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Children's Obesogenic Behaviors During Summer Versus School

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Children’s Obesogenic Behaviors During Summer Versus School

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Dedication

This dissertation is dedicated to the University of South Carolina’s Department of Exercise Science.
Acknowledgements

I would like to acknowledge several people that have helped me throughout my doctoral degree. First, and foremost, I would like to acknowledge my mentor, Dr. Beets, for providing me with a rich research experience and for his continuous feedback and guidance which has helped me grow and develop as an independent researcher. I would also like to thank Dr. Weaver for his support and mentorship over the past four years. Last but not least, I would like to thank my wife, Allison, for her continuous love and support, and all my family both here in the U.S. and back home in my native Scotland.
Abstract

Emerging evidence shows children gain 3-5 times the amount of weight and lose cardiorespiratory fitness (CRF) during summer compared to the 9-months of the school year. Notably, this trend is more pronounced in children who are already overweight or obese going into summer and/or from low-income ethnic minority households. There is little evidence to investigating the underlying mechanisms driving the pronounced occurrence of these negative health outcomes during summer.

The purpose of this dissertation as a whole was to investigate children’s obesogenic behaviors (physical activity, sedentary/ screen time, sleep, and diet) during summer versus school, and compare any differences in relation to changes in health outcomes (body mass index and CRF).

The purpose of study 1 was to provide a scientific hypothesis to explore some of the differences between summer and school months, in absence of a larger literature base to draw from. The Structured Days Hypothesis (SDH) posits that obesogenic behaviors are beneficially regulated when children are exposed to a structured day (i.e., school weekday) compared to what commonly occurs during summer. In this study, the author examined empirical data that compares weekend day (less-structured) versus weekday (structured) obesogenic behaviors in U.S. elementary school-aged children. From 190 studies, 155 demonstrated elementary-aged children’s obesogenic behaviors are more unfavorable during weekend days compared to weekdays. In light of this evidence, the SDH would suggest that structured environments (e.g., weekdays/schooldays) may
protect children by regulating obesogenic behaviors, such as exposure to compulsory physical activity opportunities, restricting caloric intake, reducing screen time occasions, and regulating sleep schedules. Summer days may be less-structured thereby allowing negative obesogenic behaviors to occur at a greater rate and for an extended period of time.

The purpose of study 2 was to examine elementary school-aged children’s obesogenic behaviors (physical activity (PA), sedentary/screen-time, diet, and sleep) during school versus summer using a repeated-measures within-subjects design. Children (n=55 mean age=8.2 years; 57% female; 37% overweight/obese; 100% African American) wore accelerometers on the non-dominant wrist and parents completed a daily diary for 9 consecutive days. Children spent more time sedentary (69 vs. 67% of wake weartime), less time in light PA (25 vs. 23% of wake weartime), had higher screen-time (242 vs. 123 min/day), slept longer (428 vs. 413 mins/night), and consumed more sugar-based foods (6 days vs. 2.5 days/week) and fruit (7 days vs. 4.7 days/week) during summer compared to school (p<0.05). Initial evidence suggests children are displaying multiple unfavorable obesogenic behaviors during summer compared to school that may contribute to the accelerated weight gain during summer. Longitudinal evidence with larger, more diverse samples of children is necessary to identify specific behavioral targets for interventions during summer.

The purpose of study 3 was to investigate changes in children’s obesogenic behaviors between summer and school in relation to their changes in body mass index (BMI) and CRF during summer. Elementary school-aged children had their BMI and CRF measured before (May) and after (August) summer (2016). A 9-day protocol
captured physical activity, sedentary/ screen time, sleep and diet during school (May) and summer (July). There was a small negative association for zBMI change and healthy summer behaviors ($r=-0.36; \ p=0.09$), and a positive association for CRF change ($r=0.31; \ p=0.14$) and healthy summer behaviors. Children who increased in zBMI and displayed a concurrent loss in CRF over summer presented less favorable obesogenic behaviors during summer. Further research is needed to confirm this relationship.

This dissertation provides preliminary evidence of differences in children’s obesogenic behaviors during summer versus school and how unfavorable obesogenic behaviors occurring during summer could be impacting health outcomes occurring during this time. Summer may be the critical period where future childhood obesity efforts need to be focused, however, longitudinal evidence with larger, more diverse samples of children is necessary to identify specific behavioral targets for interventions during summer.
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Chapter I: Introduction
Over the past 50 years prevalence of obesity in U.S. children between the ages of 6 and 11 years has quadrupled, with the most recent estimates from the Center for Disease Control and Prevention (CDC) estimating 31.8% of children and adolescents aged 2-19 years are classified as either overweight or obese. The CDC defines overweight or obese as having a BMI at or above the 85th percentile or 95th percentile, respectively, in relation to sex-specific CDC BMI-for-age growth charts. Current statistics show the prevalence of overweight/obesity is higher among children from low socioeconomic families and minority races (e.g., Hispanics, African Americans). Because obesity has been associated with increased risk for developing non-communicable diseases, it is recognized as a major public health concern. Although the primary causes of childhood obesity are far from conclusive, the majority of intervention strategies targeting prevention have focused on physical activity, sedentary/screen time, sleep, and diet.

*Physical Activity (PA)*

The World Health Organization has cited energy imbalance (i.e., calories consumed > calories expended) as one of the fundamental causes of childhood obesity. Physical activity is a primary component of energy expenditure and increases in childhood obesity, both on a global scale and here in the U.S., are in part due to a lack of daily PA. There are several benefits of regular PA including improved aerobic fitness, blood pressure, body composition, and psychological health. Because of the important role PA can play in the health and well-being of children, the U.S. government developed national daily PA recommendations for children and adults. Specifically, children should achieve 60 minutes or more of moderate-to-vigorous PA (MVPA) per day. Research has
shown how U.S. children are falling short of these recommendations; with the most recent national data showing only 42% of children ages 6-11 year met this daily goal.\textsuperscript{10} It is clear that the majority of children are not meeting PA recommendations for health benefits, thus it is likely this lack of PA is one of the main driving factors behind the childhood obesity epidemic in the U.S.

*Sedentary/Screen Time*

Sedentary behavior can be defined as sitting and lying during waking hours, with very low levels of energy expenditure.\textsuperscript{11} Such behaviors can consist of leisure-time activities such as TV viewing, playing video games, and using a computer, all commonly referred to as screen time. Other sedentary behaviors can be attributed to sitting during school or work.\textsuperscript{12} Research has shown the amount of time children spend sedentary has increased in recent years, with objectively measured data from 2005 and 2010 NHANES reporting U.S. children aged 6-11 years spend approximately six hours per day sedentary, both during and outside of school.\textsuperscript{12}

Reducing the time children spend sedentary has become a public health concern as higher levels of objectively measured sedentary time are associated with increased adiposity\textsuperscript{13,14} and an adverse cardio-metabolic risk profile in children.\textsuperscript{15} Of note, increased sedentary time is independent of PA levels,\textsuperscript{16,17} therefore, daily recommendations pertaining to sedentary time, specifically screen time, have been suggested for U.S. children. For example, the American Academy of Pediatrics recommends that parents limit school-age children’s total daily ST to two hours per day.\textsuperscript{18} Several large scale studies (sample range ~8,000 to ~68,000 children) have
reported that anywhere between 20-45% of U.S. children aged 4 to 17 years old surpass this 2-hour daily recommendation for screen time.19-21

Sleep

Current national guidelines recommend school-aged children should achieve ≥10 hours per night of sleep.22 Several studies report that school-aged children are continuing to fall short of this recommendation, with sleep estimates for U.S. children falling between 8 to 9 hours per night.23-26 A recent review by Chaput et al. (2015) on sleep deprivation in children concluded that not sleeping enough during childhood is a predictor of childhood obesity.27 Other studies, both longitudinal and experimental, have shown that short sleep duration in children is associated with weight gain, greater health risk, and a greater likelihood of being classified as Overweight or Obese.23-35 Further, children from ethnic minority backgrounds typically sleep less25 and obese children displayed shorter sleep duration and more variability in their sleep duration on weekends, compared with school days.26

A review by Miller et al. (2015) addressed some of the potential underlying mechanisms (e.g., biological, behavioral) that could be driving the obesity-sleep association.32 Two of the mechanisms explored were poor sleep-timing and variable patterns of sleep schedules. From their review, a handful of studies examined sleep timing and obesity in early childhood, reporting that late bedtimes (after 9 p.m.) independently predicted the association between short sleep duration and obesity.36,37 In addition, children and adolescents (ages 9–16 years) demonstrating a late-bedtime/late-rise time pattern were more likely than those with an early-bedtime/early-rise time pattern to be overweight and engage in more screen time and less physical activity.38 Research
has also found associations between children who sleep near a small screen, have a TV in their bedroom and watch more TV before bed with shorter sleep durations, particularly in children from low SES home environments.

Diet

As previously stated, energy imbalance (i.e., calories consumed > calories expended) is one of the fundamental causes of childhood obesity. Appropriate dietary intake is important for the optimal growth and development of children, and can reduce the risk of obesity, high cholesterol, high blood pressure, and the development of chronic diseases. For children aged 2 years or older, The Dietary Guidelines for Americans recommends a diet rich in fruits and vegetables (FV), whole grains, and fat-free/low-fat dairy products. The guidelines also suggest that children and adolescents should limit the intake of solid fats, added sugars and refined grains. National reports reveal that most U.S. children and adolescents are not meeting the recommendations for daily FV consumption or whole grains. Further, children’s diets are full of excess salt, added sugars and solid fats, with approximately 40% of their daily calories coming from these ‘empty calorie’ or fast-food sources such as sugar-sweetened beverages (SSB), grain desserts, pizza and whole milk. Studies have found associations between a poor diet and the prevalence of children being Overweight or Obese, with greater fast-food consumption observed in ethnic minorities, such as AA.

The vast majority of children spend a large portion of their childhood in schools, thus schools are in a unique position to promote healthy eating, appropriate food and nutrient intake through daily opportunities to consume healthy foods. The CDC recognized the “critical role” schools have in improving the dietary behaviors of children.
and adolescents and put forth School Health Guidelines (2011) to promote healthy eating among children and adolescents.

Largely, these four obesogenic behaviors have been investigated during school time (e.g., PE, recess, classroom) or in school-related environments (e.g., before/after school programs). This is understandable given the amount of time children spend in these domains over the 9 months of the school year.\textsuperscript{6} Evidence from some of the largest school-based longitudinal intervention studies have shown modest to little effects when attempting to reduce prevalence rates of overweight or obese children.\textsuperscript{44,48-50} Although small positive changes can be made, it appears that all children – with or without exposure to an intervention – can benefit from being at school. For example, a recent large-scale school based intervention showed that the prevalence rate of overweight or obese children declined equally (N=4600, mean age=11.3 yrs., 52.7\% female, 54.2\% Hispanic) among students enrolled in both treatment and control schools.\textsuperscript{49} This finding is particularly encouraging in the sense that it suggests that these control schools, or the school environment in general, is having a protective effect against weight gain during the school year.

While modest improvements can be made to weight status and obesogenic behaviors during the school year, evidence is emerging that suggests much of this is undermined as children are released to summer vacation. A number of studies have consistently shown that when children return to school after summer break they have accelerated weight gain compared to weight gain occurring during school year.\textsuperscript{51-54} In addition, children display a loss in cardio-respiratory fitness (CRF) gained during the school year.\textsuperscript{55,56}
One of the first studies to establish an increase in BMI over the summer months used a large nationally representative sample size (N>5000) of children from the Early Childhood Longitudinal Study. Compared to school year BMI gains, BMI gains were accelerated over summer in both normal weight and overweight groups of K-2nd grade children. Since then, several longitudinal studies have confirmed this trend in children from K-5th grade, and a systematic review examining variations in weight gain among children during summer versus school concluded there is strong evidence that the accelerated rate of weight gain is most pronounced among those falling into one of the following subgroups; already overweight/obese children, racial/ethnic minority children, and low socioeconomic status (SES) children.

The evidence pertaining to children’s CRF over summer follows a similar negative trait. When children return to school following the 3-months of summer they display a loss in cardio-respiratory fitness (CRF). Sallis et al. (1997) was one of the first studies to illustrate this trait in their 2-year study of 4th and 5th grade boys’ and girls’ (N=955) CRF levels via a timed mile run at fall and spring for 2 consecutive years. Mile run times decreased by over 60 seconds during the school year for boys and girls, however, when children returned from summer, mile run times had increased demonstrating a loss in the CRF gained over the school year. Other studies have findings showing a similar loss in CRF occurring over summer with spring and fall assessments of CRF using different measures (e.g., bench-stepping test, treadmill VO2 Max test). Put simply, children are returning to school heavier and less-fit than when they left, and, therefore, summer may be the critical period where obesity prevention efforts need to be focused.
While these studies provide robust evidence of the negative health outcomes occurring in children as a result of summer, the recent emergence of these traits means there is a lack of scientific evidence exploring obesogenic behaviors that could be attributed to these adverse health outcomes. Currently, only a handful of studies exist investigating obesogenic behaviors that may be associated with the observed accelerated weight gain and loss in CRF during summer, with studies reporting mixed findings.\textsuperscript{23,54,60} One study reported children were more active and had higher screen time during summer compared to school, with no reported differences in diet or sleep behaviors.\textsuperscript{23} Another study found similar results as the previous study PA and sedentary/screen time, but reported children had less favorable diets during summer compared to school.\textsuperscript{60} Lastly, a small within-child pilot study reported no dietary differences during summer versus school but, in opposition of the other studies, found children were more active during school compared to summer.\textsuperscript{54} This small collection of studies were limited by study-design (e.g., between-subjects), analysis (e.g., summer and winter break data combined), method (e.g., self-report measures only) and sample size (repeated measures children; N=14). To this extent, there is a clear lack of scientific evidence pertaining to children’s obesogenic behaviors during summer months which prohibits any real understanding of causal factors associated with the occurrence of these negative health outcomes.

