INHIBITORY CONTROL AND ENERGY INTAKE IN RURAL OREGON YOUTH: THE POTENTIAL MODERATING EFFECT OF CHILDREN'S PERCEIVED FOOD REWARD AND PARENTAL RESTRICTIVE FEEDING PRACTICES

by

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DISSERTATION ABSTRACT

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Title: Inhibitory Control and Energy Intake in Rural Oregon Youth: The Potential Moderating Effect of Children's Perceived Food Reward and Parental Restrictive Feeding Practices

Extant data suggest that rural children are more likely to consume a surplus of calories and energy-dense foods (e.g., candy, soft drinks, and vending machine snacks) compared to their urban peers. Eating behaviors established in childhood often persist throughout the lifespan, and longitudinal data implicate a host of medical concerns associated with a childhood diet high in calories, fat, and sugar. Executive function, specifically inhibitory control, or the ability to withhold a preplanned response, may be especially relevant to eating self-regulation in children living in rural communities. Children who already find food to be particularly rewarding may experience exceptional difficulties inhibiting their eating behaviors. Parental restrictive feeding may further complicate the relationship between inhibitory control and eating behaviors because it prevents a child from developing eating self-regulation.

The current dissertation investigated the link between inhibitory control and energy intake in rural Oregon children. Children's perceived food reward and parental restrictive feeding practices were examined as potential moderators. It was hypothesized that lower inhibitory control would be linked to greater energy intake and that children's perceived food reward and restrictive parental feeding would exacerbate this association.

Rural Oregon children (N = 92, 8-10 years, mean age = 9.05, 50% female, 74.5% white/Caucasian) participated in the current study. Children completed neuropsychological assessments of general and food-specific inhibitory control, and total caloric intake was measured via a laboratory test meal. Validated self-reported measures were used to assess children's perceived food reward and restrictive parental feeding. In this study, neither general (ps = 0.52-0.53) nor food-specific inhibitory control (p = 0.66) was significantly associated with total caloric intake. Neither children's perceived food reward (ps = 0.53-0.93) nor restrictive parental feeding (ps = 0.39-0.64) functioned as moderators in any models. Our findings suggest that, in 8-10-year-olds, inhibitory control may not be linked to greater caloric intake. Non-significant findings may also be an artifact of limited variability in the constructs of interest among children within the narrow age range of this smaller sample. Future studies should seek to examine these associations in more heterogeneous samples of rural and urban youth.

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CHAPTER I

INTRODUCTION

Eating behaviors are established during the transition from an exclusively milk or formula diet in infancy to an omnivorous diet in toddlerhood and early childhood (Birch & Fisher, 1998). During this transition period, children learn their taste preferences and that the consumption of food is associated with both post-ingestive benefits (e.g., increased energy levels, comfortable satiety) and consequences (e.g., indigestion, gastrointestinal distress) (Birch & Fisher, 1998). Multiple factors contribute to the development of nuanced eating behaviors during early childhood, such as genetic predisposition, learned food preferences, socioeconomic status, and feeding practices (Birch, 2006; Birch & Davison, 2001; Birch & Fisher, 1998). Understanding individual and contextual factors that contribute to eating behaviors is important for long-term health outcomes, as early childhood eating behaviors tend to persist throughout the lifespan (Derks et al., 2019; Ogden et al., 2018).

One form of eating that can adversely impact long-term health is positive energy balance, which refers to consuming a surplus of calories (Hales et al., 2018; Ogden & Flegal, 2015; Wang & Beydoun, 2007). According to energy balance theory, excess calories that are consumed and not used in metabolic expenditure (i.e., maintaining bodily functions and physical activity) are converted into adipose tissue and stored as body fat (Wells & Siervo, 2011). Chronic positive energy balance—consuming more calories than expended long-term—is associated with a host of medical comorbidities, including hypertension, heart disease, sleep apnea, arthritis, type 2 diabetes mellitus, autoimmune disease, and some forms of cancer (Ahima & Lazar, 2013; Calle & Kaaks, 2004; Pi-Sunyer, 1999; Semlitsch et al., 2019; Versini et al., 2014). Identifying mechanisms that contribute to positive energy balance in childhood may help to prevent long-term health risk outcomes.

Rural Residency and Greater Caloric Intake in Childhood

Multiple factors influence childhood eating behaviors, including socioeconomic status, genetic predisposition, and living conditions (Hales et al., 2018; Ogden & Flegal, 2015; Wang & Beydoun, 2007). One notable demographic factor that may render children more susceptible to greater caloric intake is living in a rural community (Johnson & Johnson, 2015). Rural children are at an increased risk for poverty, limited access to affordable and healthy foods, and lack of nutrition education services, and they report overall increased caloric consumption (Liu et al., 2012; McCormack & Meendering, 2016; Ogden et al., 2018). In a cross-sectional analysis of the 1999-2006 National Health and Nutrition Examination Survey Data, rural children (aged 2-11 years) were found to consume 90 more calories per day, on average, than their same-aged urban peers (Liu et al., 2012). Rural children in this study were also less likely to consume the recommended two cups of fruit per day and consumed significantly more dairy and dietary fat than their urban peers. In addition to reporting consuming more calories overall, rural youth also reported consuming more energy-dense and palatable foods, including candy, food from vending machines, and sugar-sweetened beverages (Cutumisu et al., 2017; Findholt et al., 2014). A childhood diet high in fat and sugar is prospectively associated with a host of medical comorbidities, including chronic disease (e.g., type 2 diabetes, components of the metabolic syndrome, and cardiovascular disease) and an altered gut microbiome that renders individuals more susceptible to infection and gastrointestinal distress (David et al., 2014; Kau et al., 2011; Shreiner et al., 2015).

Executive Function and Energy Intake

As noted, the rural food environment may predispose children to greater caloric intake from an early age (DeVoe et al., 2009; Findholt et al., 2014). A second factor that appears to be relevant to the management of energy intake is executive function (Carlson et al., 2013; Rollins et al., 2021). Broadly, executive function refers to higher-order cognitive processes that facilitate purposeful behaviors in novel circumstances and the fulfilment of long-term goals (Brocki & Bohlin, 2004; Huizinga et al., 2006). Executive function entails various self-regulatory, cognitive processes that are responsible for both monitoring and controlling thought and goal-directed behaviors (Carlson et al., 2013). There are three distinct domains that are thought to comprise executive function: (a) inhibitory control, (b) mental shifting, and (c) information updating/monitoring (Carlson et al., 2013). Extant data indicate that of all domains of executive function, inhibitory control may be especially relevant to energy intake patterns in youth (Lavagnino et al., 2016).

Inhibitory Control

Inhibitory control refers to the ability to override an impulse, habit, or planned activity (Lavagnino et al., 2016). Inhibitory control supports both flexible and goal-directed behavior in fluid contexts and is critical to self-regulation in our ever-changing food environment (Lavagnino et al., 2016). Two of the most widely used assessments that measure general inhibitory control are the Flanker Task (Eriksen & Eriksen, 1974) and the Stop Signal Task (Verbruggen & Logan, 2008). Lower general inhibitory control, as measured by these tasks, has been associated with a greater propensity towards emotional eating (e.g., eating to gain pleasure) in the absence of physiological hunger (Pieper & Laugero, 2013); maladaptive eating behaviors (Bartholdy et al., 2016); and greater intake of carbohydrates, sugar, snack foods, fast foods, and sugar-sweetened beverages (Hall et al., 2008; Levitan et al., 2015; Riggs et al., 2010. In children as young as 6 years old, poorer inhibitory control has also been associated with self-serving larger food portions, consuming multiple food portions, and eating significantly faster (Fogel et al., 2019). In sum, studies using general measures of inhibitory control suggest that degree of skill in this domain of executive functioning is related to the quality of children's eating behaviors as well as greater caloric intake in children and adolescents, perhaps reflecting their ability to inhibit problematic eating patterns and engage in more healthful eating patterns.

Food-Specific Inhibitory Control

Within the context of eating behaviors, there is increasing recognition that inhibitory control is item- and context-specific (Lavagnino et al., 2016; Wu et al., 2013). Food-specific inhibitory control refers to an individual's ability to override their natural impulses to consume palatable foods that are readily available (Leehr et al., 2018; Teslovich et al., 2014). One of the most empirically supported measures of food-specific inhibitory control in children is the Food Go/No Go Task. The Food Go/No Go task measures food-specific inhibitory control by asking participants to maintain behavioral control in the face of food-specific interfering stimuli (e.g., being instructed to ignore responding to highly palatable foods visually presented) (Teslovich et al., 2014). Poorer performance on this task is thought to reflect greater difficulties with self-regulation and behavioral inhibition in the context of food. Indeed, worse performance on the Food Go/No go task in youth is associated with attentional biases for high-calorie foods and disinhibited eating (Teslovich et al., 2014).

In another novel study, the Food Go/No Go task was used as an intervention to train preschool-age children in food-specific inhibitory control (Jiang et al., 2016). Children in the intervention group consumed significantly less palatable foods (e.g., candy, cookies, and chips) than children in the control group, who played with Legos in another classroom for the same period of time (Jiang et al., 2016). Overall, these data suggest that children with lower food-specific inhibitory control may be more prone to positive energy balance and that food-specific response inhibition may be a malleable mechanism for improving children's eating behaviors (Jiang et al., 2016). Whether general or food-specific inhibitory control differentially relate to energy intake in rural youth remains unclear. Moreover, extant research demonstrates an overreliance on self-report methods to measure energy intake, which are significantly biased, and few studies have included objective tasks to measure both general and food-specific inhibitory control (Herbert et al., 1997; Lavagnino et al., 2016).

Taken together, children with poorer inhibitory control, both general and food-specific, may be at particularly high risk for greater caloric intake and positive energy balance (Rollins et al., 2021). Because rural children may have greater access to highly palatable and energy-dense foods through their local environment, it is theorized that they may have to expend significantly more inhibitory control resources in order to regulate their eating behaviors (Liu et al., 2012; Nanney et al., 2013). While currently understudied in rural youth, inhibitory control may be an underlying mechanism relevant to the self-regulation of eating behaviors, food choices, and long-term health outcomes (Reinert et al., 2013). It is also currently unknown how the rewarding, reinforcing sensory aspects of food interact with inhibitory control to further promote greater caloric intake in rural youth.

