore J. Effects of a competency-based professional development training on children's physical activity and staff physical activity promotion in summer day camps. New Dir Youth Dev 2014;2014(143):57–78. doi:10.1002/yd.20104.
66. Kenney EL, Lee RM, Brooks CJ, Cradock AL, Gortmaker SL. What do children eat in the summer? A direct observation of summer day camps that serve meals. J Acad Nutr Diet. 2017;117(7): 1097–103. 10.1016/j.jand.2017.01.026. [PubMed: 28330733]
67. Tilley F, Beets MW, Jones S, Turner-McGrievy G. Evaluation of compliance to national nutrition policies in summer day camps. Public Health Nutr. 2015;18(9):1620–5. 10.1017/S1368980014001190. [PubMed: 24909716]
68. Alfonso ML, Thompson Z, McDermott RJ, Colquitt G, Jones JA, Bryant CA, et al. VERB summer scorecard: increasing tween girls' vigorous physical activity. J Sch Health. 2013;83(3):164–70. 10.1111/josh.12012. [PubMed: 23343317]
69. D'Haese S, Van Dyck D, De Bourdeaudhuij I, Deforche B, Cardon G. Organizing "Play Streets" during school vacations can increase physical activity and decrease sedentary time in children. Int J Behav Nutr Phys Act. 2015;12:14 10.1186/s12966-015-0171-y. [PubMed: 25888734]
70. Showell NN, Fawole O, Segal J, Wilson RF, Cheskin LJ, Bleich SN, et al. A systematic review of home-based childhood obesity prevention studies. Pediatrics. 2013;132(1):e193–200. 10.1542/peds.2013-0786. [PubMed: 23753095]
71. Bassett DR, John D, Conger SA, Fitzhugh EC, Coe DP. Trends in physical activity and sedentary behaviors of United States youth. J Phys Act Health. 2015;12(8):1102–11. 10.1123/jpah.2014-0050. [PubMed: 25347913]

72. •Moreno JP, Vezina-Im LA, Vaughan EM, Baranowski T. Impact of child summertime obesity interventions on body mass index, and weight-related behaviours: a systematic review and meta-analysis protocol. BMJ Open. 2017;7(10):e017144. 10.1136/bmjopen-2017-017144.A protocol describing what will be the first systematic review and meta-analysis of the impact of summertime obesity prevention and treatment interventions

73. Johnson JA 3rd, Johnson AM. Urban-rural differences in childhood and adolescent obesity in the United States: a systematic review and meta-analysis. Child Obes. 2015;11(3):233–41. 10.1089/chi.2014.0085. [PubMed: 25928227]

74. White AH, Maroto ME. Summer meal programs provide an opportunity for nutrition education and physical activity. J Acad Nutr Diet. 2016;116(6):905–7. 10.1016/j.jand.2016.04.003. [PubMed: 27235641]