\textit{Study 1}

Given the limited amount of evidence available, the authors propose taking a theoretical approach to understanding why children are exhibiting these unfavorable health outcomes during summer can provide some insight to researchers interested in understanding and investigating the expression of obesogenic behaviors during summer,
and perhaps provide insight for future intervention in this area. What is it that is so
different about the summer that is leading to excessive weight gain and losses in fitness?
And what is mitigating this expression during the 9-months of the school year?
Conceptually, a fundamental difference in children’s days during the school year versus
summer is the presence of a consistent, structured, and segmented day with adult (non-
family) supervision. School days are a prime example of an ever-present structured
environment with purposive, segmented, and compulsory components. Conversely,
summer days lack a regular formal structure and possess a higher degree of open-
endedness and freedoms for children. In this sense, summer days possess similarities to
weekend days (WE) throughout the school year as, within both contexts; children are free
from segmented, restrictive, and compulsory daily components. These components are
omnipresent within a typical weekday (WD) during the 9-months of the school year. In
light of the emerging evidence identifying negative health outcomes occurring over
summer, and due to the limited evidence on children’s obesogenic behaviors during
summer, identifying how children spend their unstructured time during the school year
(WE) – and examining this in relation to their structured days (WD) – might be indicative
of what’s occurring during summer. Therefore, the purpose of study 1 is to provide an
evidence-based argument referred to as the ‘Structured Days Hypothesis’ (SDH),
developed for this study. Within the confines of the SDH, the authors explore the
scientific evidence on PA, sedentary/screen time, diet, and sleep in relation to the larger
literature base that compares WD versus WE – two contexts considered structured (WD)
and unstructured (WE) environments, respectively.
**Study 2**

As mentioned previously, there is a lack of appropriate data on children’s obesogenic behaviors during school versus summer, specifically, data investigating obesogenic behavior differences in the same children during summer versus school. Adverse health outcomes impact all children, but certain high-risk subgroups have been identified in the evidence, such as children from ethnic/racial minorities and low-income households. Therefore, the purpose of study 2 is to examine within-child differences in PA, sedentary/ screen time, diet, and sleep during summer versus school in a sample of children from low-income African American households.

**Study 3**

Studies investigating longitudinal trends in children’s BMI and CRF have established evidence that during summer accelerated weight gain and losses in CRF is occurring. While these studies provide robust evidence of the negative health outcomes occurring in children during summer, there is little to no evidence investigating how children’s obesogenic behaviors differ during summer versus school in direct relation to changes in their BMI and CRF. Evidence is needed in this area in order to help researchers and public health practitioners develop and implement evidence-based strategies to mitigate the onset of adverse health outcomes associated with summer. Therefore, the purpose of this study is to investigate how changes in U.S. elementary school-aged children’s obesogenic behaviors between summer and school relate to changes in their BMI and CRF before and after summer.
Chapter II: Manuscript 1

Understanding differences between summer vs. school obesogenic behaviors of children:
The Structured Days Hypothesis\(^1\)

\(^1\) Brazendale, K., Beets, M.W., Pate, R.R., Turner-McGrievy, G., Kazcynski, A.T., Weaver, R.G., Chandler, J.L., and Bohnert, A. To be submitted to the *International Journal of Behavioral Nutrition and Physical Activity*
Abstract

**Background:** Although the scientific community has acknowledged modest improvements can be made to weight status and obesogenic behaviors (i.e., physical activity, sedentary/screen time, diet, and sleep) during the school year, studies suggest improvements are erased as elementary-age children are released to summer vacation. Emerging evidence shows children return to school after summer vacation displaying accelerated weight gain compared to the weight gained occurring during the school year. Understanding how summer days differ from when children are in school is, therefore, essential.

**Discussion:** There is limited evidence on the etiology of accelerated weight gain during summer, with few studies comparing obesogenic behaviors on the same children during school and summer. For many children summer days may be analogous to weekend days throughout the school year. Weekend days are often limited in consistent and formal structure, and thus differ from school days where segmented, pre-planned, restrictive, and compulsory components exist that shape obesogenic behaviors. The authors hypothesize that obesogenic behaviors are beneficially regulated when children are exposed to a structured day (i.e., school weekday) compared to what commonly occurs during summer. This is referred to as the ‘**Structured Days Hypothesis**’ (SDH). To illustrate how the SDH operates, this study examines empirical data that compares weekend day (less-structured) versus weekday (structured) obesogenic behaviors in U.S. elementary school-aged children. From 190 studies, 155 demonstrate elementary-aged children’s obesogenic behaviors are more unfavorable during weekend days compared to weekdays.
Conclusion: In light of the SDH, consistent evidence demonstrates the structured environment of weekdays may help to protect children by regulating obesogenic behaviors, most likely through compulsory physical activity opportunities, restricting caloric intake, reducing screen time occasions, and regulating sleep schedules. Summer is emerging as the critical period where childhood obesity prevention efforts need to be focused. The SDH can help researchers understand the drivers of obesogenic behaviors during summer and lead to innovative intervention development.
Introduction

In the United States (U.S.), the prevalence of obesity among children aged 6-11 years has quadrupled in the last five decades\(^1\), with the most recent estimates indicating 31.8% of children and adolescents aged 2-19 years are classified as either Overweight or Obese\(^2\). Children who are overweight or obese are at an increased risk for developing non-communicable diseases\(^4\), thereby establishing childhood obesity as an immediate public health concern\(^5,6\). Intervention strategies targeting obesity prevention among youth have focused primarily on four obesogenic behaviors: increasing physical activity (PA), decreasing sedentary/screen time, and improving dietary intake and sleep length and patterns. There is consistent evidence that these behaviors, alone or in combination, are associated with unwanted weight-gain in children\(^28,61-63\).

The majority of the literature describing or intervening on ‘obesogenic behaviors’ of youth has been conducted during the 9-month school year. The rationale for this is straightforward – over 90% of youth in the US attend public or private schools for approximately 6 hours each day, 180 days of the year\(^6\). However, evidence is accumulating that suggests improvements gained during the 9-months of the school year are erased as children are released to summer vacation. A number of recent studies consistently show that when children return to school after summer they display accelerated weight gains compared to the weight gain occurring during the school year\(^51-54,61,64,65\). In addition, children display a loss in cardio-respiratory fitness (CRF) over the summer compared to the school year\(^55,56\). These negative health outcomes are more pronounced in children who are already overweight or obese, of ethnic minority, and from low socio-economic-status (SES) households\(^52\).
Investigations into the causal factors associated with the accelerated weight gain and loss in CRF during summer are limited and report mixed findings. Studies report that children are more active, while others report they are less active during summer compared to school. Studies report children have higher screen time during summer compared to school, have less favorable diets or similar dietary intake during summer compared to school, and sleep the same amount during summer compared to school. These studies were limited by study-design (e.g., between-subjects), definitions of “summer” (e.g., summer, winter, and holiday break data combined), obesogenic behavior assessment (e.g., self-report measures), and/or sample size (e.g., repeated measures on 14 children). These limitations prohibit the understanding of the causal factors associated with the occurrence of accelerated weight gain during summer.

Although convincing evidence documents the accelerated weight gain and loss of fitness during summer, there is currently a lack of theories, frameworks, or working hypotheses articulating the substantive differences between summer versus the school year that may lead to negative health outcomes. Conceptually, a fundamental difference in a child’s day during the school year versus summer is the presence of a consistent, structured, less autonomous (compared to summer), and segmented day with adult supervision. School days are an example of a structured environment with purposive, segmented, restrictive, and compulsory components that potentially lead to the engagement in beneficial health behaviors and mitigate the expression of unhealthy behaviors. Conversely, summer days, for the most part, can be viewed as an environment with less formal structure and a higher degree of open-endedness. Subsequently, a more autonomous environment (e.g., summer) provides children with greater choice and the
environment within which greater choice may exist – such as the home environment – has both physical and social aspects that can negatively influence a child’s weight status, particularly in children from low-income households. Examples of physical and social aspects of the home environment associated with overweight/obesity in low-income ethnic-minority children are chaos in the home environment, lower parent/guardian screen time monitoring, inconsistent implementation of bedtime routines, and the presence of a TV in a child’s bedroom. Further, studies exploring children’s diet quality and watching television during meal or snack consumption – practices more common to the home environment compared to school – have shown poorer diet quality among children occurs whilst watching television, with a specific increase in the frequency of consumption of sugar-sweetened beverages and high-fat, high-sugar foods. On the contrary, it must be noted that children are not without choice during more structured and regulated environments, like a school day; and research shows how children will select the less-healthful option (e.g., unhealthy snack), knowingly so, in light of a more health-enhancing option. Nonetheless, it is plausible that, in comparison to school, a more autonomous and unhealthier home environment operates, and, thus, allows children to self-select and indulge in a variety of unhealthy behaviors of which, compounded over an uninterrupted 3-month period, results in adverse health outcomes (e.g., accelerated weight gain).

In absence of a literature base to draw from that investigates summer, we propose that a day during the summer can be considered analogous to a weekend day during the school year. Summer days possess similarities to weekend days throughout the school year as, within both contexts, children are largely free from segmented, restrictive, and
compulsory daily components (compared to what school demands) and allowed to make more autonomous choices in their behaviors. Thus, identifying children’s obesogenic behaviors during a less-structured day (weekend day) during the school year and comparing this in relation to a structured day (weekday) might shed light on what occurs over the summer. Further, understanding the substantive differences between these environments (structured school day and less-structured weekend day) can be used to identify targets for interventions during summer.

In this debate article, the authors propose the ‘Structured Days Hypothesis’ (SDH) which is founded on the premise that a structured day (represented by a school day), defined as a pre-planned, segmented, and adult supervised compulsory environment, plays an overall protective role for children against obesogenic behaviors, and, ultimately, prevents the occurrence of negative health-outcomes, in this case excessive weight gain and loss in CRF. Equally, the absence of ‘structure’ to summer days could be one of the reasons children return to school, after summer break, with accelerated weight gain and decreases in CRF. Within the confines of the SDH, the authors present the scientific evidence on PA, sedentary/screen time, diet, and sleep in relation to the larger literature base that compares weekdays versus weekend days – two contexts considered structured and less-structured environments, respectively.

The ‘Structured Days Hypothesis’ (SDH)

In the SDH, it is hypothesized that the consistent presence of structure, routine, and/or regulation within a day positively shapes the obesogenic behaviors of youth. The
SDH draws from concepts found in the ‘filled-time perspective’ which is based on the principal that time filled with favorable activities cannot be filled with unfavorable activities. This applies to the SDH where structure, routine, compulsory, and/or regulation – common characteristics of a school day – fills children’s time with ‘favorable activities’ such as scheduled PA opportunities (e.g., school PE, recess) and regulated caloric intake (e.g., school meal programs). During summer, the SDH proposes there is less structure, routine, and/or regulation, and more autonomy for children during summer afforded in the home environment. This leaves more time that can be filled with unfavorable activities/behaviors that are more prevalent in the home environment, such as extended periods of sedentary/screen time and/or liberties to choose when, what, and how much to eat/drink. It is hypothesized that the degree of autonomy given to a child during a pre-planned, structured day (i.e., a school day) is lower than less-structured days (i.e., a summer day). These less-structured days represent an environment where there could be a higher degree of autonomy and a greater variety of and access to unhealthy alternatives.

Using the school day as an example of a structured environment, the proposed mechanisms for how the SDH operates across PA, sedentary/screen time, sleep, and diet, are detailed below. A summary is also provided in Table 1.

1. **Physical Activity:** The authors hypothesize school days (i.e., typical weekday) are fundamentally different from less-structured days, such as a weekend day or summer days, due to the fact that they consistently contain a daily structure and routine with intentional (e.g., recess, physical education, before/after school programs, organized sports programs) and unintentional (e.g., regular transitions
between activities, walking to school) PA opportunities provide to the majority of children through the school day\textsuperscript{71}. For example, a child may be exposed to all or a combination of some of the following on a school day; a morning commute to school, recess, physical education, lunch recess, after school program or activity, organized sport program, and a commute home from school\textsuperscript{72}. Hypothetically, during less-structured days there may be less daily pre-planned PA opportunities for children, and the less-structured nature of the day itself reduces the occurrence of unintentional PA opportunities. Further, increased autonomy during less-structured days may allow children to choose to engage in physically inactive behaviors, such as screen time.

2. **Sedentary/Screen Time:** The authors hypothesize the routine structure of a school day limits the amount of time children can spend sedentary, such as when watching TV or playing video games. Although children can spend a large amount of time sitting during the school day, bouts of time spent sedentary are broken-up by transitions during the segmented day and by planned opportunities where minimal sedentary time can occur (e.g., physical education, recess)\textsuperscript{73}. Conversely, during less-structured days – where there may be less regulation or restriction – children may be exposed to increased unsupervised and open-ended periods of time where they are free to indulge in sedentary activities, such as TV viewing and playing computer games\textsuperscript{52,53}.

3. **Sleep:** The authors hypothesize the presence of the structured school day plays a role in minimizing the displacement of bed/wake times. Specifically, children are going to bed earlier and waking earlier during school days, which studies have
found is more beneficial to a child’s weight status than a late bedtime/late waketime \(^{38}\). For example, on a night that precedes a school day there is more likely to be a consistent bed-time and corresponding wake-time, followed by a typical morning routine (i.e., structure). This is incidentally enforced as a result of the presence of the school day. During a less-structured day, such as summer, there may be less structure in a child’s morning and evening periods; where children are given more freedoms to stay up later in the evening and wake later in the morning.

4. **Diet:** The authors hypothesize children have limited opportunities to eat/drink during the school day \(^{53}\) and access to regulated food programs \(^{52,65}\) that provide nutrient dense meals that meet existing federal nutrition guidelines \(^{74}\). Conversely, less-structured days (e.g., weekend day, summer day) may be giving children increased opportunities to snack and access to unhealthier foods in the home. As summer may present an open-ended and autonomous environment for children, other factors could drive increased energy intake during summer such as increased snacking of calorie-dense low nutrient foods whilst engaging in screen time activities for extended periods of time \(^{75,76}\).