Food Reward

It is theorized that for individuals with lower inhibitory control abilities, perceived food reward, referring to individual variations in sensory pleasure gained from eating, may further impact abilities to regulate food choices and eating behaviors (Guerrieri et al., 2012). Two discrete, yet interconnected neurobehavioral systems are thought to regulate eating: (a) the homeostatic system and (b) the reward-based system. Through the homeostatic system, food helps to govern energy balance by providing physiological feedback that cues hunger or satiety (Harrold et al., 2012). The reward-based eating system, on the other hand, is influenced by the hedonic sensory experiences of food (Berridge, 2009; Berridge et al., 2010). *Hedonic* eating refers to eating for sensory pleasure in the absence of pure physiological hunger (Lowe & Butryn, 2007). In this neurobehavioral system, hedonic neural circuits interact in the brain's sensory pleasure system, such as in the nucleus accumbens and ventral pallidum where sensory pleasure is amplified, to drive appetitive motivational processes and the subsequent consumption of highly palatable foods because it is pleasurable (Berridge, 2009; Berridge et al., 2010).

Eating for hedonic pleasure includes reward-based eating, which can be conceptualized as a trait-like quality, or phenotype, that encompasses the drive to overeat, the subjective experience of a lack of control over eating, a lack of satiation, and preoccupation with food (Epel et al., 2014). Indeed, individuals with reward-based eating tendencies have been identified as a phenotype at high risk for persistent weight gain and a high body mass index (BMI) (Epel et al., 2014; Murray et al., 2014; Rogers & Hardman, 2015). Children who demonstrate both lower inhibitory control and higher reward-based eating habits may experience exceptional difficulties when attempting to regulate their energy intake. Indeed, reward-based eating has been found to exacerbate the link between inhibitory control and disinhibited eating in adult women, such that women with lower inhibitory control and high appetitive drive were more likely to binge eat, referring to consuming an objectively large amount food while also feeling a sense of loss of control (Manasse et al., 2015). However, both the independent and interacting effects of reward-based eating and inhibitory control on children's eating behaviors remains unknown and has yet to be investigated in rural youth populations.

Parental Restrictive Feeding Practices

In addition to difficulties with children's inhibitory control and reward-based eating tendencies, parental feeding practices may further complicate children's responses to food. Parental beliefs and behaviors towards feeding and eating practices play a critical role in shaping the family eating environment as well as early childhood eating experiences (Birch & Fisher, 1998). Both parents' feeding attitudes (i.e., beliefs about feeding children) and behaviors (i.e., how they actually feed their children) influence which foods children are offered, the portion, the timing of feeding, and social context; all of these factors contribute to the emotional tone of eating (Birch & Davison, 2001). Restrictive parental feeding, which refers to parents intentionally limiting the type and amount of foods offered to their children for consumption, is often implemented by parents who are concerned with their child's weight (Gray et al., 2010). Paradoxically, restrictive feeding practices are associated with increased risk for weight gain in children (Bauer et al., 2017; Birch et al., 2003). It has been hypothesized that restricted foods become particularly rewarding to children, which can lead to overeating when these foods become available (Anzman & Birch, 2009). Experimental data support this idea and indicate that parental restrictive feeding patterns increase children's taste preferences for and the consumption of highly palatable foods (Anzman & Birch, 2009; Birch & Davison, 2001; Birch & Fisher, 1998).

Prospective data indicate that restrictive parental feeding is associated with increases in BMI throughout childhood and adolescence (Anzman & Birch, 2009). Inhibitory control is theorized to interact with parental restrictive feeding, such that for children with lower inhibitory control, restrictive parental feeding further interferes with a child's ability to develop autonomous eating self-regulation (Anzman & Birch, 2009; Birch & Fisher, 1998). Evidently, restrictive feeding practices exert a profound influence on children's eating behaviors and may make it especially hard for children who experience difficulties with inhibitory control to effectively manage their energy intake patterns. This theory has yet to be validated in rural children.

Summary

Positive energy balance in childhood, referring to consuming a surplus of calories, is a robust risk factor for various health concerns (Butte et al., 2007; Liu et al., 2012). Children living in rural communities may be especially vulnerable to positive energy balance given their food environment and relatively easy access to highly palatable foods (Jones et al., 2012). As such, rural children may need to expend significantly more cognitive resources in order to self-regulate their food choices. Indeed, lower inhibitory control has been identified as a robust risk factor for problematic eating behaviors, including consuming a surplus of calories and emotional-based eating (De Decker et al., 2016; Duckworth et al., 2010; Goldschmidt et al., 2015).

For children with high reward-based eating tendencies and low inhibitory control, eating beyond energy needs may be particularly common. Parental restrictive feeding may similarly exacerbate the link between low inhibitory control and energy intake. This form of parenting is thought to impede children's eating self-regulation and also renders them more susceptible to hedonic eating (Anzman & Birch, 2009; Saltzman et al., 2016). Taken together, children with lower inhibitory control may be at particularly high risk for positive energy balance. Higher reward-based eating tendencies and restrictive feeding practices may independently exacerbate this association. Self-report data on children's inhibitory control and energy intake patterns provide preliminary support for these theories, however, no studies have included objective measures of both inhibitory control (e.g., validated executive function tasks) and energy intake (e.g., a laboratory meal) (De Decker et al., 2016; Gray et al., 2010).

Study Aims and Hypotheses

The primary objective of the current dissertation was to investigate the link between inhibitory control and energy intake in a sample of rural Oregon children. It was hypothesized that: (H1) lower inhibitory control would be positively associated with total caloric intake as measured during a laboratory test meal. It was also hypothesized that: (H2) reward-based eating would exacerbate this association, such that participants who reported greater reward-based eating would demonstrate a more pronounced link between poorer inhibitory control and energy intake than participants who reported lower reward-based eating. Additionally, it was hypothesized that: (H3) restrictive parental feeding would also independently exacerbate the link between inhibitory control and energy intake, such that pediatric participants whose parents engaged in more restrictive feeding practices would exhibit an especially pronounced link between inhibitory control and energy intake.

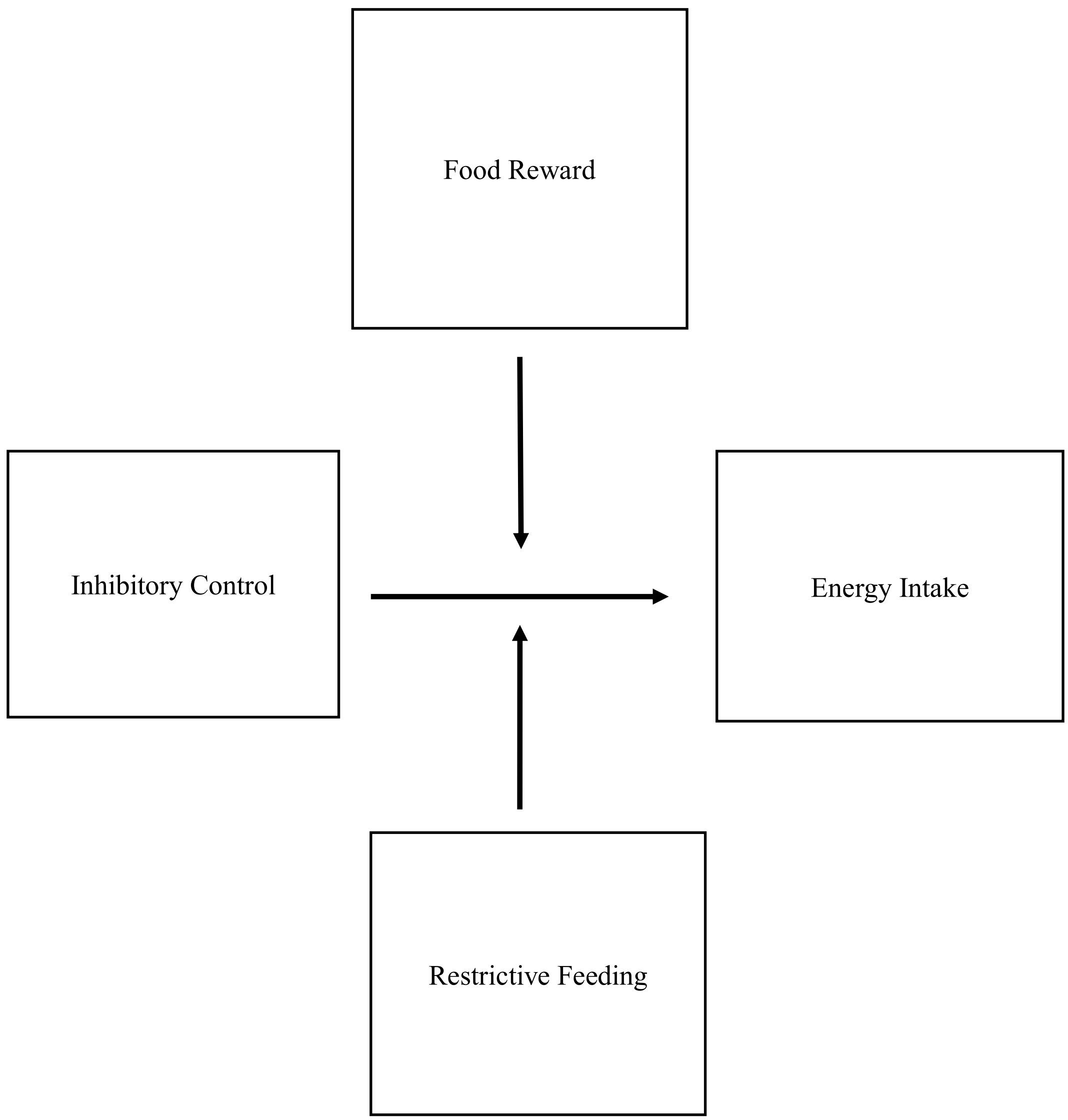

Figure 1. Theoretical model

CHAPTER II

METHODS

The current dissertation includes secondary analyses from a federally funded clinical trial (R21HD094661) examining the efficacy of a brief physical activity intervention aimed at improving executive functioning and energy intake patterns among children living in rural Oregon. For the larger clinical trial, participants completed two study visits approximately 14 days apart. Given the randomized crossover design of the clinical trial, all participants completed both the control and intervention conditions on separate study visit days. Participants' engagement in the control and intervention conditions were counterbalanced across study visits. This study was approved by the University of Oregon Institutional Review Board, and data collection began in August 2017. Due to mandated restrictions for in-person human subjects research related to the COVID-19 pandemic, enrollment for the current study was suspended from March 2020 until July 2021. Data collection was permitted to resume in July 2021 and concluded in December 2021.

