Annual Review of Developmental Psychology

Early Childhood Obesity: A Developmental Perspective

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Annu. Rev. Dev. Psychol. 2021. 3:207–28

First published as a Review in Advance on September 29, 2021

The *Annual Review of Developmental Psychology* is online at devpsych.annualreviews.org

https://doi.org/10.1146/annurev-devpsych-050620-124758

Keywords

obesity, child, eating, infant, weight gain

Abstract

Childhood obesity is a multifactorial disease, shaped by child, familial, and societal influences; prevention efforts must begin early in childhood. Viewing the problem of childhood obesity through a developmental lens is critical to understanding the nuances of a child's interactions with food and their environment across the span of growth and development. Risk factors for childhood obesity begin prior to birth, compounding across the life course. Some significant risk factors are unmodifiable (e.g., genetics) while others are theoretically modifiable. Social inequities, however, hinder many families from easily making modifications to a range of risk factors. The objective of this review is to provide background and an overview of the literature on childhood obesity in early childhood (birth to 5 years of age) in a developmental context. Special focus is placed on unique developmental considerations, child eating behaviors, and parental feeding behaviors in infancy, toddlerhood, and preschool ages.

Contents

INTRODUCTION

Childhood obesity is a significant public health problem, affecting 19% of US children (Hales et al. 2017). Obesity in childhood often persists into adulthood and is associated with a range of adverse health outcomes such as coronary heart disease, type 2 diabetes, hypercholesterolemia, asthma, hypertension, arthritis, and cancer (Ward et al. 2017). The longer that one has obesity, the greater the risk for these obesity-associated comorbidities (Abdullah et al. 2011, Arnold et al. 2016, Santamaria et al. 2011). Unfortunately, nearly 34% of children enter adulthood with an overweight or obese weight status (Hales et al. 2017). Preventing obesity is much more effective than treating it; therefore, obesity prevention must start in very early childhood.

Childhood obesity is a multifactorial disease, with no one factor explaining a substantial proportion of the variance in the population. While genetics plays an important role, many of the other risk factors are theoretically modifiable, including dietary intake, parents' feeding behaviors, child eating behaviors, and opportunities for physical activity (McMillen et al. 2009). Each of these risk factors must be considered in the context of the child's developmental stage and the dyadic parent-child relationship. Unlike in the study of adult obesity, children's interactions with food and their food environment change rapidly over the course of a few years in early childhood. Skill acquisition and mastery across domains of development shape children's abilities to eat, access, and understand the social contexts of food (**Table 1**). As with development, children's weight and height are expected to change over time and are measured using growth curves or trajectories. This is a key difference between adult and child weight gain as it relates to obesity. Adults have a static ideal weight range for each decade of life, with their height and sex used to calculate a body

Table 1 Developmental considerations for childhood obesity in early childhood

	Infancy (0–12 months)	Toddlerhood (12–36 months)	Preschool years (3–5 years)
Developmental domains			
Gross motor	In the first 6 months, infants' head and trunk control develops prior to the introduction of solid foods. Gains in mobility (crawling, cruising, walking) may increase ability to orient themselves to food or where they eat (e.g., a high chair).	Ability to walk, run, and climb solidifies. Toddlers can access some food autonomously if it is within reach.	Preschool aged children show an increasing coordination and ability to run, jump, and climb more efficiently. They are able to physically access food (e.g., open the fridge or cupboard).
Fine motor	Hand grasp is important for self-feeding and progresses from a raking grasp to a pincher grasp, which allows for more control in self-feeding.	Increasing finger and hand control allows for self-feeding finger foods and developing use of utensils.	Increased fine motor strength and coordination allow for the mastery of utensil use (fork and spoon, but not knife) as well as opening some packaging or containers independently.
Oral-motor	Suckling develops perioral muscles, necessary for chewing and swallowing of solid foods later in infancy.	Toddlers transition from bottle to sippy cups. With new teeth, they can eat more diverse textures of foods.	With the eruption of additional molars, children have the dentition to eat a full range of textures and transition from sippy cup to open top cup for drinking.
Speech/language	Ability to communicate hunger is innate in infants. Breastfed infants may benefit from a positive feedback loop where crying (vocalizing hunger) may trigger a letdown of more breast milk. Verbal and nonverbal communication of hunger may include communicative babbling, single words, gestures, and signs.	Ability to vocalize and communicate food preferences increases.	With increasing vocabulary, children can express their food preferences in more detail.
Social-emotional	Infants develop the ability to respond to emotional information (facial expressions, tone of voice, etc.) and may begin to associate feeding with emotions. Feeding to soothe an infant, as opposed to feeding because the infant is hungry, may perpetuate the use of food for emotional regulation later in life.	Toddlers begin to understand food as a reward or bribe for behavior and show increasing autonomy and assertion of control over food likes and dislikes. Food tantrums may begin. There is increasing understanding of the social contexts of food and mealtimes within the family.	Children have an increasing ability to participate in routines around eating (setting the table, assisting with preparing food).
Eating behaviors	Infants are born with a preference for sweet and salty foods. Infants consume their milk-based diet through feeding at the breast, feeding from a bottle, or a combination of both.	Toddlers develop more selective (picky) eating behaviors; however, they may benefit from repeated exposures to a variety of foods and role modeling by parents. Patterns of formal snacks may emerge.	Children show increased independence in choosing and consuming foods. They may engage in more bargaining with caregivers around food preferences. Many meals and snacks a week may be provided at school.