To support these hypotheses, a systematic search following the PRISMA guidelines \(^{77}\) of published studies reporting week day and weekend day obesogenic behaviors of elementary-age children ages 5 to 11 years was conducted. A separate search, using PubMed, Google Scholar, and Web of Science, was performed for each of the following obesogenic behaviors: PA, sedentary, screen time, sleep, and diet. The following key words and/or search terms were used: “physical activity” *sedentary*,
screen*, television*, sleep*, diet*, nutrition*. Each of these individual terms were followed by weekday* weekend* and child*. Studies were excluded if they investigated a different population (e.g., adolescents, adults, children with disabilities), did not report weekend versus weekday outcomes, and/or were not published in English. Studies reporting outcome data of children that incorporated other ages outside 5-11 year old range were included as long as data were segmented by age group/category. Included studies were stratified by country (U.S. or International) and whether or not a statistical test was carried out on the difference between the weekday and weekend day outcome (Statistical test or No test). Studies showing statistically significant (as defined within each study) favorable outcomes (e.g., increased PA, reductions in sedentary/screen time, earlier bed/wake times, and lower consumption/frequency of consumption of unhealthy foods/drinks) during weekdays (i.e., structured days) compared to weekend days (i.e., less-structured days) were classified as for the SDH. If a study reported outcomes that did not align with the above criteria (e.g., Weekend days more favorable than weekdays or no difference) was classified as against the SDH. Table 2 presents the number of studies found, excluded, and if the weekend day versus weekday outcome was for or against the SDH.

**Physical Activity**

A total of 91 studies reported weekend day and weekday PA estimates, with 18 originating from the U.S. 78-95. Of these, 81% reported findings supporting the SDH. Two recent U.S. based studies employing objective measures of PA concluded that accumulated MVPA was higher on weekdays compared to weekend days. The first study explored 187 2nd and 3rd grade children’s (48.7% boys) MVPA on weekdays and
weekend days using 5 days of accelerometer assessment. The authors reported that children’s MVPA was greater during weekdays (46.0 min/day) compared with weekend days (37.7 min/day)\textsuperscript{78}. Another accelerometer-based study examined disparities in MVPA among overweight and obese 3\textsuperscript{rd} – 5\textsuperscript{th} grade children. Children classified as Overweight or Obese accumulated 11 minutes less of MVPA on weekend days compared with weekdays \textsuperscript{79}. Similar trends have been found in the PA literature when using different objective measures of PA (e.g., pedometers\textsuperscript{85,86,91}, self-report measures of PA \textsuperscript{92}, and investigating girls PA patterns \textsuperscript{81,96}. Further, a meta-analysis of objectively measured PA revealed school-aged children are more active on weekdays than weekend days (+14 MVPA min/day) \textsuperscript{84}.

Seventy three international studies were identified that report weekday and weekend day differences in PA \textsuperscript{72,97-162}. Fifty nine of these studies drew similar conclusions to the U.S literature, with 39 of these studies showing PA was lower on weekend days compared to weekdays reporting a statistically significant difference. One cohort study (N=704) investigating seasonal variation in children’s PA was conducted in the United Kingdom (UK) and reported that across all seasons, accumulation of MVPA was higher on weekdays compared with weekend days \textsuperscript{97}. The authors suggested that PA during weekday is less likely to vary as the school day – and its corresponding daily PA segments – are less likely to be influenced by seasonal changes, whereas weekend days are more susceptible to influence due to the volitional nature of PA opportunities. Another study measuring PA levels via accelerometry in a large sample of 11-year old children (N=5,595) found weekdays to be more active than weekend days (+31 counts/min) \textsuperscript{72}, and other accelerometer-based studies conducted across different
continents (e.g., Canada, Sweden, and Singapore) in varying samples of elementary school-aged children (N~80 to 1300) report MVPA is higher on weekdays compared to weekend days.

*Sedentary /Screen Time*

A total of 62 studies were identified reporting either sedentary and/or screen time estimates for elementary school-aged children. Of these 62, 11 studies were conducted in the U.S., with the remaining studies from other countries. The majority of the sedentary/screen time estimates reported in the literature came from self-report measures (e.g., surveys, questionnaires, recalls). An early U.S. study analyzed TV viewing data from the Panel Study of Income Dynamics (PSID; 1997), collected using 24-hour time diaries completed by the primary caregiver (i.e., parent/guardian). The analysis of ~1,000 boys and girls (6-12 years) reported TV viewing increased on average by 60 minutes per day during weekend days compared to weekdays. Another study reported that during weekdays 82% of children (N=245; 6th to 8th grade) watched ≤2hrs per day of TV (screen time recommendation for US children) compared to 76% of children on weekend days during school. This finding is in agreement with several other studies conducted outside the U.S. For example, Jago et al. (2014) examined survey data from parents of 5-6 year old children (N=1,078) on several screen time behaviors (e.g., TV viewing, computer use, videogame consoles). The percent of children spending ≥2 hours per day engaged in screen time increased by approximately 34% during weekend days compared to weekdays. Another study of approximately 15,000 children across
multiple European countries reported 52% of the sample engaged in ≥2 hours per day of screen time on weekend days compared to 20% on weekdays.²⁸²

Twenty six studies reported the amount of time children spend sedentary comparing weekdays versus weekend days using objective measures (e.g., accelerometers, pedometers etc.). Atkin et al. (2016) analyzed seasonal data of 700 elementary school-aged children from a UK cohort study and reported increased sedentary time on weekend days compared to weekdays in 3 out of the 4 seasons (range; 9 – 54 additional sedentary minutes per day on weekend days)⁹⁷. Another study explored in-school versus out-of-school sedentary time patterns of 206 5th grade children across 10 elementary schools in Colorado. The authors concluded children spent more time sedentary during weekend days (+5% of wear time) compared with weekdays.⁷³ In agreement, additional accelerometer-based studies from Canada and the United Kingdom concluded children spend statistically significantly more time sedentary on weekend days versus weekdays. Fifteen of the 62 studies found no difference in sedentary/screen time between weekend days and weekdays – or reported weekend days were less sedentary than weekdays.

Sleep

A total of 22 studies reported bed and wake times for elementary school-aged children during weekdays and weekend days. Six of these studies were conducted within the U.S.²⁴,³³,¹⁹⁵-¹⁹⁸, with the remaining 16 originating from other countries.²⁷,¹⁹⁹-²¹³. One of the earliest U.S. studies conducted by Blader and colleagues had parents of 978 5-12 year old children (85% Caucasian) complete a 48-item survey. The authors reported
weekend bed/wake-times were 45 – 60 minutes later compared to weekdays \(^{24}\). A more recent study explored a large nationally representative sample of 3-18 year old U.S. children (N=2,281) and reported a clear displacement of sleep time, with children going to bed and waking later on weekend days compared to weekdays across the range of ages \(^{33}\). Studies conducted outside the U.S. show similar bed/wake time patterns between weekdays and weekend days. Gulliford et al. (1990) conducted a cross-sectional study of British school children (N=5,145) whereby parents reported their child’s bed/wake-times \(^{199}\). The authors concluded children were going to bed and waking later on weekend days compared to weekdays starting at the age of 5 years old onwards. Several other international studies incorporating larger sample sizes (N>15,000) and parent-report measures show similar findings \(^{27,204,210}\), as do studies incorporating objective measures (e.g., accelerometers) to estimate bed/wake times \(^{203,209,213}\).

**Diet**

Fifteen studies reported elementary school-aged children’s dietary behaviors between weekend days and weekdays, with eight of these studies conducted in the U.S. \(^{76,214-220}\). Findings across U.S. based studies are consistent; children display statistically significant unfavorable diets on weekend days compared to weekdays. Baranowksi et al. (1997) reported children (N=2,984) had lower consumption of FV on weekend days compared to weekdays, with lunch time during weekdays identified as the eating occasion when children consumed the most FV \(^{214}\). This particular finding was supported by a more recent study that identified eating lunch from school was associated with higher overall diet quality compared with obtaining lunch from home \(^{215}\). Other studies have extended upon these findings and reported fewer FV were consumed on
weekend days compared to weekdays, with children (N=81; age range=6-9yrs.) consuming a greater percentage of calories from fat and non-nutrient dense snack foods on weekend days compared to weekdays\textsuperscript{216}. This finding is consistent with an earlier study by Cullen and colleagues showing that, in comparison to weekdays, weekend days provided significantly more high-fat practices (e.g., choosing high-fat foods, adding fat to foods, preparing foods in fat), fewer low-fat practices (e.g., choosing lower fat foods, removing skin from chicken), and a higher percent of energy from fat when analyzing student-reported food records completed by 4\textsuperscript{th} – 6\textsuperscript{th} grade children (N=520) from Texas\textsuperscript{217}. Data from the National Health and Nutrition Examination Survey (NHANES 2003-2008) was analyzed to explore school meal participation in relation to dietary quality (N=2,376; 6-17 years old). Hanson et al. (2013) obtained dietary recalls and examined differences in Healthy Eating Index (HEI) scores for breakfast only and breakfast and lunch participants. Both categories of school meal participants (i.e., breakfast only and breakfast/lunch) had higher mean weekday HEI scores for milk and vegetables, and lower HEI scores for saturated fat and sodium compared to their HEI scores for weekend days\textsuperscript{218}. Four out of seven international studies reported statistically significant findings with children displaying unhealthy dietary behaviors, such as increased sugar intake, during weekend days compared to weekdays\textsuperscript{110,155,221,222}. Three other international studies either found no difference\textsuperscript{170,223} or presented evidence showing favorable dietary behaviors during weekends compared to weekdays\textsuperscript{224}. 
Discussion

There is a clear need for further investigation into children’s obesogenic behaviors during structured versus less-structured environments, none more so than school versus summer. The SDH presents the case that children require a structured environment to mitigate unhealthy behaviors from occurring. The evidence presented demonstrates that U.S. elementary school-aged children’s obesogenic behaviors are less favorable during less-structured (i.e., weekend days) versus structured days (i.e., weekdays). The findings herein support the argument that when elementary school-aged children are exposed to environments that contain less structure, regulation, and supervision, they indulge in a host of unfavorable behaviors. Typically, summer presents 3 months of the calendar year where a less-structured environment can exist for a prolonged period of time and the observed accelerated weight-gain and losses in CRF \(^51, 56, 61, 64, 65\) occurring during this window demonstrates the adverse impact a less-structured environment can have on children’s health and well-being.

Across all four obesogenic behaviors, 80% of the literature shows support towards the SDH. The structured nature of weekdays during the school year expose children to various PA opportunities (e.g., recess, physical education, after-school programs, commute to school, classroom transitions/breaks) not necessarily guaranteed during weekend days. This structured and regulated environment isn’t as prevalent on weekend days, thereby giving children greater choice in how they spend their time. The findings from the literature would suggest that they are not choosing to spend it participating in PA, instead choosing to spend it engaged in higher amounts of sedentary/screen time activities. Further, there is a clear displacement of sleep time with later bed/wake-times
occurring on weekend days compared to weekdays. The mere presence of the school day likely explains consistent wake times for children, and the absence of school the next day (e.g., on weekend day evenings) is likely the main factor leading to later bed times being observed. This shift in time of when sleep is occurring could reduce the hours children have to be active during the day and increasing the time they have to engage in sedentary activities in the evening (e.g., excess screen time). The literature review suggests children’s diet differs between weekend days compared to weekdays, too. During weekdays children’s eating occasions, serving sizes, food/beverage options, opportunities to access unhealthier foods/beverages are limited and/or regulated. This is supported by evidence showing favorable diets (e.g., higher HEI scores, increased FV consumption, more low-fat practices) reported on weekdays, typically when children are in school.

The literature shows children’s obesogenic behaviors are beneficially-regulated during weekdays during the school year, where there is a greater presence of structure, routine and regulation. This implies that intervention efforts should be focused on instances where a less-structured environment prevails, such as weekend days, winter breaks, and/or summer vacation. However, the authors would argue that weekend days during the school year may not merit intervention. Studies indicate that during the 9-month school year, increases in obesogenic behaviors during weekends and winter breaks do not impose the same detrimental effects on children’s health that summer does. Based on these robust findings, the adverse weight and CRF outcomes associated with the presence of less-structured days (e.g., weekend days, winter breaks) are minimized or eliminated because they are interrupted by longer periods of exposure to a structured environment. For instance, during a typical 7 day week during the school
year, only 2 of the 7 days are less-structured. Thus, less-structured environments, in and of themselves, may not be detrimental to weight gain and loss of CRF. Rather, we hypothesize it is the duration of exposure to less-structured environments, as represented by summer vacation, that leads to accelerated weight gain and loss of CRF. To support this, research has shown when children are exposed to a year-round structured environment interjected by short periodic breaks (e.g., year-round schools), they display a steady flat lining of BMI, particularly overweight and obese children. Hence, the fundamental difference between summer and weekends during the school year is the length of time children are exposed to a less-structured environment. Summer represents approximately a quarter of the calendar year, and this concentrated, largely non-interrupted exposure to a less-structured environment appears to be unfavorably impacting the health of children. This raises the question of whether summer is simply one long weekend?

In light of the SDH there are important implications to be considered by public health practitioners and researchers focused on tackling childhood overweight and obesity. A great deal of effort and resource has been allocated for intervening on and improving schools and other structured environments existing outside-of-school time (e.g., afterschool or sport programs). Reconsidering this strategy may be worthwhile given that structured environments, by the most part, appear to be doing a decent job of mitigating adverse health outcomes from occurring in children. As mentioned previously, in comparison to school, summer is a time where children have more autonomy and access to fill their time with unfavorable activities, particularly in the home environment. Even when autonomy is minimized, children inherently opt for the less-healthful
alternative (e.g., unhealthy snack, sedentary activity) and the home environment represents a more open-ended and less-regulated environment for children to overindulge in unhealthy behaviors that have been associated with overweight and obesity in children. Thus, the potential for children to adversely impact their health is much greater during summer compared to when children are in a more structured and controlled environment (e.g., school).