Participants and Recruitment

Participants in the current study included 8-10-year-old children currently residing in rural areas of Oregon. As per the Oregon Office of Rural Health (2022), rurality is defined as being at least 10 miles outside of a city of 40,000 or more people. Measures were taken to stratify recruitment, so that the sample was approximately 50% female and 50% of pediatric participants had a BMI at or above the 95^{th} percentile (Sahoo et al., 2015). Participants were recruited through mass mailings; online platforms (e.g., Facebook and Craigslist); advertisements in the form of posters and flyers at various local agencies (e.g., doctor's offices, dentist offices, and libraries); announcements distributed to students and parents at rural elementary schools in the form of flyers and emails; and formal elementary school functions (e.g., Science Night).

Pediatric participants were excluded from the study if: (a) they had a BMI $<5^{\text{th}}$ percentile; (b) a major medical condition (e.g., type 1 diabetes or cancer); (c) a current full-threshold psychiatric diagnosis (e.g., depression); (d) moderate suicide risk (i.e., expressed a plan or intent); (e) current or recent use of medication (in the past 3 months) known to affect body weight or energy intake; (f) a recent brain injury that could affect cognitive functioning, such as a concussion; (g) mobility impairments that would impede the ability to walk on a treadmill; (h) an estimated full-scale intelligence quotient score ≤ 70, suggesting an intellectual disability; (i) a history of pregnancy for females; (j) significant food allergies or dietary restrictions that would prevent them from safely consuming our study's breakfast and lunch meals; or (k) responses on a food preference questionnaire that would render more than 50% of the test meal items not preferred for consumption. At least one parent or legal guardian and their participating child were required to attend all study visits. Participating adults had to be at least 18 years of age and identify as the biological parent or legal guardian for the participating child.

Procedures

Initial Phone Screen

Interested participants were instructed to contact the research lab via phone or email to complete a brief phone screen for study staff to provide information about the study and to assess for initial eligibility. Preliminarily eligible participants were then scheduled for their first and second study visits. Participants were instructed to arrive to both study visits at 8:30 am (±30 minutes) in a fasted state, having refrained from eating or drinking anything other than water (including caffeine, vitamins, and gum) starting at 10 pm the night prior to their visit. These instructions were intended to minimize circadian influences on cognitive functioning (Valdez, 2019). All parent/guardian participants received a reminder call and text message 24-48 hours before their study visits reminding them of fasting instructions for their child.

Participant Privacy and Informed Consent

Upon arrival, participants were greeted by trained research staff and were walked through the informed consent/assent procedure. Parent/legal guardian participants received a physical copy of the consent form, and their child received a physical copy of the assent form. Trained research staff carefully read the consent form aloud to parent(s)/guardian(s) and their child to ensure comprehension and understanding. If both the parent/guardian and child consented/assented to participate, they were asked to sign two copies of the consent/assent forms: one copy for their personal records and one copy for the research staff to keep on file. Participants were verbally reminded of their rights to withdraw from participation at any time, with no penalty or loss of benefits. During the completion of the study visits, parents/guardians were permitted to stay in a nearby room. However, to reduce interference with data collection from the pediatric participant, parents/guardians were not permitted to observe any study procedures (i.e., breakfasts, interviews, neuropsychological tasks, experimental conditions, and lunch) except the body composition scan.

Study Visits

Following the consent and medical history procedures, pediatric participants were escorted to a private room to consume a standardized breakfast consisting of a banana and nutrition shake (Pediasure®). This breakfast was selected because it offers a balance of macronutrients in accordance with the National School Breakfast Program Requirements for students in Kindergarten through fifth grade (Marcason, 2012).

For the purposes of the experimental conditions, participants were then fitted with a Polar H7 heart rate monitor (using a chest strap) and accelerometer (Actigraph GT3X) on their non-dominant wrist. Next, pediatric participants completed a series of interviews, neuropsychological tasks (including measures of inhibitory control), and surveys. The participating parents/guardian also completed an interview and a battery of surveys.

Pediatric participants then participated in either the intervention (20 minutes of walking at a moderate intensity on the treadmill) or control (20 minutes of coloring or reading) condition and completed an additional neuropsychological assessment immediately afterwards. Pediatric participants were then escorted to a private room with a multi-item lunch array. Following lunch, participants completed a brief sleep interview, and then families were compensated for their time.

For the second study visit, participants were again instructed to arrive at 8:30 am (±30 min) in a fasted state. First, pediatric participants had their body composition (including lean and fat mass) measured via a dual-energy x-ray absorptiometry (DEXA). Then, pediatric participants were provided with the same standardized breakfast meal as during the first study visit. Following breakfast, pediatric participants completed several neuropsychological tasks and then completed a brief battery of surveys. Participants then completed either the intervention or control condition (whichever they did not complete during their first study visit), followed by a neuropsychological task. Next, participants ate lunch and then completed an additional psychiatric interview. Participants ended the day by completing a brief sleep interview and were compensated for their time.

Participant Incentives

All participants (parent-child dyads) in the current study received a monetary incentive in the form of checks. For full completion of the first study visit, participants received $90. For full completion of the second study visit, participants received $100. If participants were deemed ineligible during one of the first two study visits, they were paid a prorated amount of $20 per hour for their time.

Measures

Demographic and Medical History

Demographic and medical history information was gathered via a structured interview. Participating parent/legal guardians also completed an online survey in which they reported gross family income and their highest level of education (used as a proxy for socioeconomic status). Pediatric participants, with the aid of their parent(s)/legal guardian(s), reported their age, gender, race, ethnicity, and current and past medical and psychiatric diagnoses.

General Intellectual Functioning

Pediatric participants' general intellectual functioning, or Intellectual Quotient (IQ), was assessed with the Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; McCrimmon & Smith, 2013). The WASI-II is considered a reliable and valid estimation measure of general intellectual functioning for individuals as young as 6 years old (McCrimmon & Smith, 2013; Wechsler, 2011). In the current study, general intellectual functioning was considered as a covariate (Edlund, 1972; Mayes & Zickgraf, 2019).

Body Composition

Pediatric participant's body composition was measured via GE/Lunar Prodigy Pro DEXA scan. Pediatric participants were instructed to wear light, athletic clothing for their scan with no metal buttons. A cotton robe was provided to participants who forgot to dress accordingly. DEXA scans were conducted by trained graduate student research assistants who had completed Oregon State University's Bone Densitometry Equipment Operator Training Course. Prior to conducting the DEXA scan, research staff explained the scan procedure and ensured participants both understood and adhered to the following safety measures: all external metal objects removed (e.g., piercings); all internal (fixed) objects accounted for (e.g., metal screws, orthopedic implants); no current pregnancy; no radioactive scans conducted within the last 10 days; and no radioactive dyes/contrasts were injected within the last 10 days. Participants' positioning for the scan was checked twice to ensure proper positioning to maximize the validity of the scan.
Parent(s)/guardian(s) were allowed to be present for the scan, unless pregnant. Body fat (grams) and lean mass (%) were considered as covariates for the current study in order to adjust for the effects of body composition on individual energy needs (Fisher et al., 2000).

Social Desirability

Pediatric participants' tendency to display social desirability was captured with the Children's Social Desirability Scale (CSD-S; Crandall et al., 1965; Miller et al., 2015). The CSD-S measures the extent to which children over report positive behaviors and under-report negative behaviors, as a means of adhering to socially desirable norms. The CSD-S comprises 14 yes/no items (e.g., "*have you ever broken a rule*?"), with items rated as *no* scored as 0, and items rated as *yes* scored as 1. Items are summed, with higher scores indicating greater levels of social desirability responding. The CSD-S has been normed with children in grades 3 to 5 and demonstrates acceptable test-retest reliability (0.70) and internal consistency (αs = 0.80-0.85) (Miller et al., 2014). In the current study, the CSD-S was considered as a covariate to adjust for the effects of children's socially desirable responding. The internal consistency rating for the CSD-S was good for the current study, α = 0.86.

Children's Depressive Symptoms

Pediatric participants' depressive symptoms were measured with the Children's Depressive Inventory-Second Edition (CDI-2; Kovacs, 1984; Kovacs, 2011). For this survey, participants are prompted to select one of three progenerated responses that apply to their depressive symptoms as occurring over the last 2 weeks. The three choices presented to participants correspond with three levels of depressive symptomatology: 0 (*absence of symptoms*), 1 (*mild or probable symptoms*), or 2 (*definite symptoms*). For instance, the first item of the CDI-2 asks participants to choose between the following statements: (a) "*I am sad once in a while*," (b) "*I am sad many times*," and (c) "*I am sad all the time*." Statement responses are randomized throughout the 27 items to minimize potential response bias. The CDI-2 has been validated in youth aged 7 to 17 years and is considered a valid and reliable assessment of depressive symptoms in both healthy and chronically ill youth (Figueras Masip et al., 2010; Kovacs, 2011). The CDI-2 was considered as a covariate in the primary analyses in order to adjust for the potential effects of negative affect on cognitive functioning and energy intake (Byrne et al., 2021). The internal consistency for the CDI was good in the current study, $\alpha = 0.84$.

Inhibitory Control

General and food-specific inhibitory control were assessed by three neuropsychological tasks: (a) the National Institutes of Health (NIH) Toolbox Flanker Inhibitory Control and Attention Test , (b) the Stop Signal Task, and (c) the Food Go/No-Go Task (Appelhans et al., 2011; Verbruggen & Logan, 2008; Zelazo et al., 2013).

Flanker Inhibitory Control and Attention Test (the Flanker). The Flanker (Zelazo et al., 2013) was used to measure participants' ability to inhibit behavioral attention to irrelevant task dimensions. Trained research staff administered the Flanker to pediatric participants on an iPad; a practice trial was administered prior to the formal task. The Flanker consists of 40 trials, lasting approximately 4 minutes in duration. The primary task was for participants to indicate the direction of the central stimulus, with flankers facing the same direction as the target on congruent trials and the opposite direction on incongruent trials. Inhibitory control was measured via performance on incongruent trials because of the need to inhibit irrelevant conflicting stimuli (Eriksen & Eriksen, 1974). As measured by the Flanker, inhibitory control has demonstrated clinical utility in identifying poor executive attention and has also been linked to disinhibited and emotional eating patterns in children as young as 3 years old (Pieper & Laugero, 2013). Because the Flanker was administered during both visits, in which participants either competed the experimental or control paradigms, only the Flanker from the control day was selected as a covariate to control for the potential effects of physical activity on inhibitory control (Drollette et al., 2014).