(*Continued*)

Table 1 (*Continued*)

	Infancy (0–12 months)	Toddlerhood (12–36 months)	Preschool years (3–5 years)
Dietary intake	Infants follow a milk-based diet from 0–6 months, breast milk or formula, with a gradual integration of solid foods over the first year of life.	Toddlers increasingly eat table foods and shift from breast milk or formula to cow's milk or plant-based milk.	Children are able to eat an adult-like diet; however, children in this age range often consume more servings of sugars, fats, and carbohydrates than recommended by guidelines.
Measurement			
Measurement of growth	Weight and length (recumbent) are plotted on the WHO growth charts. The Fenton growth chart is used for premature infants. Weight-for-age, length-for-age, or weight-for-length z-scores or percentiles for infant age and sex are calculated. Cutoff values are ±2 SDs, which correspond with the 2.3rd and 97.7th percentiles.	Children's growth is tracked using the WHO growth charts until the age of 24 months, after which the CDC growth charts are used. Anthropometric indices of the CDC growth charts include BMI-for-age, stature-for-age, and weight-for-age and are most commonly reported as percentiles by age and sex.	Growth is plotted on the CDC growth charts until 20 years of age. Anthropometric indices of the CDC growth charts include BMI-for-age, stature-for-age, and weight-for-age and are most commonly reported as percentiles by age and sex.
Measurement of excessive weight gain	Weight-for-length greater than the 98th percentile is considered high weight-for-length. Rapid infant weight gain, defined as a change in weight-for-age z-score of >0.67 SDs over a period of months, may also be considered excessive weight gain. Categorical classifications of overweight or obese are not applied to infants.	The infant definitions of excessive weight gain continue to be applied until 24 months of age, as they follow the WHO growth charts. At 24 months and the accompanying shift to the CDC growth charts, BMI-for-age percentiles for sex between the 85th and 95th percentiles are considered overweight and ≥95th percentile is obese.	BMI-for-age percentiles for sex between the 85th and 95th percentiles are considered overweight and ≥95th percentile is considered obese on the CDC growth charts.

Abbreviations: BMI, body mass index; CDC, US Centers for Disease Control and Prevention; SDs, standard deviations; WHO, World Health Organization.

mass index (BMI). However, this range changes constantly for children as they age, and as such, measurements of weight and height by sex are calculated as percentiles or z-scores along growth curves (WHO 2006).

Viewing the problem of childhood obesity through a developmental lens is critical for intervention and prevention efforts. It allows for the appreciation of the various and compounding influences on a child's risk that start prior to birth and the quick dissolution of any notion that there could be one single cause (e.g., mother's feeding behaviors) to blame for excess weight gain in any child. The objective of this review is to provide background and an overview of the literature on childhood obesity in early childhood (birth to 5 years of age) in a developmental context. Special focus is placed on unique developmental considerations, child eating behaviors, and parental feeding behaviors in infancy, toddlerhood, and preschool ages.