Given children likely spend more time at home during summer than during the school year, it is important to consider whether interventions targeting the home environment are the solution? Home-based childhood obesity interventions are limited in number and inconclusive in their effects and can be a challenging and resource-consuming endeavor for practitioners. Further, low-income and ethnic/racial minority households, a sub-population identified as having children most-at-risk for accelerated weight gain during summer, are susceptible to other economic and environmental factors (e.g., less income/access to purchase quality foods for family, safe neighborhoods for outdoor play etc.) that may limit the success of home-based intervention strategies. An alternative and intuitive approach is to provide children with more opportunities and access to summer structured programs. When children spend summer days in a structured environment (e.g., summer day camp or program) they display more favorable obesogenic behaviors compared to a less-structured environment. Public health practitioners and policy makers need to recognize the benefit of structure to a child’s day and put more effort and resources into developing strategies and partnerships with community stakeholders to provide all children equal opportunities and access to summer structured programs. Overcoming pertinent barriers (e.g., cost) that isolate children from
these structured settings is of paramount importance, with a recent American Camp Association report revealing approximately 75% of youth attending camps in the U.S. were from middle-to-high income households and Non-Hispanic White 234.

In conclusion, the SDH posits that the school environment as a whole plays a protective role against the onset of unfavorable health outcomes by regulating obesogenic behaviors through its daily structure, regulation, and compulsory components. Within the last decade, researchers have identified summer as a time period where children are at risk of accelerated weight gain and losses in CRF 51-54,64,65. A key characteristic of both summer and weekend days is that, typically, both contexts have less consistent and formal daily structures, regulatory components, and present a more autonomous environment to children, unlike their counterparts (i.e., weekdays during the school year). However, the key element that distinguishes weekend days from summer days is the prolonged and concentrated period of time U.S. children are exposed to a less-structured environment (~3 months). Summer is clearly the critical period where obesity prevention efforts need to be focused. The SDH provides a framework that can assist researchers and public health practitioners better understand the expression of obesogenic behaviors during less-structured environments, such as summer, and aid with the development of innovative observational studies and future intervention strategies.
Table 2.1 How Structured Days Hypothesis (SDH) operates across obesogenic behavior

<table>
<thead>
<tr>
<th>OB</th>
<th>Protective Element of “Structured” School Day</th>
<th>Impact on OB</th>
<th>School Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Activity</td>
<td>Compulsory and voluntary PA opportunities for physical activity to occur before, during, and/or after school.</td>
<td>Increased daily PA</td>
<td>• Walking to/from school.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Recess.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Physical education.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Transitions between class/activities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Classroom PA Promotion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Before/after-school programs or sports clubs.</td>
</tr>
<tr>
<td>Sedentary/ST</td>
<td>Segmented school day limits amount of time children spend seated. Limited non-educational screen time.</td>
<td>Decreased daily sedentary/screen time.</td>
<td>• Bouts of sedentary time broken up by transitions in and to/from class.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Classroom teachers control screen time exposure.</td>
</tr>
<tr>
<td>Sleep</td>
<td>Presence of school day establishes consistent early bed/wake times for children and evening/morning routines and rules.</td>
<td>Earlier bed/wake times.</td>
<td>• Parent/Guardian enforces earlier bed/wake time rules on school days.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Child is awake for more daylight hours (e.g., more hours to engage in PA).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reduced time in evening for child to engage in sedentary/screen time.</td>
</tr>
<tr>
<td>Diet</td>
<td>Structure of school day limits eating occasions for children. Schools offer regulated access to nutritious dense meals.</td>
<td>Decreased access to unhealthy foods/beverages/reduced overconsumption.</td>
<td>• Scheduled opportunities to consume foods/beverages in school (e.g., breakfast, recess, lunch).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Serve nutritionally balanced, appropriate portions.</td>
</tr>
</tbody>
</table>

OB = Obesogenic Behavior
Table 2.2 Weekend Day (WE) vs Weekday (WD) evidence

<table>
<thead>
<tr>
<th>OB</th>
<th>SEARCH</th>
<th>EXCLUDED</th>
<th>USA STUDIES (INTERNATIONAL STUDIES)</th>
<th>Number of Studies:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Different population</td>
<td>No outcome</td>
<td>Foreign language</td>
</tr>
<tr>
<td>PA</td>
<td>339</td>
<td>171</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td>SED/ST</td>
<td>256</td>
<td>126</td>
<td>62</td>
<td>6</td>
</tr>
<tr>
<td>Sleep</td>
<td>133</td>
<td>73</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Diet</td>
<td>139</td>
<td>84</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>Totals</td>
<td>867</td>
<td>454</td>
<td>198</td>
<td>25</td>
</tr>
</tbody>
</table>

OB=Obesogenic Behavior, PA=Physical Activity, SED=Sedentary Time, ST=Screen Time, Stat=Statistical Test
*Reported statistical outcome either null or in opposite direction (p-value 0.05)
Chapter III: Manuscript 2

Children’s Obesogenic Behaviors during Summer versus School: A Within-Person Comparison

2 Brazendale, K., Beets, M.W., Turner-McGrievy, G.M., Kaczynski, A.T., Pate, R.R., Weaver, R.G. To be submitted to *Childhood Obesity*
Abstract

**Background:** Evidence consistently shows U.S. children gain 3-5 times more weight during summer vacation (~2.5 months) compared to the 9 month school year. Few studies have used a within-person design to examine children’s obesogenic behaviors during summer and how these compare to school. The purpose of this study is to examine within-child differences in 4 obesogenic behaviors (physical activity (PA), sedentary/screen-time, diet, and sleep) during school versus summer.

**Methods:** Using a repeated-measures within-subjects design, children (n=55 mean age=8.2 years; 57% female; 37% overweight/obese; 100% African American) wore accelerometers on the non-dominant wrist for 24hr/d over 9 consecutive days during school and summer of 2016 to capture PA, sedentary time, and sleep. Parents completed a daily diary to report bed/wake times, diet (food/beverage questionnaire), and screen-time of their child each day. Mixed effect models, conducted 2016, compared summer and school behaviors. All models included age, sex, and weight-status as covariates.

**Results:** Children spent more time sedentary (69 vs. 67% of wake weartime), less time in light PA (25 vs. 23% of wake weartime), had higher screen-time (242 vs. 123 min/day), slept longer (428 vs. 413 mins/night), and consumed more sugar-based foods (6 days vs. 2.5 days/week) and fruit (7 days vs. 4.7 days/week) during summer compared to school (p<0.05).

**Conclusion:** Initial evidence suggests children are displaying multiple unfavorable obesogenic behaviors during summer compared to school that may contribute to the accelerated weight gain during summer. Longitudinal evidence with larger, more diverse
samples of children is necessary to identify specific behavioral targets for interventions during summer.
Introduction

The prevalence of childhood obesity among United States (U.S.) children aged 6-11 years has quadrupled in the last five decades.\textsuperscript{1} Children who are classified as overweight or obese are at an increased risk for developing several different chronic health diseases,\textsuperscript{4} bringing childhood obesity to the forefront of public health concern.\textsuperscript{6} The majority of intervention strategies targeting obesity prevention have focused on four obesogenic behaviors: physical activity (PA), sedentary/ screen time, diet, and more recently, sleep.\textsuperscript{28,61,63} Understandably, studies examining these behaviors have been conducted in settings where children spend the majority of their time, such as during the 9-months of the school year, hereon referred to as ‘school’.\textsuperscript{6} The scientific community has acknowledged that modest improvements can be made to weight status and obesogenic behaviors while children are in school,\textsuperscript{23,54,60} yet evidence is gathering that suggests these improvements are undermined as children are released to summer vacation.\textsuperscript{52} Specifically, children return to school after summer vacation displaying accelerated weight gain relative to the weight gain occurring during the school year,\textsuperscript{65} and fitness gains children achieved during the school year are erased over summer months.\textsuperscript{55} The occurrence of these negative health outcomes are most pronounced in children who are already overweight or obese, of ethnic minority, and from low socio-economic-status (SES) households.\textsuperscript{52}

Currently, only a handful of studies have examined differences in children’s obesogenic behaviors during summer versus school.\textsuperscript{23,54,60} One cross-sectional study reported children were more physically active and had higher TV viewing during school holidays compared to school, with no reported dietary or sleep differences.\textsuperscript{23} An analysis
of secondary-data of U.S. children from the National Health and Nutrition Examination Survey (NHANES 2003-2008) reported children were more active, had less healthful diets, and watched more television during school breaks compared to school. Although an objective measurement of PA was used, winter and summer break data were combined and 30-day recall methods for TV and diet overlapped between school break and in-school periods, limiting conclusions drawn solely for summer. Another key limitation is the use of a between-subjects design employed in both of the previous studies. Demographically, children may possess commonalities; but behaviorally, differences exist, and employing a between-subjects approach can overlook important and existing patterns. One study has employed a within-subjects study design to investigate differences in children’s obesogenic behaviors during summer versus school. McCue et al. (2013) reported data on a sample of 14 children (10 years old; Non-Hispanic White) for PA; assessed by a 7-day accelerometer protocol, and diet; assessed by a food-frequency questionnaire. The authors reported children spent a greater percent of time in light and moderate PA, less time sedentary during school versus summer, and no reported dietary differences. The occurrence of negative health outcomes during summer is of concern, and given the limited evidence, there is a clear need for further investigation. The purpose of this study is to examine within-child differences in PA, sedentary/ screen time, diet, and sleep during summer versus school in a sample of children from low-income African American households.
Methods

Study Overview

A repeated measures observational within-subjects study design was conducted. In total, children from one elementary school located within the southeastern region of the U.S. were invited to be part of the pilot study. Information fliers were sent home with approximately 100 children (1st through 4th grade) during physical education class inviting children/parents to be part of the study. The school was located in a district that primarily serves African American families from low-income households. Children enrolled in the elementary school were 85% African American, and 96.4% of children were on free/reduced lunch. All study procedures were approved by the author’s Institutional Review Board and parents provided written informed consent for the child. Each parent-child dyad received a $50 gift card for participating in school and summer measurement protocols ($100 total).

Study Protocol

Children/parents with completed consent forms (N=55) were given data collection materials for a 9 day period during school and summer. These materials consisted of a water-proof wrist-based activity monitor and a parent survey packet (including a 9-day daily diary). Parents were sent text message reminders over the course of the 9 days to remind them to complete the parent survey packet. For school, consented children were given the activity monitor and parent survey packet to take home in their bags during scheduled physical education (PE) class. The materials were distributed by a research assistant with support from the PE teacher. After 9 days, the child returned the
accelerometer and completed parent survey packets to the PE teacher. School data were collected early May 2016. For summer, the same materials were distributed for 9-days during the summer protocol; however, distribution of materials differed due to the school being closed over summer. Because of its familiarity to the families/children involved in the study, the elementary school was selected as the pick-up/drop-off location for the summer data collection materials. Three different dates were provided during the month of July (2016) and research assistants offered a 4 hour window on each date.

**Measurements**

*Anthropometric Assessment*

Using a portable stadiometer (Model S100, Ayrton Corp., Prior Lake, Minn.) and digital scale (Healthometer model 500KL, Health o meter, McCook, Ill.), children’s heights (nearest 0.1 cm) and weights (nearest 0.01 lbs), without shoes, were collected by two research assistants during a separate visit to the school in May.

*Physical Activity/Sedentary Time Assessment*

Children’s PA and sedentary time was captured via a wrist-based activity monitor (ActiGraph Link GT9X+ accelerometer, Shalimar, FL). During school and summer, a trained research assistant strapped the accelerometer to each child’s non-dominant wrist and encouraged the child to wear the water-proof device for 9 days (day and night) without removal. The epoch was set at five-second intervals to account for the transitory PA patterns of children and to align with the validation epoch length. Validated non-dominant wrist-based cutpoints of ≤161 and ≥ 530 accelerometer counts per 5 seconds were used to distill sedentary time and moderate-to-vigorous physical activity.
A valid day of accelerometer data was total wear time ≥600 minutes per day (excluding sleep) with removal of non-wear time identified as consecutive zeros for 30 minutes or more.

**Screen Time Assessment**

During school and summer protocols, children’s daily screen time estimates were reported by parents for 9 days by completing a daily diary, a section within the parent survey packet. Parents reported whether or not their child engaged in screen time on that particular day and if so, estimated the total amount of time (hours and minutes) their child spent in front of a screen (e.g., TV, computer, video-game, smartphone, tablet). In accordance with other studies using similar screen time protocols, hours were converted to minutes, summed to provide a daily screen time duration, and an average calculated by dividing the summed value by the number of days the daily diary was completed.

**Diet Assessment**

Children’s diet was assessed using the Beverage and Snack Questionnaire (BSQ). The BSQ is a cost-effective, easy-to-use tool to assess frequency of consumption of foods and beverages high in energy but poor in nutrients (e.g., savory snacks, sweets). Parents were asked to complete this 19-item checklist with their child every day for 9 days. There were a total of four response categories with individual items scored 0 (‘child did not consume’) to 3 (‘child consumed a lot’). For this study, individual BSQ items were grouped in accordance with the Healthy Meal Index (HMI) food categories as follows; fruits, vegetables, dairy, convenience foods, sweets and desserts, and sugar sweetened beverages. Reported consumption was dichotomized (i.e., ‘did’ vs.
‘did not’ consume) and standardized to represent mean days per 7 day week. For example, if a parent/child reported eating fruit on 5 of the 9 days (55% of days), this was transformed to 3.9 days/week (55% of 7 days). A BSQ was completed during the school 9-day protocol, and again during the summer 9-day protocol.