Stop Signal Task (SST). The SST measures response inhibition through the ability of participants to stop or cancel an ongoing speeded motor response (Schachar et al., 1995; Verbruggen & Logan, 2008). The SST was administered via a laptop equipped with Inquisit software. The SST was administered by trained research staff and was completed in about 20 minutes. Pediatric participants were asked to respond to a visual stimulus of an arrow (go trials) as quickly as possible by pressing one of two buttons. If the arrow pointed to the left, participants were instructed to press the "D" key, and if the arrow pointed to the right, they were instructed to press the "K" key. On 25% of the trials, an auditory stimulus was presented following the go signal indicating that participants should inhibit their response (i.e., participants were instructed "if you hear a beep or tone, do not press anything"). All participants completed a practice trial to ensure understanding of the task. The SST consists of four trials and adjusts its difficulty based on poorer response inhibition. Longer reaction times to the stop signal indicate poorer stop signal reaction time (SSRT), with higher SSRT scores representing poorer inhibitory control. The SST has been widely used to study inhibitory control in children as young as 6 years old (Senderecka et al., 2012) and effectively identifies children with a BMI above the 95^{th} percentile from those with a BMI below the 85^{th} percentile (Nederkoorn et al., 2012).

Food-Specific Inhibitory Control (FGNG). The FGNG (Teslovich et al., 2014) was administered via a laptop equipped with Inquisit software. The FGNG measures inhibitory control specifically within the context of food cues. During the task, pediatric participants were instructed to press the spacebar when target *go* images (either food or toys) were presented and to withhold their response when *no-go* (opposite of the go-image) stimuli were presented. The FGNG was administered by trained research staff and took about 12 minutes to complete. Over the course of 192 total trials, four randomized blocks of go/no-go image pairs were presented to participants: (a) high-calorie food (go-image) paired with toy (no-go-image); (b) toy (go-image) paired with high-calorie food (no-go-image); (c) low-calorie food (go-image) paired with toy (no-go-image); and (d) toy (go-image) paired with low-calorie food (no-go-image). Target stimuli were presented for 500 ms, with 2000-4000 ms between trials. Commission errors—the number of responses incorrectly made to no-go trials—were used as a measure of behavioral disinhibition. Commission errors were defined as the false alarm rate in food across both low and high calorie food (e.g., participants responded to food during no-go trials, meaning they pressed the spacebar when they saw low or high calorie food when they should have withheld their response). Higher commission error scores overall represented greater behavioral disinhibition. The FGNG is considered a valid measure of inhibitory control in the context of food cues and has been found to help identify individuals prone to excess energy intake (Jiang et al., 2016; Mayes & Zickgraf, 2019).

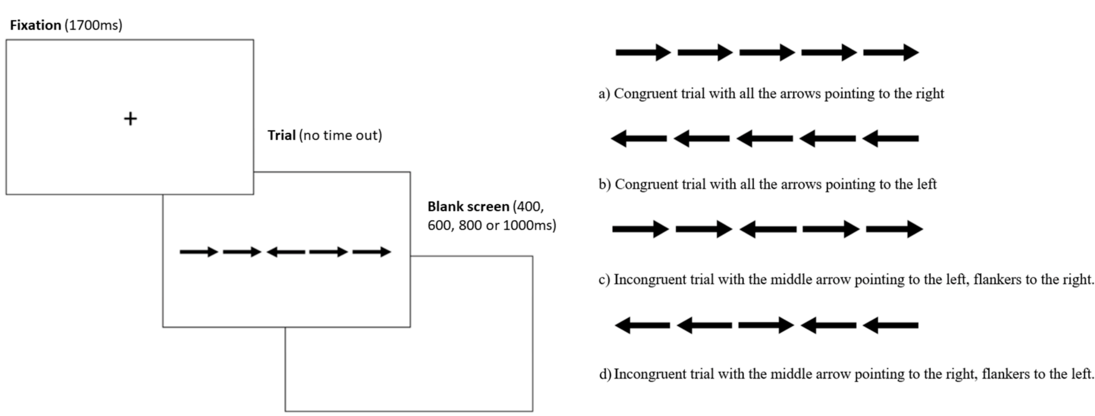

Figure 2. Visual Stimuli for NIH Flanker Task

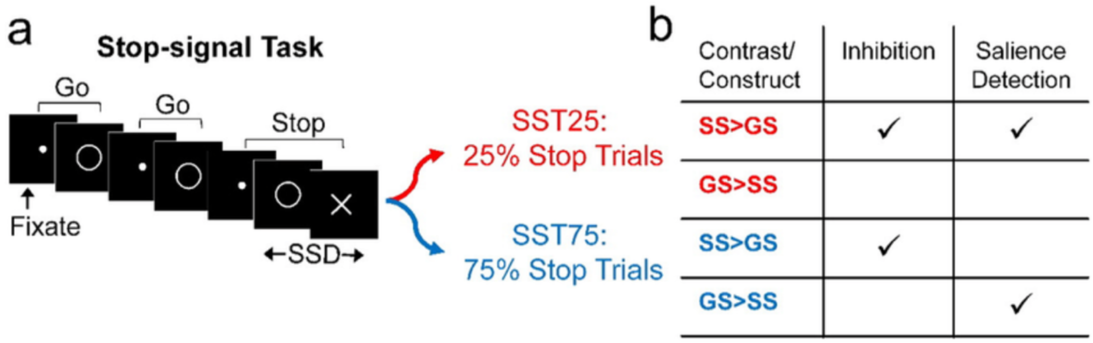

Figure 3. Visual Stimuli for Stop Signal Task

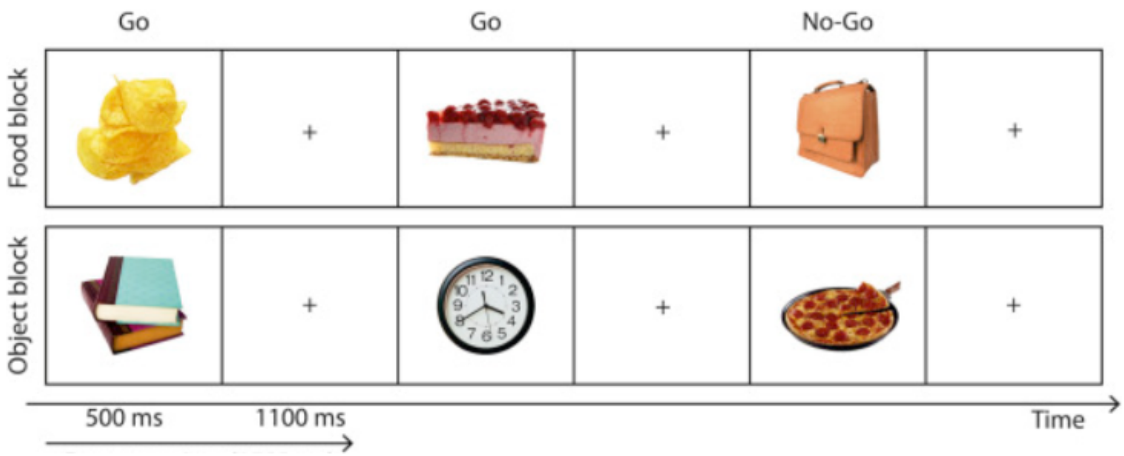

Figure 4. Visual Stimuli for Food Go/No Go Task

Food Reward

Pediatric participants' reward-based eating was assessed by the Reward Based Eating Drive Scale for Children (REDS-C; Epel et al., 2014). The REDS-C is a nine-item questionnaire that measures three aspects of reward-based eating: (a) lack of control overeating (e.g., "*I feel out of control in the presence of yummy food*"); (b) lack of satiation (e.g., "*I don't get full easily*"); and (c) preoccupation with food (e.g., "*food is always on my mind*"). Individual items are rated on a 5-point Likert-type scale (0 =

Strongly Disagree) to (4 = *Strongly Agree*). Items are summed and averaged, with higher mean scores indicating greater reward-based eating. The REDS-C has evidenced high internal consistency ($\alpha = 0.92$) and invariance across demographic factors and is considered a highly useful tool for measuring vulnerability to reward-based eating and identifying those at higher risk for excess weight gain over time (Epel et al., 2014). In the current study, the internal consistency for the REDS-C was good, $\alpha = 0.83$.

Parental Restrictive Feeding

The Child Feeding Questionnaire (CFQ; Johnson & Birch, 1994), which was completed by the participating parent of the pediatric participant, is a 31-item self-report measure that evaluates seven factors of child feeding attitudes and practices: (a) perceived responsibility (three items), (b) parent's perceived weight (4 items), (c) perceived child weight (six items), (d) parent's concern about their child's weight (three items), (e) restriction (eight items), (f) pressure to eat (four items), and (g) monitoring of eating (three items). In the current study, parental restrictive feeding practices were measured with the eight items that comprise the restriction factor (e.g., "*If I did not guide or regulate my child's eating, she/he would eat too much of her favorite foods*"). Items were rated on 5-point Likert-type scale (1 = *disagree* to 5 = *agree*), and were summed and averaged, with higher mean scores indicating greater restrictive feeding practices. The CFQ has been applied to investigate parental child feeding beliefs and practices in association to child weight status, with restrictive parental feeding being identified as highly predictive of increases in children's BMI (Campbell et al., 2010). Since its development, the CFQ restriction subscale's internal consistency ratings have ranged from $\alpha = 0.73$-0.89 (Campbell et al., 2010; Johnson & Birch, 1994; Saltzman et al., 2016). In the current study, the internal consistency rating was $\alpha = 0.76$.

Energy Intake

Energy intake was assessed using a standardized test meal consisting of diverse food items varied in macronutrients (54% carbohydrates, 33% fat, and 12% protein) (Shomaker et al., 2010). While prior research studies using a similar paradigm have included test meals consisting of up to 12,000 calories for children up to 17 years old (Kelly et al., 2020; Shomaker, Tanofsky-Kraff, Zocca, et al., 2010; Tanofsky-Kraff et al., 2011), the current study's test meal consisted of approximately 5,000 calories. The test meal for the current study was reduced in overall size from past research in order to limit food waste and due to the expected average consumption of 8-10 year old children enrolled in the current study (Mirch et al., 2006); indeed, participants only consumed an average of 874.73 kcal ($SD = 312.95$) during the lunch meal. The test meal was presented buffet-style and consisted of 30 items, including main course options (e.g., chicken nuggets and ingredients for a sandwich), sides (e.g., pretzels and chips and salsa), fruits and vegetables (e.g., carrots, oranges, and grapes), sauces (e.g., ranch dressing, mustard, mayonnaise, and barbeque sauce), desserts (e.g., Oreo cookies and candy), and beverages (e.g., milk, juice, and water). A full list of items comprising the test meal used for lunch can be found in Appendix A. An image of the lunch array can be found in Appendix B.