THEORETICAL FRAMEWORK

Social-Ecological Model

The evolving body of research relating health behaviors to obesity in children must be considered within social-ecological and social-contextual models that consider the influence of different environmental and organizational contexts affecting children's nutrition and physical activity behaviors (McLeroy et al. 1988). Children's eating and physical activity are influenced by more than their own choices; they make choices on the basis of the food and activity opportunities available to them in their homes, schools, and communities. Research to date using the social-ecological model has largely investigated only relationships between some social-ecological levels (e.g., child and family). It has not investigated all level determinants jointly or policy-level determinants, nor determinants from other levels. Despite widespread utilization of the social-ecological framework in discussions of childhood obesity, relatively few data sets have information on organizational and environmental/place-based influences or have study designs that allow inferences about the role of these influences on children's health behaviors in the context of implementing interventions (Pereira et al. 2019).

Six C's Model

The multiple contributing factors have previously been conceptualized by Harrison et al. (2011) as occurring at the levels of the Six C's: cell, child, clan, community, country, and culture. This comprehensive model provides a useful framework for considering a multitude of influences. A growing body of work has provided additional insight into the relative contributions of each of these levels of influence, with substantial evidence for a robust effect of cell, or genetic, factors. In a cohort of more than 80,000 twin pairs, the proportion of BMI variation explained by additive genetic factors was lowest at 4 years of age in boys ($a^2 = 0.42$) and girls ($a^2 = 0.41$) and then generally increased ($a^2 = 0.75$) in both sexes at 19 years of age (Silventoinen et al. 2016, 2017). Notably, while socioeconomic status seems to modify the effect of genetics on BMI after age 5, it plays less of a role at ages younger than 5 (Silventoinen et al. 2019). In a study of more than 1,000 adults in Spain, the percent variance in BMI accounted for by each variable was 4.2% for age, 0.04% for sex, 8.3% for energy intake, and 7.3% for physical activity level. Sixteen polymorphisms previously related to obesity and lipid metabolism each accounted for <0.05% of the variance. This multivariable regression model accounted for 21% of the variance in BMI (Goni et al. 2018). Among 175 preschool-aged children in Australia, maternal education, family income, and maternal BMI collectively accounted for <1% of the variance in child BMI, maternal warmth and control jointly an additional 5% variance, maternal feeding practices collectively an additional 3%, mother-child dysfunctional interaction an additional 3%, and child eating behaviors an additional 1% (McPhie et al. 2011). In a recent study examining contributions to the variance in BMI among more than 6,000 children age 9–11 years, the amount of variance explained by the individual versus the school and the country was 91.9%, 3.3%, and 4.8%, respectively (Katzmarzyk et al. 2018), suggesting that school and community factors make relatively modest contributions to obesity risk as compared with individual factors (most of which are, based on other work, genetic). Thus, the majority of emerging evidence suggests that while obesity is a multifactorial disease, and environment and modifiable behaviors can contribute to risk, a large majority of the variance in BMI in young children is related to genetics.

Modifiable risk factors are also included in both the social-ecological and Six C's models, of which the primary contributor to child obesity risk is consistently found to be dietary intake. Dietary patterns associated with obesity in children include consumption of high-sugar, energy-dense, low-fiber, high-fat foods (Ambrosini 2014). By age 4, these foods (e.g., cakes, cookies) are the number one dietary source of energy. A main focus of obesity interventions in both children and adults is therefore to reduce intake of low-nutrient-density foods (Mead et al. 2017). However, cutting down on these foods is challenging for most people, including parents trying to manage their children's dietary intake (Perry et al. 2017). Greater screen time is also linked with increased obesity risk, and reducing screen time reduces obesity (Fang et al. 2019). Physical activity has also been inversely correlated with obesity risk in young children, although the effect size is relatively modest (Mead et al. 2017).

The ability of many families to make behavioral modifications to lower the risk of obesity is indirectly influenced by the greater food culture and society (Burgess et al. 2017). Structural racism and inequities limit the ability of disadvantaged families to access resources needed to make behavioral changes. For instance, food deserts result in a lack of affordable fresh fruits and vegetables (Pereira et al. 2019).

INFANCY

From birth to 12 months of age, infants rapidly develop across domains, and development in each of these domains contributes to their ability to eat and access foods. Over this relatively short period, infants transition from a milk-based diet (breast milk or formula) to a more varied diet that may include fruits, vegetables, starches, and animal- and plant-based proteins (Grummer-Strawn et al. 2008). With the consolidation of sleep, feeding schedules shift from milk consumption every 2 to 4 h to daytime meals and snacks. The dyadic feeding relationship between parent and infant has been the focus of much obesity prevention research, which almost exclusively focuses on mothers and not fathers or other caregivers (Owen et al. 2005). Mothers' feeding behaviors, from the choice of breast milk or formula to how often infants are fed and how they are fed (bottle versus breast, quickly versus slowly, for only hunger or also for soothing), have increasingly been studied as risk factors for later child obesity (Matvienko-Sikar et al. 2019). Only relatively recently has investigation extended to include infants' innate eating temperaments, which likely shape maternal feeding behaviors in a transactional manner (Faith & Hittner 2016).