**Sleep Assessment**

Children’s sleep was captured via the wrist-worn ActiGraph Link GT9X+ accelerometer (Shalimar, FL). This procedure has been validated as a measure of sleep, is used extensively in studies evaluating sleep of elementary school-aged children, and is preferred to hip-based accelerometer placement for sleep detection. Proprietary ActiGraph sleep algorithms validated for children (Sadeh Algorithm) were used to determine total sleep duration. Individual files were reintegrated to 60-second epochs and analyzed for inconsistencies with sleep duration ≤4 and ≥15 hours per night removed from further analysis. In addition, parents reported the bed and wake times for their child as part of the 9-day daily diary. Parent-reported sleep duration was calculated by assessing the amount of time that had lapsed between the bed-time reported for the previous night and the wake-time for the current day.

**Data Analysis**

Only children with data from both school and summer that met the following criteria were included for analysis: ≥4 days (including 1 weekend day) of valid PA/sedentary data, ≥5 nights (including 1 weekend night) of valid sleep, and ≥7 days with complete daily diaries for screen time and diet outcomes, including one weekend day. Independent sample t-tests examined differences between the children who did and
did not return for the summer protocol across demographics and obesogenic behaviors. Paired samples t-tests were used to compare school and summer data for diet (p<0.05). Mixed-effects models were employed to assess differences that existed between school and summer on repeated measures data for PA, sedentary/screen time, and sleep. All models took into account clustering at the child level, and controlled for age, sex, and weight-status. A secondary descriptive analysis explored the mean number of days per week children met PA (≥60 minutes per day of MVPA), screen time (≤2 hours per day), sleep (9 – 12 hours per night), and dietary (≥1 fruit and vegetable per day) guidelines during summer and school. All statistical analyses were performed using Stata (v.14.1, College Station, TX).

Results

Fifty five children/parents expressed interest in the study during the school spring semester. Of these, 3 children were unavailable for summer data collection, 16 children/parents did not respond for summer data collection, and 6 children had either lost/broke their activity monitor or did not have accelerometer data meeting inclusion criteria. This left a final sample of 30 children for within-subject analysis. No statistical differences existed in terms of baseline child-level demographics or obesogenic behaviors among the children who returned for the summer and those who did not. Table 1 displays the child-level and family-level demographics for the final within-subjects sample. Children (mean age= 8.2 years; 43% male; 100% African American; 57% normal weight) mainly came from single-parent (66.7%) households that included at least 2 other
siblings/children (53.3%) and reported an annual household income of $19,999 or less per annum (46.6%).

On average, children wore the activity monitors for 8.3 and 8.7 valid days during summer and school, respectively. Wake weartime between school (934.9 min/day) and summer (892.7 min/day) was statistically significant so PA data was expressed as a percent of time (Table 2). Children had a reduced percent of time in light-intensity PA (-2.0%, 95% CI= -2.8, -1.1), a greater percent of time sedentary (+2.2%, 95% CI= 0.9, 3.4), more screen time (+120.6 min/day, 95% CI=100.5, 140.7), more sleep (+14.3min/night, 95% CI= 1.2, 27.4), and a higher frequency of consumption of both fruits (+2.3 days/week, p<0.01) and sweets and desserts (+3.5 days/week, p<0.01), during summer compared to school. Children met PA guidelines on 5.0 vs. 4.4 days/week, and screen time guidelines on 3.1 vs. 1.5 days/week during school versus summer, respectively. Guidelines for children’s sleep and diet (both parent-reported) were met on 1.7 vs. 4.1 nights/week, and 4.0 vs. 5.7 days/week, during school versus summer, respectively (Table 3).

**Discussion**

This study investigated within-child differences during summer versus school in PA, sedentary/screen time, diet, and sleep. Over summer children were less active, more sedentary, engaged in higher amounts of screen time, slept longer, and more frequently consumed sugar-sweetened foods and fruit. In total, results from this study suggest children, on average, are displaying multiple unfavorable health behaviors during the
summer months compared to school. In addition, the observed differences provide preliminary evidence for targets of an intervention directed at minimizing children’s accelerated weight gain and losses in CRF during summer.

On average, children engaged in less light-intensity PA and spent more time sedentary during summer compared to school, with no observed differences in MVPA. This finding is in agreement with another within-subject study investigating children’s PA during summer versus school, and one study using a summer comparison group of children to compare to children measured during school. On average, children in the present study met the daily PA guidelines for health benefits 5 days/week during school compared to 4.4 days/week during summer. The majority of children from this study appear to find ways to achieve health-enhancing PA on the majority of days during summer and school; however, sedentary time may be an area worthy of further investigation. During school sedentary time was replaced by more light-intensity PA. This could be a result of the various intentional (e.g., recess, PE) and unintentional (e.g., walk to/from school, transition between classes) PA opportunities that exist in a typical school day. Beck et al. (2016) reported children were more sedentary during outside of school hours versus during school hours. This shift in light intensity PA to sedentary during summer is concerning given the health and obesity risks associated with sedentary time independent of MVPA.

Parents reported children had almost double the amount of daily screen time during summer versus school. This finding is not particularly surprising given the presence of the 6-hour school day which can limit screen time opportunities to mainly before/after-school, evenings and weekends. A handful of studies that also used parent
self-report estimates of screen time during summer versus school reported similar findings,\textsuperscript{23,60,164,252} although the screen time estimate of the difference in the present study was greater in comparison (+120 min/day vs.+18 min/day,\textsuperscript{60} +30min/day\textsuperscript{23}). Further, when screen time does exist in school, duration and frequency is likely regulated. During summer, the potential for unsupervised and open-ended screen time over the course of a day is relatively high. In light of these findings, increased screen time during summer carries several important implications. Studies have found a positive association between screen time and overweight/obesity among U.S. children,\textsuperscript{253} with a meta-analysis concluding a 1-hour per day increment in TV watching corresponded to a 13% increased risk of obesity.\textsuperscript{13} Further, screen time could be playing a role as a mediator to other unhealthy behaviors. For example, research has found associations between increased screen time and over-consumption of calorie-dense low-nutrient foods and increased TV viewing influences children’s food choices through child-targeted food advertisements.\textsuperscript{254,255}

Parents and children reported a greater frequency of weekly consumption of fruits and sweets/desserts categories during summer versus school. These findings are in contrast to other studies either reporting lower frequency in consumption of fruit and vegetables during summer compared to school months,\textsuperscript{60,256} or concluding no dietary differences exist between summer and school months.\textsuperscript{23,54,257} The data shows children are consuming sweets and desserts (e.g., candy, doughnuts, cookies etc.) on average 6 out of 7 days per week during the summer, compared to school where this frequency drops to 2.5 days per week. Reported frequency of fruit consumption was also greater during summer, along with the remaining food/beverage categories that did not reach statistical
significance. It could be the case children are consuming more of everything during summer, with meal assistance programs in schools controlling daily caloric intake by regulating what, when, and how much is served.\textsuperscript{215} During summer children may be allowed more freedoms and opportunities to snack unsupervised on foods with low nutritional quality and it is plausible that an energy imbalance (i.e., caloric intake $>$ caloric expenditure) is occurring at a greater magnitude during summer compared to school.

This is among one of the first studies to report objective sleep data on the same children for summer and school in the U.S. On average, children slept marginally longer during summer compared to school (7.1 vs. 6.9 hours/night). One other study reported sleep outcomes derived from a youth survey and found no differences in sleep duration between school term versus school holidays.\textsuperscript{23} Parent-reported child sleep duration in the present study was longer during summer versus school (10.1 vs. 9.4 hours/night), too. Previous studies have concluded that school-age children sleep approximately 10 hours per night,\textsuperscript{28} however; the majority of children’s sleep estimates are derived from self-report surveys and time diaries which are open to overestimation.\textsuperscript{28} In the present study, the accelerometer-derived sleep duration during both summer and school was markedly lower (~7 hours/night), and falls considerably short of the sleep recommendations put forth by the American Academy of Pediatrics (9-12 hours/night) for optimal health.\textsuperscript{258} In this regard, children in this study – irrespective of during school or summer – are not getting adequate sleep, which is of concern given the negative association found between weight status and sleep duration in children.\textsuperscript{30}

This study has several strengths and limitations. One of the main strengths of this study is the within-subject study design and assessment of a relatively unexplored area
The use of objective measures to capture PA, sedentary, and sleep is also a strength. Children from ethnic minority and low-income families have been identified as one of the at-risk sub-groups more susceptible to accelerated weight gain and loss in CRF over summer, and this study provides preliminary evidence of obesogenic behaviors during summer versus school in this population. The final within-subjects sample size (N=30) prohibited further analysis stratified by sex, age/grade, or weight status. Retention for summer was a challenge, with 16 parent/child dyads not returning. Other limitations include the generalizability of the findings given the results pertain to children from one school, one region of the U.S., and from one school-summer cycle.

In conclusion, preliminary evidence suggests children are displaying multiple unfavorable obesogenic behaviors during summer versus school that may be contributing to accelerated weight gain and losses in CRF during summer. The highly open-ended and unstructured nature of summer days, where children are given more freedoms and autonomy to choose how they spend their time, is a stark comparison to the regulated and structured days that occur during school months. In this light, it is plausible that children are making choices to engage in a host of unfavorable behaviors, sometimes concurrently (e.g., excessive screen time and snacking on energy-dense foods/beverages). The continuous presence of these unhealthy traits over the course of summer could be leading to the adverse health outcomes observed in children when they return to school after summer. Longitudinal evidence investigating multiple summers, with larger, more diverse samples of children is necessary to identify specific behavioral targets for interventions that occur during summer.
Table 3.1 Child and family-level demographics of within-subjects sample

<table>
<thead>
<tr>
<th>Child-level</th>
<th>All</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>30</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Age – years, (mean±SD)</td>
<td>8.2, (1.2)</td>
<td>8.0, (1.4)</td>
<td>8.4, (1.1)</td>
</tr>
<tr>
<td>African-American – n, (%)</td>
<td>30, (100.0)</td>
<td>15, (100.0)</td>
<td>15, (100.0)</td>
</tr>
<tr>
<td><strong>BMI Classification – n, (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>17, (56.7)</td>
<td>7, (53.9)</td>
<td>10, (58.8)</td>
</tr>
<tr>
<td>Overweight/Obese</td>
<td>11, (36.7)</td>
<td>5, (38.5)</td>
<td>6, (35.2)</td>
</tr>
<tr>
<td>Missing</td>
<td>2, (6.7)</td>
<td>1, (7.7)</td>
<td>1, (5.9)</td>
</tr>
<tr>
<td><strong>Family-level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent/Guardian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>27</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td>2</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>Grandmother</td>
<td>1</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No High School Diploma</td>
<td>2</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>High School Diploma</td>
<td>17</td>
<td>56.7</td>
<td></td>
</tr>
<tr>
<td>College Degree</td>
<td>11</td>
<td>36.7</td>
<td></td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>7</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td>Single and Never Married</td>
<td>20</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td>Widowed/Divorced/Separated</td>
<td>3</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td><strong>Annual Household Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$19,999 or less</td>
<td>14</td>
<td>46.6</td>
<td></td>
</tr>
<tr>
<td>$20,000 – $39,999</td>
<td>9</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>$40,000 or more</td>
<td>7</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td><strong>No. of People in Household</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 or less</td>
<td>8</td>
<td>26.7</td>
<td></td>
</tr>
<tr>
<td>4 or more</td>
<td>22</td>
<td>73.3</td>
<td></td>
</tr>
<tr>
<td><strong>No. of Children in Household</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 or less</td>
<td>14</td>
<td>46.7</td>
<td></td>
</tr>
<tr>
<td>3 or more</td>
<td>16</td>
<td>53.3</td>
<td></td>
</tr>
</tbody>
</table>

SD = Standard Deviation, BMI = Body Mass Index
*Including respondent
**Including child participant
Table 3.2 Child-level obesogenic behaviors during school versus summer

<table>
<thead>
<tr>
<th>Obesogenic Behavior</th>
<th>School</th>
<th>Summer</th>
<th>Difference*a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ±SD (Range)</td>
<td>Mean ±SD (Range)</td>
<td>Paired Sample T-Test (p-value)</td>
</tr>
<tr>
<td><strong>Activity – min/day</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wake Weartime</td>
<td>934.9 ±83 (662 - 1310)</td>
<td>892.7 ±112 (615 - 1200)</td>
<td>n/a (-58.8, -25.5)</td>
</tr>
<tr>
<td>Sedentary (% of time)</td>
<td>66.7 ±7 (43 - 91)</td>
<td>68.9 ±9 (44 - 94)</td>
<td>n/a (0.9, 3.4)</td>
</tr>
<tr>
<td>LPA (% of time)</td>
<td>24.9 ±5 (8 - 40)</td>
<td>22.9 ±6 (5 - 43)</td>
<td>n/a (-2.8, -1.1)</td>
</tr>
<tr>
<td>MVPA (% of time)</td>
<td>8.3 ±3 (2 - 21)</td>
<td>8.1 ±3 (1 - 22)</td>
<td>n/a (-0.7, 0.2)</td>
</tr>
<tr>
<td>TPA (% of time)</td>
<td>33.2 ±7 (10 - 57)</td>
<td>31.0 ±9 (7 - 56)</td>
<td>n/a (-3.4, -0.9)</td>
</tr>
<tr>
<td><strong>Screen Time – min/day</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ScreenTime</td>
<td>123.6 ±91 (0 - 475)</td>
<td>244.2 ±172 (0 - 1010)</td>
<td>n/a (100.5, 140.7)</td>
</tr>
<tr>
<td><strong>Sleep – min/night</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration – Objective</td>
<td>413.8 ±74 (241 - 654)</td>
<td>428.1 ±89 (235 - 761)</td>
<td>n/a (1.2, 27.4)</td>
</tr>
<tr>
<td>Sleep duration – Subjective</td>
<td>563.0 ±86 (300 - 830)</td>
<td>604.8 ±93 (300 - 865)</td>
<td>n/a (27.1, 56.8)</td>
</tr>
<tr>
<td><strong>Diet – Daily Diary</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>4.7 ±2.1 (0.0 - 7.0)</td>
<td>7.0 ±0.0 (7.0 - 7.0)</td>
<td>&lt;0.01 n/a</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5.3 ±2.0 (0.0 - 7.0)</td>
<td>5.7 ±1.5 (1.5 - 7.0)</td>
<td>0.18 n/a</td>
</tr>
<tr>
<td>Dairy</td>
<td>2.7 ±2.5 (0.0 - 7.0)</td>
<td>3.2 ±2.8 (0.0 - 7.0)</td>
<td>0.22 n/a</td>
</tr>
<tr>
<td>Convenience Foods</td>
<td>2.3 ±1.8 (0.0 - 7.0)</td>
<td>2.8 ±1.6 (0.0 - 6.2)</td>
<td>0.23 n/a</td>
</tr>
<tr>
<td>Sweets and Desserts</td>
<td>2.5 ±1.5 (0.4 - 7.0)</td>
<td>6.0 ±0.9 (4.3 - 7.0)</td>
<td>&lt;0.01 n/a</td>
</tr>
<tr>
<td>SSBs</td>
<td>2.1 ±1.5 (0.0 - 6.4)</td>
<td>2.5 ±1.5 (0.1 - 5.8)</td>
<td>0.13 n/a</td>
</tr>
</tbody>
</table>