Participants consumed their lunch in a private room and were instructed by research staff to: "*Please eat until you are no longer hungry. Take as much time as you need. Open the door when you are done*" (Kelly et al., 2020; Shomaker, Tanofsky-Kraff, Savastano, et al., 2010). Research staff waited outside to time approximately how long participants at for and to ensure that pediatric participants did not save food for later. Each food item was measured to the nearest 0.1 gram, pre- and post-meal, so to measure the precise number of grams consumed for each food type. Participants' total caloric intake (kcal) was calculated with the dietary analysis software ProNutra from Viocare Technologies. The values used with this software are from the United States Department of Agriculture (USDA) National Nutrient Database for Standard Reference, Release 24.

Data Analytic Plan

Preliminary Analyses and Assumption Testing

All statistical analyses were conducted using IBM SPSS statistical software version 27 and R Studio Statistical Software. Data were first screened for degree of missingness (Orcan, 2020). Next, data were tested for the four main assumptions of parametric tests: (1) additivity and linearity, (2) normality (skewness and kurtosis), (3) homoscedasticity and homogeneity of variance, and (4) independence/multicollinearity (Field, 2013). The additivity and linearity assumption were evaluated by testing whether the outcome variable, total caloric intake, was linearly related to the predictors (general and food-specific inhibitory control). The second parametric test assumption of normality was evaluated by plotting the sampling distribution of the linear regression models to ensure the residuals in the sample were normally distributed, so to evaluate skewness and kurtosis. For the third assumption, homoscedasticity and homogeneity of variance, the predictor variables (general and food-specific inhibitory control) were plotted against the outcome variable (total caloric intake) using a scatterplot of residuals. In order to assess for the fourth assumption, independence and multicollinearity, the strength of the relationship between covariate, independent, dependent, and moderator variables in the current study was examined (Orcan, 2020). Pearson Product-Moment correlations (Pearson's *r*) were calculated for associations among continuous variables (IQ, body composition, social desirability, depressive symptoms, inhibitory control [Flanker, SST, FGNG], food reward, parental restrictive feeding, and energy intake) and Spearman's Rho (Spearman's ρ) correlations were calculated for the association between the categorical variable (child sex) and all continuous variables.

Primary Analyses

Covariate Selection. Child sex, lean mass (%), fat mass (g), depressive symptoms, social desirability bias, and general intellectual functioning were initially considered as covariates given prior research identifying them as significantly correlated with energy intake patterns in youth (Baxter et al., 2004; Bozkurt et al., 2017; Goulding et al., 1996; Reinert et al., 2013; Shomaker, Tanofsky-Kraff, Savastano, et al., 2010). To maximize power and parsimony, the six initial covariates and indicators of inhibitory control were examined in three separate multiple linear regression models to determine if the selected covariates were statistically significantly linked to the primary outcome—total caloric intake. Covariates were retained in all models if they were statistically significant in any single model.

Hypothesis-Testing. A total of nine hierarchical linear regression models were conducted to investigate: (a) the link between general and food-specific inhibitory control and energy intake, (b) the potential moderating role of children's perceived food reward on the link between inhibitory control and energy intake, and (c) the potential moderating role of parental restrictive feeding on the link between inhibitory control and energy intake. Separate regression models were conducted for each indicator of general and food-specific inhibitory control. Covariates were entered into the first level of each linear regression model. Indicators of inhibitory control and each of the moderator variables (children's perceived food reward and restrictive parental feeding) were entered into the second level of their own model. To reduce concerns of multicollinearity, all inhibitory control indicators, children's perceived food reward, and restrictive parental feeding variables were centered based on their grand mean prior to calculating interaction terms between each inhibitory control indicator and either children's food reward or parental restrictive feeding (Iacobucci, 2016). These two-way interaction terms were entered in the third and final level of the hierarchical linear regression models.

Adjusting for Multiple Comparisons. The Benjamini-Hochberg correction (Benjamini & Hochberg, 1995) was applied within families of analyses for each predictor variable (general and food-specific inhibitory control) in relation to total caloric intake to reduce the likelihood of type 1 errors associated with multiple statistical tests (Chen et al., 2017). Adjusted *p* values are reported. Results were considered significant at $p < .05$ and R^2 effect sizes were calculated with an effect size of 0.02 indicating a small effect, 0.15 indicating a medium effect, and 0.35 indicating a large effect (Algina et al., 2007; Rodríguez-Barranco et al., 2017).

Post-hoc Power Analysis. Because this study presents secondary data analysis, an *a priori* power analysis was not conducted for the proposed hypotheses. A post-hoc power analysis was conducted using G*Power software, which is a stand-alone power analysis program (Faul et al., 2009). At the recommended power convention of 0.85 for post-hoc power analyses (Faul et al., 2009), a two-sided alpha of .05, and an F^2 of 0.12 (medium effect), a sample size of 95 should be adequate to detect the medium effect size found in prior studies examining the link between inhibitory control and energy intake in youth (Kelly et al., 2020). Using the same recommended power convention of 0.85, a two-sided alpha of .05, and an F^2 of 0.12, a sample size of 126 would have been required in order to detect a medium effect of the hypothesized interactions (Faul et al., 2009).

CHAPTER III

RESULTS

Preliminary Analyses

Missing Data

Two participants had missing body composition data, due to the Lunar DEXA experiencing technical difficulties. One participant had two missing survey items from the measure of perceived food reward. There were no other missing data. As such, the degree of missingness was less than <3% and, therefore, listwise deletion was employed (Buhi et al., 2008).

Assumption Testing

Data fulfilled assumptions of parametric statistical tests with respect to (a) additivity and linearity; (b) normality of X (Skewness < 1.5, Kurtosis < 3); (c) homoscedasticity/homogeneity of variance; and (d) independence (Field, 2013). See Figure 2 for plots of all predictors in relation to total caloric intake (Wickham, 2016). With regards to independence, measures of inhibitory control (i.e., Flanker, SST, FGNG) were not significantly correlated with one another, supporting the *a priori* decision to conduct separate linear regression models for each task. Regarding considered covariates, body fat (grams) was the only statistically significant covariate across all models ($p < .05$) and thus was retained for final analyses. Child sex, lean mass (%), depressive symptoms, social desirability bias, and general intellectual functioning were eliminated from final analyses to maximize power (Chen et al., 2017).

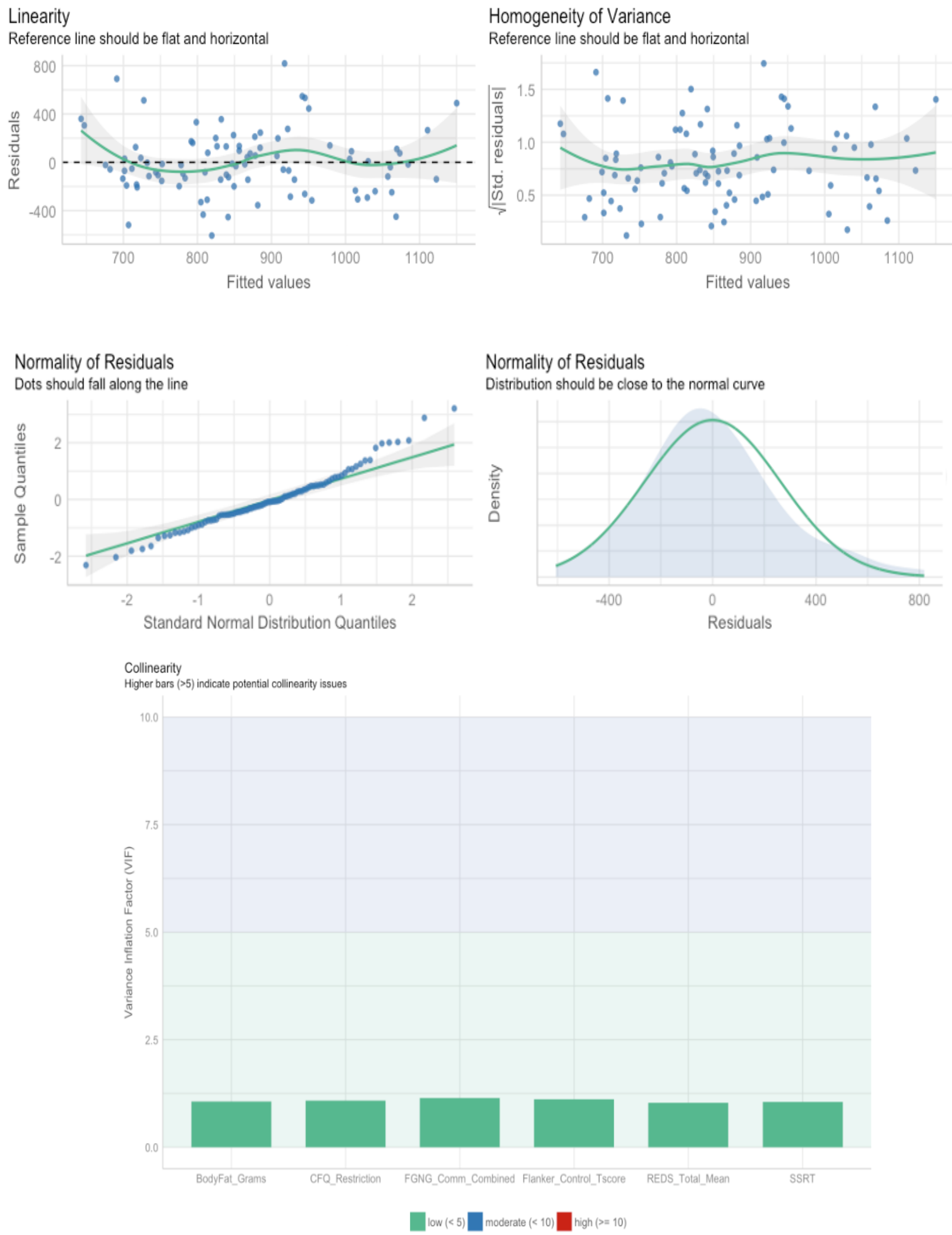

Figure 2. Assumption Testing for Predictors in Relation to Outcome (Total Kcal)

Participants

Figure 3 displays the participant flow-chart summarizing recruitment, enrollment, baseline and follow-up assessments, and final inclusion for analyses

With regards to the final sample included in analyses (N = 92 parent-pediatric participant dyads), 50% of the pediatric participants were girls and most pediatric participants were white/Caucasian (74.5%) and non-Hispanic (90.2%; see Tables 1 and 2). The mean age for pediatric participants was 9.05 years, 5.24 months. Despite efforts to recruit a sample wherein 50% of pediatric participants had a BMI at or above the 95th percentile) (Sahoo et al., 2015), only 34.9% of the final sample had a BMI at or above the 85th percentile and 16.3% of the sample had a BMI at or above the 95th percentile.