Infant Growth and Weight Gain

Rapid infant weight gain, defined as an increase in the weight-for-age z-score $\geq$0.67 standard deviations in the first year of life, has been recognized as a risk factor for later child obesity (Zheng et al. 2017). Rapid infant weight gain is experienced by about one in five infants in the United States, with a longer period of rapid infant weight gain being associated with a stronger effect size (Zheng et al. 2017). Rapid infant weight gain does not necessarily equate to high infant weight-for-length ($\geq$98th percentile for age and sex), and while an infant may not be considered high weight-for-length at a single point in time, the trajectory of weight gain still confers increased risk of later obesity (Savage et al. 2016). Rapid weight gain in infancy has been predicted by male sex, black and Hispanic (versus non-Hispanic white) race/ethnicity, being firstborn, maternal smoking, maternal adiposity, excess maternal gestational weight gain, bottle feeding, formula feeding, early introduction of solid food, and infant difficult temperament (Heerman et al. 2014, Ong et al. 2006, Paul et al. 2009, Young et al. 2012). One study identified lower breast milk leptin content as associated with more rapid infant weight gain (Miralles et al. 2006), and two studies identified prenatal exposure to certain environmental toxins as associated with rapid infant weight gain (Mendez et al. 2011, Fleisch et al. 2015). Short sleep duration has also been a frequent suspect, but the association is inconsistent at younger ages (Hiscock et al. 2011, Klingenberg et al. 2013) and has not yet been demonstrated in infants younger than age 6 months.

Infant Eating Behaviors

To date, eating behaviors in infancy have been studied as closely tied to parental feeding behaviors. In early infancy this includes feeding mode (bottle versus breast), milk type (breast versus formula), and the amount of milk offered and consumed. Little research to date has examined the influence of early infant suckling behaviors (e.g., strength and rapidity of suckling, rate of milk transfer) or later infant eating behaviors (e.g., bite rate, bite size, chewing speed) on risk of excessive weight gain (Lumeng et al. 2020), although this remains an area of active research.

The protective effects of breastfeeding and breast milk consumption against later childhood obesity have been explored over the last several decades (Yan et al. 2014). Longer duration of exclusive breastfeeding has been found to be associated with increased consumption of fruits and vegetables as toddlers (Specht et al. 2018), lower trajectories of weight gain in infancy (Patel et al. 2018), and decreased risk of later childhood obesity in some but not all studies to date (Yan et al. 2014). A recent multinational cross-sectional study that included 4,740 children across 12 countries examined the association of recalled breastfeeding duration with later risk of childhood obesity, adjusting for important confounders such as maternal age at delivery, maternal BMI, educational attainment, gestational diabetes, infant gestational age, and birthweight, as well as several childhood factors (e.g., unhealthy diet, physical activity, sleep duration) (Ma et al. 2020). Results showed that the duration of exclusive breastfeeding was associated with lower odds of obesity at ages 9–11 years as compared with exclusive formula feeding (Ma et al. 2020). This association has not been found consistently, however, which may be due in part to lack of controlling for confounders or imprecise measurement of breast milk consumption (duration, exclusive versus mixed breast milk feeding, breast versus bottle feeding of breast milk, etc.). Several biological mechanisms have been proposed as possible explanations for the protective nature of breastfeeding against childhood obesity, including the nutritional and bioactive components of breastmilk, such as hormones that may help in insulin regulation (Miralles et al. 2006). It is also theorized that breastfed infants are better able to self-regulate intake as opposed to bottle-fed infants, who may be encouraged to finish a certain quantity of milk (Li et al. 2010). Many childhood obesity prevention efforts starting in infancy have included the promotion of breastfeeding (Hennessy et al. 2019).