SD = Standard Deviation, LPA = Light Physical Activity, MVPA = Moderate-to-Vigorous Physical Activity, TPA = Total Physical Activity, SSBs = Sugar Sweetened Beverages, 95% CI = 95% Confidence Interval

*a Bolded values indicate statistical significance (p<0.05)

b Mixed effects model including age and sex as covariates and accounting for children nested within observations
Table 3.3 Days per week children met daily guideline during school versus summer

<table>
<thead>
<tr>
<th>Obesogenic Behavior</th>
<th>Source</th>
<th>Guideline</th>
<th>Assessment</th>
<th>Mean days/week children met guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Activity</td>
<td>U.S. Department of Health and Human Services, 2008</td>
<td>≥1 hour per day of MVPA</td>
<td>Accelerometer</td>
<td>School: 5.0, Summer: 4.4</td>
</tr>
<tr>
<td>Screen Time</td>
<td>American Academy of Pediatrics, 2001</td>
<td>≤2 hours per day of screen time</td>
<td>Parent/child-report</td>
<td>School: 3.1, Summer: 1.5</td>
</tr>
<tr>
<td>Sleep</td>
<td>National Heart, Lung, and Blood Institute, 2005</td>
<td>≥10 hours per night</td>
<td>Parent-report</td>
<td>School: 1.7, Summer: 4.1</td>
</tr>
</tbody>
</table>

MVPA = Moderate-to-vigorous physical activity; USDA = United States Department of Agriculture
*Minimum dietary guideline
Chapter IV: Manuscript 3

Changes in children’s obesogenic behaviors during summer versus school and their association with summer health outcomes

Brazendale, K., Beets, M.W., Kaczynski, A.T., Pate, R.R., Turner-McGrievy G.M., Weaver, R.G. To be submitted to Pediatric Obesity
Abstract

**Background:** During the 3 months of summer, children gain weight at a greater rate and display a loss in cardio-respiratory fitness (CRF) compared to the 9 month school year.

**Objective:** To investigate changes in children’s obesogenic behaviors between summer and school in relation to their changes in body mass index (BMI) and CRF during summer.

**Methods:** A within-child repeated measures design of elementary school-aged children captured BMI and CRF before (May) and after (August) summer (2016). A 9-day protocol captured physical activity, sedentary/screen time, sleep and diet during school (May) and summer (July). Paired sample t-tests and Spearman correlations assessed relationships between and among health outcomes and obesogenic behaviors.

**Results:** African American children (N=23; mean age 8.1 years; 13 females) showed a small negative association for zBMI change and healthy summer behaviors (r=-0.36; p=0.09), and a positive association for CRF change (r=0.31; p=0.14) and healthy summer behaviors. Children who increased in zBMI and displayed a concurrent loss in CRF over summer presented less favorable obesogenic behaviors during summer.

**Conclusions:** Children who displayed more healthy changes in obesogenic behaviors during summer compared to school showed more positive health outcomes during summer. Further research is needed to confirm this relationship.
Introduction

Recent estimates classify approximately a third of elementary school-aged children (6-11 years) as Overweight or Obese. The prevalence of children who are overweight or obese is higher among children from low socioeconomic households and minority races (e.g., African Americans, Hispanics). Classification as either overweight or obese is associated with an increased risk for developing non-communicable diseases and is recognized as a major public health concern.

Over the past decade, a body of evidence has emerged that consistently shows during the 3 months of summer children gain weight at a greater rate compared to the 9 month school year. Further, a systematic review examining variations in weight gain among children during summer versus school concluded there is strong evidence that the accelerated rate of weight gain is most pronounced among those falling in to one of the following subgroups; already overweight/obese children, racial/ethnic minority children, and low socioeconomic status (SES) children. Additional evidence shows that when children return to school following the 3-months of summer they display a loss in cardio-respiratory fitness (CRF).

While studies provide evidence of the negative health outcomes occurring in children as a result of summer, there is a lack of research investigating potential causal factors. A great deal of focus has been placed on exploring children’s obesogenic behaviors (e.g., physical activity, sedentary behavior, screen time, diet, sleep) during the 9-month school year, hereon referred to as ‘school’, with very little attention given to measuring these same behaviors on the same children during summer. Previous studies that have investigated summer versus school differences in children’s obesogenic
behaviors have focused on one or two obesogenic behaviors, employed a between-subjects study design, used self-report subjective measures of obesogenic behaviors, and included other non-school vacation periods with summer data (e.g., winter breaks). Understanding how children’s obesogenic behaviors differ during summer versus school in direct relation to changes in children’s health outcomes is pertinent to aid researchers and public health practitioners in the development and implementation of evidence-based intervention strategies to mitigate the onset of adverse health outcomes currently associated with summer. Therefore, the purpose of this study is to investigate changes in U.S. elementary school-aged children’s obesogenic behaviors between summer and school in relation to their changes in BMI and CRF during summer.

Methods

Participants and Setting

Fifty-five children from one elementary school (Grade 1 – 4th) located within the southeastern region of the U.S. were invited to be part of the pilot study. The elementary school was located in a school district that predominately serves African American families from low-income households. Children enrolled in the elementary school were 85% African American, and 96.4% of children qualified for free/reduced lunch. All study procedures were approved by the author’s Institutional Review Board and parents provided written informed consent for the child. Each parent-child dyad received a $100 gift card for participating in the study.
Study Protocol

A repeated measures within-subjects study design was conducted during spring, summer, and fall of 2016. Children had BMI and CRF assessed at the end of the spring school semester, and again at the beginning of the fall school semester. The same children also participated in a 9-day measurement protocol assessing the following obesogenic behaviors during school (spring semester) and summer: physical activity, sedentary/screen time, diet, and sleep.

Measures

Health Outcome Assessments

Using a portable stadiometer (nearest 0.1 inches) and digital scale (nearest 0.1 lbs), children’s heights and weights were collected by two trained research assistants during regularly scheduled physical education (PE) classes. Prior to conducting the anthropometric measurements children wore light clothing and removed their shoes. BMI was calculated \( \text{weight (lb)/[height (in)]}^2 \times 703 \) and translated into a standardized score (zBMI) and percentile using sex and age normative data from the Centers for Disease Control and Prevention. Children’s CRF was assessed by the Progressive Aerobic Cardiovascular Endurance Run (PACER) 20-meter multistage shuttle run. The test was administered during regularly scheduled PE class by two trained research assistants, and with the support of the PE teacher.

Obesogenic Behaviors

Objective measures were used to capture children’s physical activity, sedentary time, and sleep. A wrist-based activity monitor (ActiGraph Link GT9X+ accelerometer, Shalimar, FL) was worn for 9 consecutive days during school and summer. A trained
research assistant strapped the activity monitor to the child’s non-dominant wrist and encouraged the child to wear the water-proof device for 9 days (day and night) without removal. The epoch was set at five-second intervals to account for the transitory PA patterns of children and to align with the validation epoch length. Validated non-dominant wrist-based cutpoints of \( \leq 161 \) and \( \geq 530 \) accelerometer counts per 5 seconds were used to distill sedentary time and moderate-to-vigorous physical activity (MVPA), respectively. A valid day of accelerometer data was total wear time \( \geq 600 \) minutes per day (excluding sleep) with removal of non-wear time identified as consecutive zeros for 30 minutes or more. Proprietary ActiGraph sleep algorithms validated for children (Sadeh Algorithm) were used to determine total sleep duration and individual files were reintegrated from 5-second epochs to 60-second epochs and analyzed for inconsistencies with sleep duration \( \leq 4 \) and \( \geq 15 \) hours per night removed from further analysis.

Children’s screen time and diet was assessed using self-report measures reported daily for 9 days by the parent with their child. Parents/children estimated the total amount of time (hours and minutes) spent in front of a screen that day (e.g., TV, computer, video-game, smartphone, and tablet). Hours were converted to minutes, summed to provide a daily screen time duration, and an average calculated by dividing the summed value by the number of days the daily diary was completed. For diet, parents completed a Beverage and Snack Questionnaire (BSQ) with their child. The BSQ is a cost-effective, easy-to-use tool to assess frequency of consumption of foods and beverages high in energy but poor in nutrients (e.g., savory snacks, sweets). There were a total of four response categories with individual items scored 0 (‘child did not consume’) to 3 (‘child consumed a lot’). For this study, individual BSQ items were grouped in
accordance with the Healthy Meal Index (HMI) food categories; fruits, vegetables, dairy (non-sugar based), convenience foods, sweets and desserts, and sugar sweetened beverages. Reported consumption was dichotomized (i.e., ‘did’ vs. ‘did not’ consume) and reported as mean days/week. Two groups were created for analysis of diet; healthy foods/drinks (fruits, vegetables, and dairy) and unhealthy foods/drinks (sugar-sweetened beverages, convenience foods, and sweets/desserts).

Data Analysis

To be included in the final analysis children had to have pre and post summer BMI and CRF measurements, and school and summer data that met the following criteria: ≥4 days (including 1 weekend day) of valid PA/sedentary data, ≥5 nights (including 1 weekend night) of valid sleep, and ≥7 days with complete daily diaries for screen time and diet outcomes. Child demographics and health outcomes (BMI and CRF) were presented as means and standard deviations, unless otherwise stated. Paired sample t-tests were used to compare obesogenic behaviors during school and summer, and pre and post-summer health outcomes. An alpha value of 0.05 was used to signify statistical significance.

Change in health outcome was calculated by subtracting the spring measure from the fall measure. Data were analyzed by exploring 1) changes in zBMI, 2) changes in CRF, and 3) changes in both health outcomes, in relation to changes in obesogenic behaviors of PA, sedentary/screen time, sleep, and diet during school versus summer. Children were split according to change in zBMI (Gain vs. No Gain or Loss) and change in CRF (Loss vs. No Loss or Gain) to explore patterns in the data. For exploring changes
across both health outcomes, children were split by those who displayed a gain in zBMI and a loss in CRF, versus the remaining children who did not meet this criterion.

Health Behavior Index

For changes in children’s obesogenic behaviors during summer versus school, a health behavior index (HBI) was created. The author’s hypothesize obesogenic behaviors during the 3-months of the summer are less healthy compared to school months. The direction of this hypothesis is based on pre-existing literature showing associations between the specific obesogenic behavior and a corresponding adverse health outcome (e.g., shorter sleep duration is associated with childhood obesity\(^27\)). For the present analysis, it was hypothesized that during summer children were; 1) less active (MVPA), 2) spent more time sedentary, 3) had higher amounts of screen time, 4) had shorter sleep duration, 5) consumed healthy foods/drinks less frequently, and 6) consumed unhealthy foods/drinks more frequently. The changes in these 6 obesogenic behaviors were calculated by subtracting the measure of the school behavior from the summer measure of the behavior. A positive difference for MVPA, sleep duration, and healthy foods/drinks, and a negative difference for sedentary time, screen time, and unhealthy foods/drinks, signified that the child made a healthy change for the obesogenic behavior during summer in comparison to school. The opposite of these directions would be considered an unhealthy change (i.e., the behavior was less healthful during summer compared to school). Each child received a ‘1’ for every healthy change made during the summer and a ‘0’ if an unhealthy change was observed. An HBI was created for each child by summing the score across all six obesogenic behaviors (maximum HBI score=...
6/6 indicating all behaviors changed favorably during the summer compared to school). If no change was observed between summer and school for any behavior, this was viewed as a healthy change on the basis that a child’s obesogenic behavior did not worsen over summer in comparison to school. For healthy and unhealthy food/drinks categories the majority score was given (1 or 0). For example, if a child displayed a healthy change in fruit (1), vegetables (1), but not in dairy (0), the child still received a healthy change score (1) as 2 out of the 3 components were a healthy change. Spearman’s correlations were computed to assess the relationship between the health outcomes and children’s HBI. All analyses were performed using Stata (v.14.1, College Station, TX).

Results

Of the 55 children invited to be part of the study, 23 children were included for a final within-subject analysis. The 32 children not included either were absent on one of the BMI/CRF assessment days (N=14), were not present for summer data collection (N=12), or had invalid data from school or summer data collection (N=6). The final within-subjects sample of children (N=23) had a mean age of 8.1 years (±1.2 years), with all being African-American (N=23), female (N=13), from a low-income household (median $10,000 - $19,000 per annum), and classified as normal weight (N=15) during pre-summer BMI measurement (Table 1). Independent sample t-tests found no differences between the children who did and did not return for the summer protocol across demographics and obesogenic behaviors. Children’s median zBMI increased by +0.22 during summer (p<0.01) and median CRF decreased (8 PACER laps; p=0.26). Wake accelerometer weartime was slightly higher during school versus summer (934.8
vs. 895.1 min/day; p<0.01), thus, percent of time spent in sedentary and MVPA was reported. On average, children spent more time sedentary, reported higher amounts of screen time, and more frequently consumed healthy and unhealthy foods during summer compared to school (p<0.05). Children slept longer during summer compared to school and spent a greater percent of time in MVPA during school compared to summer, but these differences did not reach statistical significance (p>0.05).