The demographics for parent/legal guardian participants were as follows: the average age was 38.64 years (*SD* = 6.81); the majority of participants identified as women (83.7%); 93.5% of parent participants identified as white/Caucasian (3.3% Mexican, 1.1 Asian, 2.2% multiracial); and the majority of parent participants identified as non-Latinx/Hispanic (95.7%) (See Table 3). With regards to SES, the median family income was $70,000-$79,999 (57.6% of the sample) and the median level of education was a 4-year college degree (32.6% of the sample).

Due to ongoing recruitment challenges during the COVID-19 pandemic, enrollment was opened to children living in non-rural Oregon in June 2021. A total of 13 of the 92 children in the final sample (14%) resided in non-rural cities. Importantly, rural and non-rural participants did not differ significantly with regards to any of the primary variables of the current study, so analyses were conducted with the full sample of both rural and non-rural participants to maximize power.

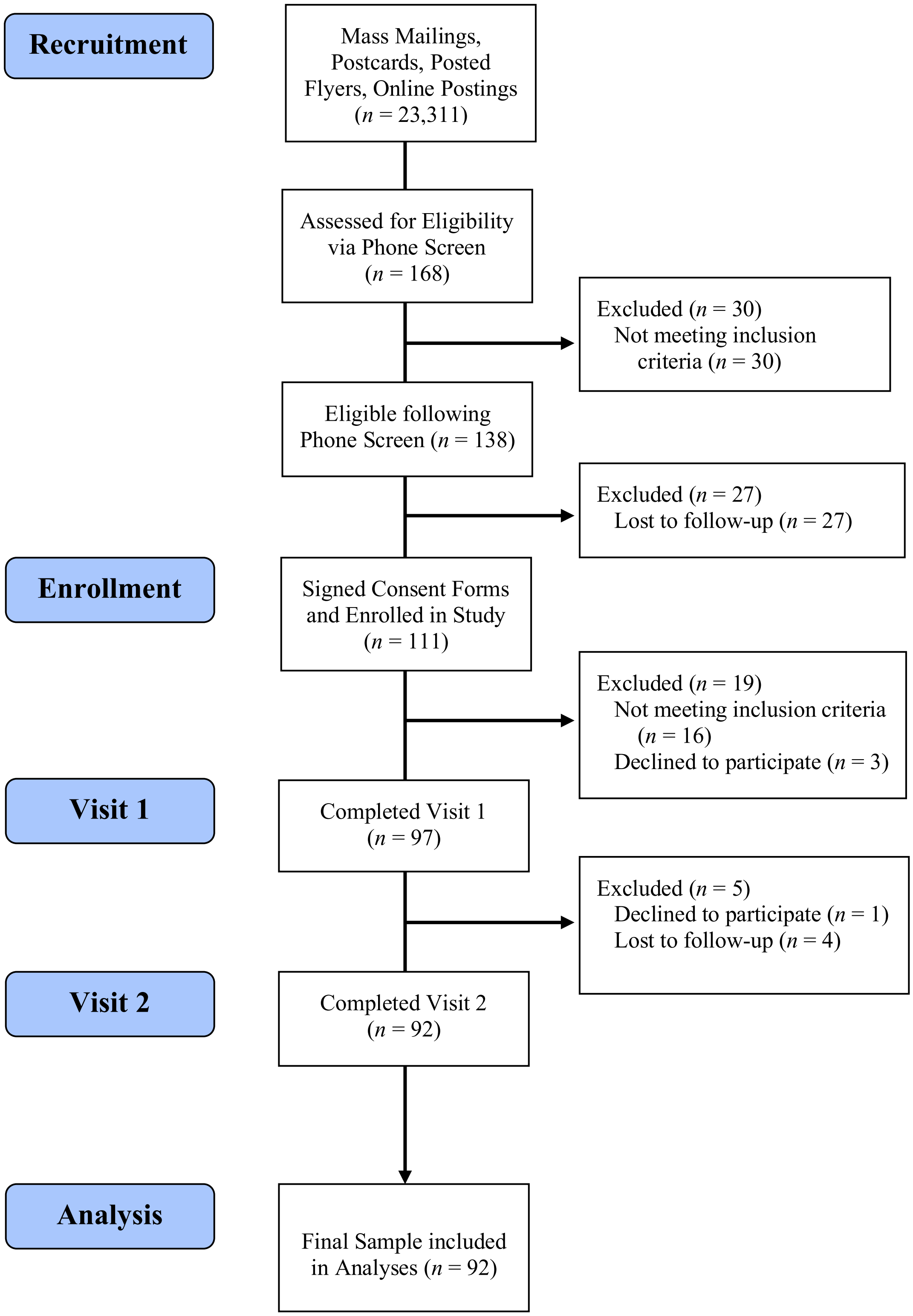

Figure 3. Participant Flow-Chart

Table 1. Correlations among Study Variables

	1	2	3	4	5	6	7	8	9	10	11
1. Child Sex											
2. IQ	-.09										
3. Body Fat (grams)	.10	-.12									
4. Lean Mass (Percent)	-.11	.17	-.95**								
5. Social Desirability	-.04	-.21	-.01	-.01							
6. Depression	-.02	-.04	-.07	.09	-.33**						
7. Flanker	-.23*	.03	.04	-.04	.07	-.07					
8. SSRT	.20	-.11	.01	-.06	.02	.07	.11				
9. FGNG	-.08	-.27**	.11	-.14	.03	.20	.25	.18			
10. Reward-Based Eating	-.12	-.14	-.08	.45*	-.25*	.38**	-.11	.07	.03		
11. Restrictive Feeding	-.23*	.04	-.21*	-.24*	-.14	.05	-.05	.03	.18	.03	
12. Energy Intake (kcal)	-.15	.05	-.29*	-.24*	-.23*	.18	.10	-.08	-.01	.17	.20

Note. Spearman's ρ correlations are reported for categorical variables; Pearson's *r* correlations are reported for continuous variables; IQ = Full Scale Intellectual Quotient; SSRT = Stop Signal Reaction Time; FGNG = Food Specific Inhibitory Control.

*p < .05, **p < .01.

Table 2. Pediatric Participant Demographics (N = 92)

	% or *M* (*SD*)
Child Age (years)	9.05 (0.84)
Child Age (months)	5.24 (3.42)
Sex (female)	50%
Race	
White	74.5%
Black	1.9%
Asian	0.9%
Native American	2.8%
Pacific Islander	0.9%
Mixed Race	18.1%
Other	0.9%
Ethnicity (non-Hispanic)	90.2%
Body Fat (grams)	10666.94 (6044.47)
Lean Mass (percent)	71.36% (10.16%)
Lived in Rural Area	85.9%
Social Desirability	7.25 (4.01)
Depressive Symptoms	0.30 (0.19)
Inhibitory Control: Flanker	46.43 (8.26)
Inhibitory Control: Stop Signal Task	378.10 (101.17)
Inhibitory Control: Food Go/No Go Task	0.85 (0.39)
Food Reward	1.45 (0.73)
Parental Restrictive Feeding	2.88 (0.83)
Energy Intake (kcal)	868.69 (317.11)

Table 3. Parent Participant Demographics (N = 92)

	% or *M* (*SD*)
Parent Age (years)	38.64 (6.81)
Sex (female)	83.7%
Race	
White	93.5%
Mexican	3.3%
Pacific Islander	1.1%
Multiracial	2.2%
Ethnicity	
Mixed Race	95.7%
Other	4.3%
Highest Level of Education	
<High School	2.2%
High School Degree	5.4%
Some College	26.1%
Associate Degree	14.1%
4-year (Bachelor's) Degree	32.6%
Some Graduate School	3.3%
Master's Degree (e.g., M.A., MBA)	12.0%
Professional Degree (e.g., MD, JD)	2.2%
Doctorate Degree (e.g., PhD)	2.2%
Gross Family Income	
<$19,999	7.6%
$20,000-$39,999	16.3%
$40,000-$59,999	15.2%
$60,000-$69,999	6.5%
$70,000-$79,999	12.0%
$80,000-$149,999	35.5%
$150,000 or more	6.5%

Hypothesis-Testing Results

Table 4 displays the findings for the hypothesis-testing analyses. After adjusting for body fat mass (in grams), the link between general inhibitory control (Flanker) and energy intake was non-significant, $F(1, 87) = 0.42$, $B = 2.50$, $p = .52$, $R^2 = .10$; the link between general inhibitory control (SST) and energy intake was non-significant, $F(1, 87) = 0.40$, $B = -.20$, $p = .53$, $R^2 = 0.10$; and the link between food-specific inhibitory control (FGNG) and energy intake was non-significant, $F(1, 87) = 0.19$, $B = -35.85$, $p = .66$, $R^2 = 0.10$. Neither perceived food reward nor parental restrictive feeding practices functioned as significant moderators in any of the models, *p*s = .13-.82.