Consideration must also be given to the fact that some mothers may not be able to breastfeed or express breast milk for their infants or may choose formula feeding for a variety of reasons. Recent qualitative work found that nonbreastfeeding mothers may experience greater levels of distress, anxiety, and depression relative to breastfeeding mothers, which may be related to societal pressures to breastfeed (Penniston et al. 2020). Other work has found that pressures associated with breastfeeding increase the risk for postpartum depressive symptoms (Dias & Figueiredo 2015). In addition, striking differences in breastfeeding rates between women of marginalized communities (e.g., black non-Hispanic race/ethnicity or those living in poverty) suggest that underlying social determinants of health and cultural differences may influence breastfeeding initiation and duration (Li et al. 2019, Louis-Jacques et al. 2017). While encouraging breastfeeding may be an effective public health intervention for childhood obesity, a balance between infant and mother well-being must be maintained.

Infant Eating Temperament

Eating temperament, or an individual's behavioral predisposition toward differences in appetite, has been found to be associated with environmental and genetic factors as well as later risk of obesity (Carnell & Wardle 2007, Kininmonth et al. 2021, Kral & Faith 2007). Individual differences in mother-reported infant appetite in the first 3 months of life predict weight gain in ages 9–12 months (Llewellyn et al. 2011, van Jaarsveld et al. 2011, Wright et al. 2006). Infants rated by their mothers as "more difficult than average" across temperamental traits (Carey 1985, Wells et al. 1997) are fed more often to soothe (Stifter et al. 2011) and with more sweet foods (Vollrath et al. 2012) and show more weight gain (Slining et al. 2009, Wells et al. 1997). Infants with high appetitive drive composed of lesser satiety responsiveness (i.e., eating too much each time) and greater hunger are at risk for obesity and rapid weight gain (Kininmonth et al. 2021).

This high appetitive drive is thought to have a genetic basis (Faith 2005). Likewise, infants with difficult temperaments are also at risk—they are fed more often (Vollrath et al. 2012) and gain more weight (Stifter & Moding 2018). With regard to satiety, many infants do not provide clear cues (Savage et al. 2016), their cues (e.g., becoming sleepy) are not specific to feeding (Skinner et al. 1998), and mothers struggle to recognize the cues (McNally et al. 2016) and tend to rely on the most overt, as opposed to subtle, cues (McNally et al. 2016). Hunger is distinct from satiety (Shloim et al. 2017), with cues that are clearer at younger ages than satiety (Shloim et al. 2017) but still nonspecific for feeding and difficult to reliably identify (Shloim et al. 2017, Ventura et al. 2019).

Parental Feeding Behaviors

Parental feeding behaviors, defined as parents' approaches to feeding their child, are known risk factors for child obesity (Vaughn et al. 2015). Classically, these behaviors have been described as a parent restricting or pressuring their child's intake of certain food types or amounts. Feeding responsiveness, or how a parent responds to their child's hunger and satiety cues, overlays these parental feeding behaviors of restriction or pressuring. As reviewed in a recent comprehensive report on feeding from birth to 24 months (Matvienko-Sikar et al. 2019), responsive feeding is grounded upon the child signaling hunger and satiety and the caregiver recognizing the cues and responding promptly in an appropriate manner. Several interventions testing responsive feeding in infancy as an intervention component have found improvements in weight outcomes (Matvienko-Sikar et al. 2019), providing a firm basis for ongoing development of interventions including responsive feeding as a key component. Building on classic goodness of fit and differential susceptibility models in child development (Chess & Thomas 2013), intervention effects might be further strengthened by tailoring to the characteristics of the individual child. For example, maternal use of food to soothe was associated with greater weight gain among infants with more surgent (Stifter & Moding 2018) and negative (Stifter et al. 2011) temperaments, and infants with more negative temperaments benefited more from an intervention focused on soothing and sleeping strategies for some outcomes (Savage et al. 2016). Soothing strategies may not be enough to prevent rapid weight gain among some infants. Indeed, among infants whose mothers had discontinued breastfeeding (which is often caused by the mother perceiving the infant as hungry), soothing strategies did not reduce feeding frequency (Ahluwalia et al. 2005). In addition, only 14% of low-income mothers reported that soothing strategies are helpful in reducing overfeeding (Paul et al. 2011).