Across the 6 obesogenic behaviors for 23 children (138 possible change scores), there were only 13 occurrences (9.2%) where the change was zero, all of which occurred in the healthy food obesogenic behavior. Table 2 presents HBI scores for each child stratified by groups based on changes in zBMI (a), CRF (b), and both health outcomes combined (c). For zBMI, children in the no gain group had a median HBI score of 4 during summer compared to those children in the gain group, who had a median HBI score of 2. A similar pattern was observed in CRF. Children who displayed no loss in their CRF over summer had a higher median HBI than children who displayed a loss in CRF during summer (3 vs. 2 HBI, respectively). Children who displayed a concurrent gain in zBMI and loss in CRF had a lower HBI (median HBI=1) compared to other children (median HBI=3). A weak negative correlation between HBI score and zBMI (ρ= -0.36, p=0.09), and a positive correlation between HBI score and CRF (ρ= 0.31, p=0.14) was observed, although neither reached statistical significance.

**Discussion**

The purpose of this study was to explore changes in children’s obesogenic behaviors during summer versus school in relation to zBMI and CRF changes over
summer. This study provides preliminary evidence showing children who display more unhealthy changes in their obesogenic behaviors during summer compared to school, exhibit greater gains in zBMI and losses in CRF than that observed in their counterparts. Evidence consistently shows that when children return to school after summer they display accelerated weight-gain and a loss in CRF.\textsuperscript{52,55-59,65,259,260} Given the lack of existing studies, the data herein provides initial evidence that can help inform future investigative studies and public health practitioners looking to intervene on children’s health-related behaviors during summer.

The present sample of children showed an increase in median zBMI during summer (zBMI change +0.22) similar to other studies reporting summer zBMI increases investigating larger samples of children (N>3,000) over multiple summer-school cycles (zBMI change +0.20).\textsuperscript{65} Children’s median CRF decreased over summer (-8 PACER laps) which is in accordance with other studies using PACER (-6 PACER laps)\textsuperscript{260} or employing different measures of CRF (e.g., mile-run time,\textsuperscript{58} bench-stepping test,\textsuperscript{56} treadmill walking test\textsuperscript{59}). Although BMI measurements were not collected at the beginning of the previous school year–making it impossible to determine if weight gain was accelerated– it appears that children in the present study are showing similar adverse patterns in weight-gain during summer that other, more comprehensive (e.g., larger, more diverse samples, multiple school-summer cycles), studies have shown.\textsuperscript{53,57,65,259}

Investigating the mechanisms underlying children’s weight gain and declines in fitness levels over summer has, until this point, remained speculative.\textsuperscript{259} This study provides initial evidence of the differences in the patterns of children’s obesogenic behaviors in relation to their health outcomes as a result of summer. Children who
exhibited more favorable changes in their health outcomes during summer (e.g., no zBMI gain and no CRF loss) scored higher on the HBI. Specifically, children who increased in zBMI and presented a simultaneous loss in CRF made only one healthy change out of the 6 obesogenic behaviors, compared to their counterparts, who made 3 healthy changes out of the 6 obesogenic behaviors during summer compared to school.

Of further interest, there does not seem to be a distinct pattern where all children are changing the same in one – or a combination of – obesogenic behaviors and producing a similar direction of change (gain/loss) in health outcome (BMI or CRF). Table 2 (a-c) illustrates how children can attain the same HBI score but have different individual changes in their obesogenic behaviors, and subsequent health outcomes. For example, one child may achieve a HBI score of 3 from a healthy change in MVPA, sleep, and unhealthy food versus a child who made a healthy change in screen time, healthy food, and MVPA. Further, these children with the same HBI score could exhibit similar health outcomes, or conversely, vastly different health outcomes. The variability by child across obesogenic behaviors and its impact on a child’s BMI and CRF highlights the complex and individualistic nature of the interaction between a child and their family/home environment, and from a public health standpoint, complicates the process of identifying specific points of intervention. Examining patterns of individual child behaviors in relation to their health outcomes is a more favorable approach rather than reporting group-level means that may mask patterns in the data and lead to conclusions that are misleading to subsequent intervention methods.

To date, there are limited interventions targeting children’s obesogenic behaviors in relation to the family/home environment. Of those that do exist, the focus has

6
primarily been on a single obesogenic behavior, with limited effects on weight outcomes. ²²⁹,²⁶³ In light of the present data, it is clear that future studies need to conduct large-scale within-subject evaluations of multiple obesogenic behaviors in relation to health outcomes occurring over summer. With this, specific obesogenic behaviors and patterns of interaction can be identified, leading to better-informed intervention approaches. This study has strengths and limitations that need to be considered. First, this is one of the first studies to examine children’s changes across multiple obesogenic behaviors during summer versus school in relation to children’s changes in BMI and CRF. Second, the use of a within-subjects study design and objective measures to capture sedentary, MVPA, and sleep are also strengths. Lastly, the demographic of the sample (low-income, African American) represents a subgroup identified in the literature as most-at-risk of accelerate weight gain during summer. ⁵² The final sample size of 23 is a limitation, as it prohibits a more in-depth statistical analysis. Further, the sample represents children from one school, during one summer, in a Southeast region of the U.S.; therefore, findings may not generalize to other populations. Lastly, BMI and CRF data were not collected at the beginning of the previous school year making it impossible to distinguish if changes in health outcomes differed from changes occurring over the course of the school year.

In conclusion, this study provides preliminary data examining children’s obesogenic behaviors during summer versus school in relation to health outcomes occurring over summer. Children in this study displayed weight gain and a loss in fitness during summer, with approximately half of the sample displaying both adverse health outcomes. Generally, children who displayed a higher number of healthy changes in obesogenic behaviors during summer compared to school showed more positive health outcomes. Further research in large diverse
samples of children, incorporating a within-subjects design, and investigating multiple summer-
school cycles is needed to confirm this relationship.
### Table 4.1 Descriptive child/famil demographics (a), health outcomes (b), and obesogenic behaviors (c)

<table>
<thead>
<tr>
<th>(a) Child Demographics</th>
<th>All</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>23</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Age – years, (±SD)</td>
<td>8.1 , (1.2)</td>
<td>7.9, (1.4)</td>
<td>8.2, (1.1)</td>
</tr>
<tr>
<td>African-American – n, (%)</td>
<td>23, (100.0)</td>
<td>10, (100.0)</td>
<td>13, (100.0)</td>
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<tr>
<td>Household Income – median</td>
<td>$10,000 - $19,000</td>
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</tr>
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<table>
<thead>
<tr>
<th>(b) Health Outcomes</th>
<th>Pre-summer</th>
<th>Post-summer</th>
<th>Statistical Significance (p-value)*</th>
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</thead>
<tbody>
<tr>
<td>Body Mass Index – n, (%)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>15, (65.2%)</td>
<td>12, (52.2%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Overweight</td>
<td>1, (4.3%)</td>
<td>4, (17.4%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Obese</td>
<td>7, (30.5%)</td>
<td>7, (30.4%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Median zBMI – (±SD)</td>
<td>0.60 (1.18)</td>
<td>0.82 (1.16)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Cardio Respiratory Fitness

| Median PACER laps (±SD) | 30 (17) | 22 (17) | 0.26 |

<table>
<thead>
<tr>
<th>(c) Obesogenic Behaviors</th>
<th>School</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean, (±SD)</td>
<td>Mean, (±SD)</td>
<td></td>
</tr>
<tr>
<td>Wake wcartime – min/day</td>
<td>934.8, (82.5)</td>
<td>895.1, (111.4)</td>
</tr>
<tr>
<td>Sedentary - % of time</td>
<td>66.6, (4.6)</td>
<td>69.3, (5.6)</td>
</tr>
<tr>
<td>MVPA - % of time</td>
<td>8.4, (1.9)</td>
<td>8.0, (2.1)</td>
</tr>
<tr>
<td>Screen time – min/day</td>
<td>136.6, (63.2)</td>
<td>240.6, (152.3)</td>
</tr>
<tr>
<td>Sleep – min/night</td>
<td>416.4, (43.1)</td>
<td>428.8, (50.8)</td>
</tr>
<tr>
<td>Healthy foods* - days/week</td>
<td>4.6, (1.5)</td>
<td>5.2, (1.2)</td>
</tr>
<tr>
<td>Unhealthy foods* - days/week</td>
<td>2.5, (1.4)</td>
<td>3.7, (0.9)</td>
</tr>
</tbody>
</table>

SD = Standard Deviation, MVPA = Moderate-to-vigorous physical activity,
*Fruits, vegetables, dairy
*Sugar-sweetened beverages, sweets/desserts, convenience foods
*Paired sample t-test of difference (p<0.05)
Table 4.2 Children’s health behavior index (HBI) in relation to changes in zBMI (a), CRF (b), and both zBMI and CRF (c)

<table>
<thead>
<tr>
<th>Group</th>
<th>Child</th>
<th>zBMI Change</th>
<th>Healthy (green) vs. Unhealthy (red) Change</th>
<th>Health Behavior Index*</th>
<th>Spearman’s rank (p-value)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No Gain/Loss</td>
<td>-0.255</td>
<td>MVPA SED ST Sleep HF UP</td>
<td>4</td>
<td>4 (1.6)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>-0.156</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>-0.018</td>
<td></td>
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<td></td>
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<tr>
<td>4</td>
<td></td>
<td>-0.004</td>
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<td>6</td>
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<td>0.022</td>
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<td>7</td>
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<td>8</td>
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<td>0.064</td>
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<td>9</td>
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Note: MVPA = Moderate to Vigorous Physical Activity; SED = Sedentary; ST = Sleep; HF = Healthy Eating; UP = Upstairs Activity; HBI = Health Behavior Index.
<table>
<thead>
<tr>
<th>Group</th>
<th>Child</th>
<th>CRF change (PACER Laps)</th>
<th>Healthy (green) vs. Unhealthy (red)</th>
<th>Health Behavior Index</th>
<th>Spearman’s rho (p-value)</th>
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<td></td>
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<td>MVPA  SED  ST  Sleep  HF  UF  cb</td>
<td>Child Score</td>
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<tr>
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<td>4</td>
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<td></td>
<td>3</td>
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<td>CRF change (PACER Laps)</td>
<td>zBMI Change</td>
<td>Healthy (green) vs. Unhealthy (red) Change</td>
<td>Health Behavior Index (HBI)</td>
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CRF= Cardiorespiratory fitness, BMI=Body Mass Index, MVPA=Moderate-to-vigorous physical activity, SED=Satentary time, ST=Screen Time
*Increase in MVPA, less sedentary screen time, greater sleep duration, more frequent consumption of Healthy food, and less frequent consumption of unhealthy foods during summer versus school

HF=Healthy Foods=Frutas, Vegetables, Dairy
UF=Unhealthy Foods=Sugar Sweetened beverages, sweets/desserts, and convenience foods

*The sum of green health behaviors (max score = 6)
Chapter V: Overall Discussion
Discussion

The prevalence of childhood obesity among United States (U.S.) children aged 6-11 years has quadrupled in the last five decades. Classification as either overweight or obese is associated with an increased risk for developing non-communicable diseases and is recognized as a major public health concern. The majority of intervention strategies targeting obesity prevention have focused on four obesogenic behaviors: physical activity (PA), sedentary/ screen time, diet, and more recently, sleep. Understandably, studies examining these behaviors have been conducted in settings where children spend the majority of their time, such as during the 9-months of the school year, hereon referred to as ‘school’. The scientific community has acknowledged that modest improvements can be made to weight status and obesogenic behaviors while children are in school, yet evidence is gathering that suggests these improvements are undermined as children are released to summer vacation.

Over the past decade, a body of evidence has emerged that consistently shows during the 3 months of summer children gain weight at a greater rate compared to the 9 month school year. Further, a systematic review examining variations in weight gain among children during summer versus school concluded there is strong evidence that the accelerated rate of weight gain is most pronounced among those falling in to one of the following subgroups; already overweight/obese children, racial/ethnic minority children, and low socioeconomic status (SES) children. Additional evidence shows that when children return to school following the 3-months of summer they display a loss in cardio-respiratory fitness (CRF).
Currently, there is a distinct lack of scientific evidence exploring obesogenic behaviors during summer, and of the studies that do exist, there are mixed findings and limitations in methodology. To this extent, there is a clear lack of scientific evidence pertaining to children’s obesogenic behaviors during summer months which prohibits any real understanding of causal factors associated with the occurrence of these negative health outcomes.

This dissertation addresses this gap in the literature by exploring children’s obesogenic behaviors during summer versus school incorporating a within-subject study-design and investigating an at-risk population.

Purpose

The objectives of the research conducted in this dissertation were to:

1) Provide an evidence-based argument in absence of a summer versus school literature base - referred to as the ‘Structured Days Hypothesis’ - which explores the scientific evidence on PA, sedentary/screen time, diet, and sleep in relation to the larger literature base that compares WD versus WE – two contexts considered structured (WD) and unstructured (WE) environments, respectively.

2) Examine within-child differences in PA, sedentary/ screen time, diet, and sleep during summer versus school in a sample of elementary school-aged children from low-income African American households.