Table 4. Hypothesis-Testing Results

	Inhibitory Control Variable	β^a	*SE*	R^{2b}	ΔR^2
Flanker					
1	Body Fat (grams)	*0.02	0.01	0.09	*0.09
2	Inhibitory Control (Flanker)	2.50	3.84	0.10	0.00
	Food Reward	78.80	41.94	0.14	0.04
	Restrictive Parental Feeding	67.35	38.52	0.13	0.04
3	Food Reward Moderation	1.14	4.90	0.14	0.00
	Restrictive Parental Feeding Moderation	3.15	3.91	0.14	0.01
Stop Signal Task (SST)					
1	Body Fat (grams)	*0.02	0.01	0.09	*0.09
2	Inhibitory Control (SST)	-0.20	0.31	0.10	0.00
	Food Reward	79.58	41.87	0.14	0.04
	Restrictive Parental Feeding	66.67	38.51	0.13	0.04
3	Food Reward Moderation	-0.35	0.41	0.14	0.01
	Restrictive Parental Feeding Moderation	0.18	0.37	0.13	0.00
Food Go/No Go Task (FGNG)					
1	Body Fat (grams)	*0.02	0.01	0.09	*0.09
2	Food-Specific Inhibitory Control (FGNG)	-35.85	81.37	0.10	0.00
	Food Reward	75.91	41.73	0.14	0.04
	Restrictive Parental Feeding	70.47	38.97	0.13	0.04
3	Food Reward Moderation	134.78	98.02	0.16	0.02
	Restrictive Parental Feeding Moderation	161.84	110.98	0.15	0.02

Note. Statistics presented for levels 1 and 2 include non-centered variables used to examine the association between indicators of inhibitory control and total energy intake (kcal); level 3 includes data from separate moderation models conducted; [a]β = unstandardized regression coefficient at each step; [b]R^2 = proportion of variability in the dependent variable accounted for by model.

**$p < .01$; *$p < .05$ following Benjamini-Hochberg correction for multiple tests.

CHAPTER IV

DISCUSSION

Children living in rural communities have been identified as a group at increased risk for chronic disease, such as type 2 diabetes, hypertension, and components of the metabolic syndrome (DeVoe et al., 2009; Jones et al., 2012). Consuming a surplus of calories, particularly from fat and sugar, is one factor that may contribute to these health disparities (Davis et al., 2008; Kuo et al., 2008; McCormack & Meendering, 2016). Extant data suggest that multiple factors predispose children living in rural communities to consuming more calories, including limited access to affordable and healthy foods (e.g., food deserts), greater accessibly to snack foods (e.g., food from vending machines), and lack of nutrition education services (Cutumisu et al., 2017; Findholt et al., 2014; Liu et al., 2012). In this rural context, exercising inhibitory control around eating-related decisions may be particularly difficult for children.

The goal of the current study was to evaluate the link between inhibitory control and energy intake in a sample of children underrepresented in the current literature – those living in rural communities. Based on existing data, it was hypothesized that lower inhibitory control, as measured by both general and food-specific behavioral tasks, would be positively associated with greater energy intake (kcal) as measured with a laboratory test meal (Fogel et al., 2019; Rollins et al., 2021). Further, it was hypothesized that children's reward-based eating and restrictive parental feeding practices would exacerbate this association (Anzman & Birch, 2009; Campbell et al., 2010; De Decker et al., 2016). In this sample of rural Oregon children, none of the hypotheses were supported.

When examining prior research, links have been observed between inhibitory control and energy intake in preschool-aged and 8-17 year-old children (Fogel et al., 2019; Jiang et al., 2016; Kelly et al., 2020). As such, it is unclear why our study did not identify a significant association between lower inhibitory control and greater caloric intake. One explanation is that the current study's sample includes a narrow age range with little-to-no pubertal stage variation, which has not been the case in prior studies (e.g., Kelly et al., 2020). Some data suggest that the link between poorer inhibitory control and greater caloric intake may be more pronounced among adolescents than children (Egbert et al., 2019; Pearce et al., 2018). It is theorized that this link may be stronger for adolescents versus children because behavioral disinhibition, including risk for disinhibited eating, increases dramatically during adolescence, likely as a result of ongoing neurocognitive changes that occur during puberty (Booth et al., 2018; Romer, 2010). Lower inhibitory control may not be linked to greater caloric intake in 8- to 10-year-olds because most children in this age range are prepubertal and have yet to experience the developmentally normative neurocognitive changes in behavioral inhibition that occur later in life (Ernst & Fudge, 2009). This phenomenon may have contributed to less variability in inhibitory control abilities in the current sample of 8- to 10-year-olds. This theory is partially supported when comparing the means and standard deviations of general inhibitory control measured in our study with those of prior research that have found a significant and positive link between lower inhibitory control and energy intake in youth. For instance, Fogel and colleagues (2019) found a positive link between general inhibitory control (as measured by the SST) and greater caloric intake in 6-year-old boys and girls. Inhibitory control was measured to be similar to our sample (*M* = 376.6 compared to *M* = 378.10 in our sample), but the variability was greater (*SD* = 125.10 compared to *SD* = 101.17 in our sample) (Fogel et al., 2019).

In addition to less variability in general inhibitory control, our sample also presented with less variability in food-specific inhibitory control, when compared to prior research. For instance, in the validation study of the Food Go/No Go Task, which examined food-specific inhibitory control, the commission error rate for low-calorie and high-calorie foods was lower (*M* = 0.62) compared to in our sample (*M* = 0.85), and the variability was slightly larger (*SD* = 0.49 compared to *SD* = 0.39 in our study) (Teslovich et al., 2014). A similar pattern was also found in a recent study that examined the link between executive function and disinhibited eating in children and adolescents (Kelly et al., 2020). Like Teslovich and colleagues' (2014) validation study, the mean commission error rate was lower when compared to our study (*M* = 0.67 compared to *M* = 0.85 in our study), but the variability was greater (*SD* = .45 compared to *SD* = 0.39 in our study) (Kelly et al., 2020). These comparisons help provide preliminary support for the notion that overall, our sample may have had less variability in inhibitory control abilities.

In considering our non-significant findings with regards to the link between inhibitory control and energy intake in our sample of rural Oregon youth, it is important to highlight the fact that our inhibitory control indicators were poorly correlated with one another (see Table 1). The correlations between the Flanker, SST, and FGNG were all non-significant and ranged from 0.11-0.25. Indeed, there is increasing recognition that objective cognitive tasks often possess poor psychometric properties, with regards to internal reliability between tasks, and fail to yield reliable individual differences that are predictive of real-world outcomes (Cyders & Coskunpinar, 2011; Rouder & Haaf, 2019).

For instance, self-reported measures of inhibitory control are often found to be a more reliable predictor of real-world outcomes when compared to objective laboratory tasks (Cyders & Coskunpinar, 2011; Rouder & Haaf, 2019). In a meta-analysis of 28 published studies examining the construct of inhibitory control, using both objective and self-report measures, there was little overlap between self-report and lab task inhibitory control, with self-report and object tasks seemingly measuring different underlying constructs (Cyders & Coskunpinar, 2011). Recent research suggests that this may due to the differences in how behavioral inhibition is operationalized and measured (i.e., response times, commission errors, accuracy, etc.) (Cyders & Coskunpinar, 2012). Moreover, extant data also suggest that overall, self-reported measures of inhibitory control may be a more reliable predictor of real-world outcomes, including eating behaviors (Cyders & Coskunpinar, 2012). The current study is limited by only objective, laboratory assessments of inhibitory control. Future research should seek to include both laboratory tasks and self-report measures in order to compare if and how these constructs compare to one another within the context of predicting energy intake, and which measure is more predictive of actual behavioral outcomes.

It was also hypothesized that children's perceived food reward would exacerbate the link between lower inhibitory control and greater caloric intake in our sample. However, this hypothesis was not supported; children's perceived food reward did not function as a significant moderator. While prior research has found that greater reward-based eating tendencies exacerbate the link between lower inhibitory control and disinhibited eating, this research was conducted with adult women who binge eat (Manasse et al., 2015), whereas our study was conducted with a healthy pediatric sample.

It is possible that reward-based eating may be more relevant to individuals who are prone to binge eating, as some theories suggest that elevated hedonic hunger, a key component of reward-based eating, maintains the appetitive drive to overeat (Hofmann et al., 2007; Manasse et al., 2015; Rollins et al., 2010). Importantly, in the current study, most children reported not engaging in any binge eating, and reward-based eating scores were relatively low compared to prior studies (Epel et al., 2014). For instance, though the range was the same in both studies (0 to 4), the mean reward-based eating score in our sample was 1.45 (*SD* = 0.73) whereas children in the validation study recorded a mean score of 1.70 (*SD* = 0.95). Taken together, the nature of our sample and restricted range in survey responses may have made it difficult to detect any significant moderating associations (Bland & Altman, 2011). It may also be that the interacting effect of food reward becomes stronger as children age and self-directed restriction increases, thus exacerbating the rewarding properties of food and drive to eat (Marcus & Kalarchian, 2003; Smith et al., 2020).

Restrictive parental feeding was also hypothesized to moderate the link between lower inhibitory control and greater caloric intake. In our sample, restrictive parental feeding did not function as a moderator. Importantly, the empirical support for restrictive feeding practices exacerbating the link between lower inhibitory control and eating outcomes is from longitudinal studies of 5- to 9-year-old girls in middle-income, urban white American families (Anzman & Birch, 2009; Birch, 2006; Birch et al., 2003). Our study was cross-sectional in design and included both girls and boys (though we were underpowered to examine sex differences within our sample). Parental restrictive feeding may not be as robust of an exacerbating factor for the link between inhibitory control and energy intake in rural, 8- to 10-year-old boys and girls, though further research is needed in order to support this theory.

In considering the non-significant findings regarding the moderating effect of restrictive feeding on inhibitory control and energy intake, it is important to highlight that the parents in our sample reported relatively low restrictive feeding practices, as measured by the Restriction Subscale of the Child Feeding Questionnaire (M = 2.88, SD = 0.83). For instance, in the prospective study that identified an exacerbating effect of restrictive feeding practices on the link between lower inhibitory control and greater caloric intake in children, mothers in the study obtained a mean Restriction Subscale score of 3.72 (SD = 0.15) (Birch et al., 2003). Of note, any parent or legal guardian was permitted to participate in the current study. Prior research has almost exclusively evaluated maternal feeding practices, with research suggesting that mothers may be more prone to restrictive feeding, especially with their daughters (Anzman & Birch, 2009; Birch, 2006; Birch et al., 2003). However, we were underpowered to examine whether restrictive feeding practices differed by parent/caregiver or child sex. It is also possible that a restrictive feeding style is not as prominent in rural parents, which may allow for the development of more autonomous eating self-regulation. Future research should seek to evaluate rural parents' involvement with feeding and concern over their child's weight, both of which are known to influence children's eating behaviors (Campbell et al., 2010; Gray et al., 2010). Finally, overall, we were underpowered to detect significant moderation findings. Increasing power with a larger sample may help clarify whether children's perceived food reward and restrictive parental feeding meaningful influence inhibitory control and energy intake in rural youth.