There has also been a significant focus on the early introduction of solid (complementary) foods as a potential contributor to obesity (Lumeng et al. 2015). Complementary foods are often introduced around 3–4 months (Am. Acad. Pediatr. 2017), and by six months, most infants (66%) have already received grain products, with 42% receiving fruits, 40% receiving vegetables, and 14% receiving meat (Gidding et al. 2005). Baby-led weaning is an alternative approach to introducing solid foods to infants that has been gaining popularity in the United States but remains underresearched (Brown et al. 2017). In baby-led weaning, infants are presented with table foods first, forgoing traditional pureed foods and spoon feeding (Pesch et al. 2019a). Proponents of baby-led weaning posit that it should allow infants to develop better self-regulation in eating, thereby preventing obesity; however, there exists little research to support this notion (Brown et al. 2017). In fact, a recent randomized controlled trial found no effect of baby-led weaning on infant weight gain trajectories, even finding that infants who had been fed using a baby-led weaning approach had a higher risk of obesity-promoting eating behaviors (Taylor et al. 2017). Critics of baby-led weaning posit a greater risk of choking, growth faltering, and iron deficiency anemia, which is not supported by the literature to date (Daniels et al. 2018, Taylor et al. 2017, Williams

Erickson et al. 2018). Infants fed by baby-led weaning have been found to be exposed to more varied and textured foods in infancy, as well as to have more variety in fruit and vegetable intake at 2 years of age (Morison et al. 2018). Overall, baby-led weaning has been found to be safe, but with limited evidence to support it lowering the risk of child obesity.

Physical Activity

Physical activity has been recognized as an important contributor to early obesity prevention (McGuire 2012). During infancy, opportunities to participate in physical activity are largely dependent on parents and caregivers as infants have to be physically placed in an environment for unrestricted movement and gross motor development. Such skills include arm and leg movements, rolling, lifting of the head, reaching, sitting, and eventually crawling and walking. For infants less than 6 months of age, it is recommended that caregivers provide daily tummy time and opportunities for unrestricted movement on the floor that may increase both activity and energy expenditure (Hagan et al. 2007). In fact, infants who engage in more tummy time have been found in a recent review to have lower BMI z-scores in later childhood as well as improved gross motor skills and total development (Hewitt et al. 2020). Infants who have earlier gains in gross motor skills have more opportunities for movement and thus energy expenditure (Hnatiuk et al. 2013).

TODDLERHOOD

The toddler years, from 12 to 36 months of age, are thought to be a critical time for the establishment of food preferences and eating behaviors. During this developmental period, the balance of control over food and eating begins to shift as toddlers develop stronger preferences and increasing autonomy in eating. Parents begin to relinquish degrees of control over feeding and eating to their child. From ages 12 to 24 months, infants transition from a milk-based diet to an adult-like diet in which, in the United States, the most commonly consumed vegetable is fried potatoes (chips or French fries) (Welker et al. 2018). From 12 to 24 months, vegetable consumption decreases by 25% (Deming et al. 2017). Diets of children in this age range include too few fruits and vegetables and are too high in sugar and fat (Welker et al. 2018). These consumption patterns track into the preschool and school ages (Grimm et al. 2014), suggesting that the manner in which the diet expands from 12 to 24 months may be a critical target for obesity prevention.

Toddler Growth and Weight Gain

Between 12 and 24 months of age, toddlers' growth continues to be plotted and monitored using the World Health Organization (WHO) growth charts (WHO 2006), primarily using the definition of high weight-for-length for age and sex (≥98th percentile) as the threshold to indicate excessive weight status. However, after 24 months of age, height can be reliably measured, which allows the calculation of BMI and the emergence of the ability to categorize children as having an overweight or obese weight status on the basis of BMI. At age 24 months, researchers and clinicians in the United States also generally shift from the WHO growth charts to the US Centers for Disease Control and Prevention (CDC) growth charts (Kuczmarski et al. 2000), although, beyond infancy, the WHO and CDC growth references are relatively similar.

Toddler Eating Behaviors and Temperament

During toddlerhood, children begin to develop strong food preferences and independent eating habits and also gain increased access to palatable foods (e.g., desserts) that can promote obesity (Shutts et al. 2013). Eating temperaments or behaviors can be conceptualized as the behaviors that occur proximally to dietary intake and weight gain, with eating in the absence of hunger conceptualized as the final common pathway between specific eating behaviors and excess dietary intake.

The trait referred to as eating in the absence of hunger is commonly measured using a protocol to assess how many calories of palatable foods an individual will eat after having just eaten a satiating meal (Fisher & Birch 2002). In our own work following a cohort at ages 21, 27, and 33 months (Asta et al. 2016), we found significant increases in consumption of sweet foods during the eating in the absence of hunger protocol across this age range. Greater intake of sweet food during this protocol at age 27 months was prospectively related to higher BMI z-scores at age 33 months (Asta et al. 2016). The increased eating in the absence of hunger that occurs with age may reflect increasing food responsiveness, decreasing satiety responsiveness, or increased enjoyment of food. Greater food responsiveness and weaker satiety responsiveness have each been linked with greater obesity risk (French et al. 2012).