3) Investigate how changes in U.S. elementary school-aged children’s obesogenic behaviors between summer and school relate to changes in their BMI and CRF before and after summer.
Major Findings

Study 1 presented the SDH, and used the larger literature base of WD versus WE evidence to support the argument that children require a structured environment to mitigate unhealthy behaviors from occurring. The evidence demonstrated that U.S. elementary school-aged children’s obesogenic behaviors are less favorable during less-structured (i.e., weekend days) versus structured days (i.e., weekdays), and, hence the findings supported the SDH that when elementary school-aged children are exposed to environments that contain less structure, regulation, and supervision, they indulge in a host of unfavorable behaviors. Approximately 80% of studies reporting estimates of WE versus WD obesogenic behaviors showed support towards the SDH and the fundamental difference between summer and WE during the school year is the length of time children are exposed to a less-structured environment. The concentrated, largely non-interrupted exposure to a less-structured environment over summer could be unfavorably impacting the health of children. Given evidence showing that when children spend summer days in a structured environment (e.g., summer day camp or program) they display more favorable obesogenic behaviors compared to a less-structured environment \(^{232,233}\), a key message for public health practitioners and policy makers from this study is the need to recognize the benefit of structure to a child’s day. A shift of focus, effort and resources is required to developing strategies and methods that ensure all children are given an equal opportunity to access and participate in summer structured programs.

Study 2 investigated within-child differences during summer versus school across multiple obesogenic behaviors (e.g., in PA, sedentary/screen time, diet, and sleep). Over
summer children were less active, more sedentary, engaged in higher amounts of screen
time, slept longer, and more frequently consumed sugar-sweetened foods and fruit.
Collectively, the findings suggest children are displaying multiple unfavorable health
behaviors during the summer months compared to school. It is highly plausible that the
regular occurrence of these obesogenic behaviors during summer compared to school
may be contributing to the accelerated weight gain and losses in CRF during summer.
These findings support the basis of the SDH presented in Study 1, where the open-ended
and unstructured nature of summer days could be presenting children with more freedoms
and autonomy to choose how they spend their time; and is a stark comparison to the
regulated and structured days that occur during school months. Further, in consideration
of the evidence presented herein it is possible that children are making choices to engage
in a host of unfavorable behaviors, sometimes concurrently (e.g., excessive screen time
and snacking on energy-dense foods/beverages), and the continuous presence of these
unhealthy traits over the long duration of summer is compounding the adverse health
outcomes observed in children when they return to school after summer. The data,
although preliminary, provides initial evidence for targets of an intervention directed at
minimizing children’s accelerated weight gain and losses in CRF during summer.

Study 3 explored patterns in the data to see if differences in children’s obesogenic
behaviors were related to changes in their health outcomes occurring over summer, such
as BMI and CRF. The evidence showed children who display more unhealthy changes in
their obesogenic behaviors during summer compared to school, exhibited greater gains in
zBMI and losses in CRF than that observed in their counterparts. The gains in zBMI were
comparable to other studies that assessed summer zBMI gains from longitudinal evidence
of over 3,000 elementary school-aged children in the U.S. Another key finding from Study 3 was the variability by child across obesogenic behaviors and its impact on a child’s BMI and CRF. There did not seem to be a distinct pattern where all children are changing the same in one – or a combination of – obesogenic behaviors and producing a similar direction of change (gain/loss) in the health outcome (BMI or CRF). Not only does this variability highlights the complex and individualistic nature of the interaction between a child and their family/home environment, and from a public health standpoint, confounds the process of identifying specific points of intervention, it provides valuable insight for future targeted interventions to consider examining individual child behaviors/patterns in relation to health outcomes rather than reporting group-level means that could present misleading data.

**Implications and Considerations**

In total, this dissertation has explored the potential mechanisms that may be driving accelerated weight gain and loss in CRF in children during summer. This exploration began with the development of the SDH, where it was presented that the characteristics (e.g. routine, regulation, compulsory components) and presence of a structured day may be mitigating the occurrence of unfavorable obesogenic behaviors (low physical activity, increased sedentary time, poorer diets etc.). It is hypothesized that this structure to the day may not be as present over summer, and certainly the exposure to the home environment could be seen as greater over summer than during the 9-months of the school year, therefore, it is not inconceivable that summers could be one long weekend. The WE versus WD literature suggests that during WE children exhibit unfavorable obesogenic behaviors compared to WD (~80% of studies in support of
SDH), yet longitudinal non-intervention evidence showing children’s weight gain trajectories are either steady, flat-lined or reversed suggests that the periodic and short bouts (2 days) of less-structured days (i.e. WE) don’t seem to have the same impact on health outcomes (e.g., weight gain, CRF) compared to the longer summer period (~75 days). Ultimately, it could be the length of time that children are exposed to this less-structured environment that is driving accelerated weight gain and loss in fitness, and, thus, the authors suggest that this prolonged period of time that summer affords to children in a less-structured environment is detrimental to the health of children. Further, research has shown how structure in the home environment in the form of routine and regulation (e.g., regular bedtimes, screen time rules, and eating with family) is associated with 40% lower prevalence of obesity.\textsuperscript{264} A follow up study by Anderson et al. (2017) determined that these household routines were independent predictors of obesity at age 11, illustrating the importance of having structure in the home environment from an early age.\textsuperscript{265}

The initial evidence presented herein from primary data acquisition (Study 2) investigating children’s obesogenic behaviors during summer versus school in a sample of African-American children from low-income shows that children display multiple unfavorable obesogenic behaviors, and the authors theorize that it is structured nature of the school day that is providing a protective effect on children’s weight gain during the 9-months of the school year. A further analysis of the PA data from the 30 within-subjects segmenting out the day on an hourly basis (e.g., before, during, and after-school) shows that when children are within school hours on school WD they achieve higher amounts of total PA compared to the same segment of time on summer WD (i.e., school hours on a
Further, the coefficient of variation – which is a measure of spread that describes the amount of variability relative to the mean – is much smaller during school versus summer (0.32 vs. 0.75) illustrating the beneficial impact the structure nature of the school day can have on all children’s total PA. Of further interest, when children left school (i.e., after school hours), their total PA levels dropped to that similar of a summer WD, with the coefficient of variations very similar (0.48 vs. 0.49). In light of this, a key component that has changed during these after-school hours is the consistent presence of structure to their day. Only a small portion of children in this study reported attending a structured after-school program (~30%) for around 50% of WD, thus, it is likely that on school WD children are returning home to environments where there is less-structure and more opportunities to engage in unfavorable behaviors, and these behaviors are mirrored during summer WD.

So how are children spending their days over summer during the hours when they would be in school during the 9-months of the school year? Descriptive information obtained from the children/parents showed that 12 of the 30 children reported spending at least one day at a camp or summer structured program. However, the mean amount of days spent in camps or programs over summer was 14 out of possible 75 days; therefore, the exposure to a structured environment that is consistent with a school day is low. Interestingly, 90% of parents reported their child was in the care of a relative (e.g., Grandparent, Aunt) for approximately 5 out of 7 days per week during summer. Although we were unable to distinguish the exact length of time children spent at a relative’s house each day, this provides some insight as to how children may be spending their summer days. It is plausible that when in the care of others, they have less regulation and routine
to their day and have greater opportunities to indulge in multiple unfavorable obesogenic behaviors (e.g., snacking whilst watching TV/playing video games) over long periods of time. From this initial evidence it is apparent that children in our sample are not regularly attending structured programs over summer which may provide some benefit to health outcomes. Recent summer day camp evidence of over 1,000 children demonstrates that approximately 80% of boys and girls in attendance achieved over 60 minutes e day of MVPA. However, there is a noticeable trend in the demographic of children who attend camps or summer programs, with the most recent report from the American Camping Association (Fall Report, 2016) showing greater than 75% of children in the U.S. attending summer structured programs are Non-Hispanic White and from middle-to-high income families. The sample of children herein represent those who are not frequent attenders of camps or summer structured programs (i.e., ethnic/racial minority, low-income families) placing further emphasis on the need to provide access to these summer opportunities for all children. In addition, other studies have shown that children’s weight gain is either minimized or flat-lined just from being in a summer structured program or year round school.225,266 This evidence, coupled with the initial evidence presented from Study 2, shows support towards the SDH and how a lack of structure over summer may be driving the occurrence of these adverse health outcomes.

Another finding from this dissertation that is of interest is the low sleep duration observed during school and summer. Previous studies have concluded that school-age children sleep approximately 10 hours per night,28 however; the majority of children’s sleep estimates derive from self-report surveys and time diaries which are open to overestimation.28 In the present study, the accelerometer-derived sleep duration during
both summer and school was markedly lower (~7 hours/night), and falls considerably
short of the sleep recommendations put forth by the American Academy of Pediatrics (9-
12 hours/night) for optimal health. In this regard, children in this study – irrespective
of during school or summer – are not getting adequate sleep, which is of concern given
the negative association found between weight status and sleep duration in children. A
recent systematic review of sleep duration concluded that approximately 20% of current
studies have used objective measurements of sleep, meaning the majority of sleep
duration studies have opted for self-report methods that are open to bias and/or issues
with accuracy of reporting. This was observed in our study, with parents reporting
much longer sleep duration for their children than captured via the wrist-worn device.
However, wake time estimates across measurements (objective vs. self-report) were
accurate. The discrepancies in sleep duration came from the time parents reported their
child going to bed and the time the children actually fell asleep according to the wrist-
worn device. There was approximately a 90-120 minute period where the child was still
awake but in their bedroom. This could be a critical time where children are engaging in
screen time before bed. Twenty three of the 30 parents in this study reported children had
at least 2 screen time devices in their bedroom and research on the use of screen time
devices has shown how it can disrupt children’s sleep quality and circadian rhythm
through psychological and physiological arousal from the content and light from the
screen. Additionally, extended periods of screen time before bed would be replacing
time that children could be sleeping. This is an example of filled time perspective – a
theory addressed earlier in Study 1 – whereby children are filing their time with
unfavorable activities at the expense of favorable activites. The limited objective
evidence that currently exists for children’s sleep warrants a clear need for further investigation in both children’s sleep duration and underlying mechanisms that impacts sleep duration, and other sleep deficiencies such as sleep quality and sleep timing. Although further sleep deficiencies were not investigated in this dissertation, the authors speculate that sleep deficiencies may be more prevalent in less-structured environments where certain obesogenic behaviors are allowed to flourish, and, thus, the underlying mechanisms of sleep deficiencies (i.e. sleep duration, quality, Timing, circadian rhythm) are contingent upon the very structure of a child’s day.

Limitations to Dissertation

Study 1 was limited by the inclusion criteria where studies reporting WE versus WD estimates of obesogenic behaviors for elementary school-aged children were examined. As this evidence base was used to support the SDH one could argue that the SDH only holds true for this specific population and the hypothesis may change when exploring a different population (e.g., pre-school children, adolescents etc.). Further, although a comprehensive and systematic search was included, the authors cannot explicitly state that all literature reporting WE versus WD estimates of elementary school-aged children’s obesogenic behaviors was examined.

Study 2 and Study 3 were limited the final within-subjects sample sizes (Study 2 N=30; Study 3 N=23). The small sample size for both studies prohibited further analysis such as exploring sex, age/grade, or weight status differences among obesogenic behaviors during summer versus school. For Study 2 specifically, the self-report diet data collected did not include reporting serving size thereby making it difficult to interpret daily consumption in the context of national guidelines (e.g. United States Department of
Agriculture Guidelines for Americans). For Study 3, BMI and CRF data were not collected at the beginning of the previous school year (fall, 2015). This would have been useful to explore changes in health outcomes occurring over the school year and compare these in relation to changes occurring over the course of the school year, specifically identifying whether or not summer weight gain was accelerated in comparison to the school year. Overall, this dissertation may lack generalizability given the results pertain to low-income African American children from one Elementary school, in one region of the U.S., and from one school-summer cycle.

Future Research

The findings presented in this dissertation provide a starting point for which future research can build on. In light of the SDH, it is worth examining this hypothesis in a different population (e.g., adolescents) and perhaps testing this hypothesis directly by examining obesogenic behaviors in two opposing environments (structured vs. unstructured) to see if it holds true.

Although this dissertation attempts to fill the gap in the literature pertaining to children’s obesogenic behaviors during summer versus school, there is a clear need for further investigation. Future research should incorporate a longitudinal within-subjects design exploring a large and diverse sample of children (e.g., high vs. low SES) across multiple summer-school cycles in order to better understand the underlying mechanisms leading to accelerated weight gain and losses in CRF. With this, specific evidence-based behavioral targets for interventions can be developed and implemented during summer. Hypothetically, intervention efforts targeting specific obesogenic behaviors could take place prior to summer during the last month of school and could take the shape of parent
education and outreach initiatives with the aim of improving awareness and knowledge on the potential adverse health outcomes that can occur over summer. Senior school staff and community stakeholders could come together to work on initiatives to get children from low-income households in to structured programs over summer. An example of how this may operate is having the school provide access to their building over the summer for a period of time where a camp or program could take place.

Conclusion

In summary, this dissertation has addressed a novel and relatively unexplored area in the field of public health. Within the last decade, researchers have identified summer as a time period where children are at risk of accelerated weight gain and losses in CRF, but little is known about the causes of these adverse health outcomes. The SDH would suggest that the school environment as a whole plays a protective role against the onset of unfavorable health outcomes by regulating obesogenic behaviors through its daily structure, regulation, and compulsory components, as demonstrated by the body of evidence that demonstrates favorable obesogenic behaviors on weekdays (i.e., school days). Typically summer, just like weekend days, have less consistent and formal daily structures, regulatory components, and present a more autonomous environment to children, with the fundamental distinguishing characteristic of summer days compared to weekend days identified as the prolonged and concentrated period of time children are exposed to a less-structured environment (~3 months). The data presented in this dissertation provides preliminary evidence of differences in children’s obesogenic behaviors during summer versus school and how unfavorable obesogenic behaviors occurring during summer such as greater time spent sedentary, less total
physical activity, higher frequency of consumption of foods/beverages, and higher screen
time, could be impacting health outcomes occurring during this time, such as the
increases in weight and losses in CRF observed in this small sample. Summer may be the
critical period where future childhood obesity efforts need to be focused; however,
longitudinal evidence with larger, more diverse samples of children is necessary to
identify specific behavioral targets for interventions during summer.
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