Strengths and Limitations

The current study expands upon prior research through investigating context specific inhibitory control (i.e., general and food-specific) in an understudied, yet high-risk population for excess energy intake—rural youth (Johnson & Johnson, 2015; Rollins et al., 2021). Study strengths included attempts to limit the inherent bias of self-reported measures of inhibitory control and energy intake through the use of objective measurements of both constructs. Inhibitory control was assessed with three, domain-specific neuropsychological tasks, and energy intake was assessed with a validated test meal (Shomaker, Tanofsky-Kraff, Zocca, et al., 2010; Teslovich et al., 2014; Verbruggen & Logan, 2008; Zelazo et al., 2013). These methods improved internal validity for our constructs of interest.

Despite the strengths of the current study, there are some important limitations that warrant discussion. First, the data presented in the current dissertation are cross-sectional in design and prospective data are needed to evaluate the link between inhibitory control and energy intake longitudinally in rural youth, as well as how factors like children's perceived food reward and restrictive parental feeding mediate and moderate this trajectory. How youth perceive and interact with food and their bodies changes substantially over time (Byely & Archibald, 2000; Herle et al., 2020). For example, while restrictive eating behaviors, including dieting, have been reported in preschool children as young as 5-years-old, extant data suggest that dieting may peak during adolescence due to growing body image concerns, puberty, peer influences, increasing social media use, and parental feeding and eating behaviors (Abramovitz & Birch, 2000; Byely & Archibald, 2000; Dohnt & Tiggemann, 2006; Woelders et al., 2010). These data indicate that the nature of the associations among inhibitory control, food reward, feeding practices, and eating behaviors may fluctuate across childhood. Longitudinal data are needed to parse out these nuances related to how children view food and eating, as well as how their parents feed them.

It also seems important to evaluate whether there are meaningful temporal association between inhibitory control indicators, food reward, and restrictive parental feeding with energy intake in rural youth. Methods using momentary evaluations, such as ecological momentary assessment, may help capture how these constructs vary throughout the day (Maugeri & Barchitta, 2019; Shiffman et al., 2008). According to research on the wake and circadian-dependent modulation of attentional control, inhibitory control has been found to be lowest at the end of the day as a result of continuous allocation of attention to competing stimuli (Collet et al., 2020). At the same time, some data suggest that palatable food consumption (e.g.,, snacking) and overeating is highest in the evening (Ciccone et al., 2013; Karatzi et al., 2017). Because parents are often involved in feeding children dinner, in particular, there may be a compounding effect when examining these constructs: inhibitory control may be lowest in evening, resulting in greater caloric consumption, particularly of palatable foods, and factors like restrictive feeding and food reward may exacerbate this link (Moding & Fries, 2020; Walton et al., 2021). Though this theory has yet to be empirically validated, methods such as ecological momentary assessment would help to clarify these potential temporal associations.

Energy intake was measured with a laboratory test meal in the current study, which necessarily limits energy intake to a discrete episode and consequently limits the generalizability of the findings. In order to maximize external validity and generalizability of energy intake, future research should seek to include both laboratory and free-living (e.g., 24-hour food recall) measures of energy intake (Dalton et al., 2013). While lower inhibitory control was not linked to greater caloric intake during a discrete eating episode in our study, it is possible that an association exists when examining this link over time. Prospective data are needed to clarify this theory.

Another limitation is the relatively homogeneous sample of rural Oregon youth, with regards to age (8-10 years), race (74.5% white/Caucasian), and ethnicity (90.2% non-Hispanic). Our data were collected from rural Oregon families, within approximately 90 miles of a small city, and therefore reflect the sociodemographic characteristics of a specific region of the country. The findings of our study provide support for the potential uniqueness and specificity of our sample, with our null findings mostly contrasting with extant data that has found empirical support for our study hypotheses. In considering our unique study sample, prior research examining rural versus urban health disparities in pediatric samples at the national level has included far more racial and ethnic diversity, with findings strongly indicating that health disparities increase dramatically for African American and Hispanic rural children, which is a very small subset of our sample (DeVoe et al., 2009; Findholt et al., 2014; Liu et al., 2012). Future research with more diverse sociodemographic representation is warranted. Inclusion criteria for the current study were also quite stringent and disqualified participants with pre-existing physical and mental health conditions. While these measures helped minimize any confounding influences on children’s inhibitory control and energy intake, they may have also eliminated meaningful variability with regards to children's executive functioning (i.e., inhibitory control) and energy intake.

Lastly, a great deal of time and, potentially, resources were required in order to participate in the current study. Each study visit lasted approximately 5-6 hours, and most participants completed two study visits within 2 weeks, totaling 10-12 hours for participation. Participants were also required to commute, from rural Oregon, to the University of Oregon's main campus in Eugene, Oregon. As such, our sample may represent a unique subset of rural families who had both the time and economic resources (e.g., access to a vehicle) required to participate in this research and likely does not fully represent the sociodemographic diversity of rural Oregon families. Indeed, the median family income for the current study was $70,000-$79,999, whereas the median family income for rural Oregon families was $56,312 in 2020 (Oregon Office of Rural Health, 2022). While poverty was not particularly relevant to our specific sample of rural Oregon families, prospective data indicate that poverty detrimentally affects children's executive functioning, perhaps even exacerbating eating self-regulation (Evans et al., 2021; Haft & Hoeft, 2017; Raver et al., 2012). Future research may seek to address these barriers and issues of equity by traveling to families and conducting home visits (Nayak et al., 2007; Pereles, 2000). The use of technology may also help to address some of these barriers, with the aim of conducting research visits either entirely remote or a hybrid of remote and in-person (Coulby et al., 2020).

When considering the findings of our unique rural sample, it is also important to highlight the nuances of rurality. Rurality is often conveyed as a sociodemographic risk factor for various health comorbidities (Davis et al., 2008; DeVoe et al., 2009; Hartley, 2004). Yet, some data suggest that there are health benefits to living in a rural community, such as increased immunity in response to greater and more diverse bacterium exposure, and greater accessibility to fresh and local produce through local agriculture (Böbel et al., 2018; von Mutius, 2022). Overall, there is significant diversity within rural samples with regards to sociodemographic characteristics, health status, and eating behaviors (Findholt et al., 2016). However, rural communities have historically been characterized as a unidimensional community plagued by poverty and various health-related comorbidities (DeVoe et al., 2009; Hartley, 2004). Future research should seek to better understand the nuances and diversity of rural communities, and how specific aspects of rurality function as both risk and protective factors for health-related outcomes.

Summary and Conclusions

This study contributes to a growing body of research examining physical and mental health in rural youth, a historically underrepresented and understudied sample (Nanney et al., 2013). Previous studies have identified a significant link between lower inhibitory control and greater energy intake in pediatric samples (Fogel et al., 2019; Hall et al., 2008; Riggs et al., 2010). However, many of these studies used self-report measures of inhibitory control and energy intake, with even fewer studies examining this association in children residing in rural communities (Rollins et al., 2021). This was the first known study to examine the link between inhibitory control and energy intake, using objective measures of both constructs, in rural children. It was also the first known study to examine the potential moderating effects of children's perceived food reward and restrictive parenting feeding, which historically have been found to exacerbate problematic eating behaviors in children. The current study's findings did not support the hypotheses that lower inhibitory control would be linked to greater caloric intake or that children's perceived food reward and restrictive parental feeding would exacerbate this association.

In conclusion, the current study's non-significant findings may suggest genuine, non-significant links between inhibitory control, children's perceived food reward, and restrictive parental feeding practices with greater caloric intake in preadolescent children. However, the non-significant findings may also be an artifact of the homogeneity of the sample, which presented with little variability in the constructs of interest, as well as demographic characteristics. Thus, future research that interrogates the questions posed by this study using data from larger and more diverse samples of rural children is needed.

APPENDIX A: TEST MEAL DATA ENTRY FORM

Test Meal
Data Entry Form

Study ID: _________

Study date: __________

Study Visit 1 or Study Visit 2 (circle one)

Instructions (read verbatim) : *Please eat until you are no longer hungry. Take as much time as you need. Open the door when you are done.*

Start time: ____:____ AM / PM

End time: ____:____ AM / PM

Duration: _____ minutes

Politely assess whether participant saved any food for later: _____ (check mark to indicate completion and, if yes, make any relevant notes below)

- Please put post-it note on lid and container so to avoid mix-up (i.e., "1" on lid and container for white bread)
- Food mixtures: Please refer to the full instructions for post-consumption measurements if multiple foods are mixed together. Please consult with a graduate student or Dr. Kelly if there is any confusion.

Food item	**Check if present**	**Pre-consumption weight**	**Post-consumption weight**
1. 4 pieces, white bread (measured on its own, outside of platter)			
2. 4 pieces, wheat bread (measured on its own, outside of platter)			
3. 2 rolls (measured on its own, outside of platter)			
4. 4 pieces of ham (measured on its own, outside of platter)			
5. 4 pieces of turkey (measured on its own, outside of platter)			
6. 4 pieces of American cheese (measured on its own, outside of platter)			
7. 12 chicken nuggets (measured in container, top on)			
8. 3 oz creamy peanut butter (measured in container, top on)			
9. 3 oz strawberry jelly (measured in container, top on)			
10. 4 slices of tomatoes (measured on its own, outside of platter)			

11. 3 pieces of lettuce (measured on its own, outside of platter)			
12. 3 oz bag of baby carrots (measured in container, top on)			
13. 2 bananas (measured on its own, outside of platter)			
14. 1 sliced orange (measured on its own, outside of platter)			
15. grapes (measured on its own, outside of platter)			
16. 6 oreo cookies (measured on its own, outside of platter)			
17. 10 large/16 small vanilla wafers (measured on its own, outside of platter)			
18. 96 grams of tortilla chips (measured in container, top on)			
19. 50 grams of pretzels (measured in container, top on)			
20. 3 oz mayonnaise (measured in container, top on)			
21. 3 oz yellow mustard (measured in container, top on)			
22. ¾ cup ranch dressing (measured in container, top on)			
23. 3 oz barbeque sauce (measured in container, top on)			
24. ¾ cup mild salsa (measured in container, top on)			
25. 5 oz gummy bears (measured in container, top on)			
26. 5 oz M & M's (measured in container, top on)			
27. 24 oz water (measured in container)			
28. 24 oz 2% Milk (measured in container)			
29. 24 oz apple juice (measured in container)			
30. 24 oz lemonade (measured in container)			

Notes

APPENDIX B: TEST MEAL IMAGE

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