Picky eating is generally defined as a reluctance to eat familiar foods, while food neophobia is defined as a reluctance to eat new foods. Both behaviors are common in early childhood (Taylor et al. 2015) and are generally viewed as a benign developmental phase with multiple studies describing these behaviors as peaking around age 2 years (Taylor et al. 2015). In the second year of life, enjoyment of food declines (van Jaarsveld et al. 2011) and picky eating increases. Folk wisdom and professional guidance often focus on the emergence of picky eating by age 2 (Dovey et al. 2008) and provide parents with strategies for preventing or overcoming picky eating behaviors in the service of promoting health. Overcoming picky eating is often a target of obesity prevention programming, though the evidence supporting this strategy is lacking (Fernandez et al. 2020), and a recent systematic review (Brown et al. 2016) reported inconsistent associations between picky eating or food neophobia and child weight status. Further, while dietary and professional organization guidelines promote dietary variety (Kleinman 2019), dietary variety has either shown no association (Shi et al. 2018) or positive associations with obesity risk (Fernandez et al. 2016). Thus, parents' efforts to overcome picky eating and increase their children's enjoyment of food may inadvertently increase obesity risk.

Food responsiveness is defined as the degree to which external food cues, such as the sight of food, encourage an individual to eat, potentially to excess (Carnell et al. 2013). Food responsiveness increases in the second year of life (van Jaarsveld et al. 2011), tracks through childhood (Ashcroft et al. 2008), and is associated with eating more frequently (Syrad et al. 2016), having more rapid weight gain, and having greater obesity risk (Blissett et al. 2016).

Parents report that their children are less hungry and therefore more satiety responsive during the second year of life (van Jaarsveld et al. 2011). However, although children may eat less overall, the precision with which they are able to up- or downregulate intake in response to a caloric preload is also thought to decline (Fisher et al. 2007) and could be an obesity risk factor. Caloric intake in relation to frequency of eating is very tightly regulated in early infancy (Lumeng et al. 2007). However, by age 20 months, this regulation loosens dramatically and becomes much more variable. Caloric content per feeding at 20 months ranges from 59 to 417 kcal and feeding frequency varies from 1 to 10 times per day (Syrad et al. 2016).

Parental Feeding Behaviors

Feeding styles embody the general emotional climate and approach taken in the feeding domain, whereas feeding practices are specific goal-oriented behaviors that caregivers use to direct what, when, and how much a child eats (van der Horst & Sleddens 2017). Structure is defined as the organization of the child's environment to facilitate competence, including helping young children maintain certain dietary boundaries and organization of their food environment (Vaughn et al. 2015). Components of structure include rules and limits, monitoring, routines, modeling, food availability and accessibility, and permissiveness. Monitoring (i.e., the extent to which parents keep track of child intake) (Vaughn et al. 2015), modeling (i.e., parental intake of healthy food, sometimes also including demonstrating the benefits of those foods to children) (Yee et al. 2017), and food availability and accessibility (for healthier foods) have all been associated with dietary quality that predicts reduced obesity risk (Gross et al. 2012). Autonomy support is defined as providing sufficient support to nurture young children's capacity to self-regulate when the parent is not present and includes child involvement, encouragement and support, praise, reasoning, and negotiation (Vaughn et al. 2015). Encouragement (i.e., positively, gently, and supportively inspiring young children to adopt healthy eating habits), praise (i.e., positive reinforcement through verbal feedback), and reasoning (i.e., using logic to persuade children to change their eating habits) have each been associated with healthier diets predictive of reduced obesity risk (Vaughn et al. 2015). Coercive control (parental directives that reflect domination and/or attempts by the parent to impose their will on the child) (Vaughn et al. 2015) is composed of restriction, pressure to eat, threats and bribes, and soothing with food. Excessive parental restriction and pressure-to-eat in the toddler years have received much attention as a potential cause of obesity. Higher levels of restriction have been associated with later eating in the absence of hunger and greater risk of obesity among toddlers; however, other studies have found no associations with child eating behaviors or weight status (Rollins et al. 2014a). Similarly, pressuring toddlers to eat has been associated with increased, decreased, or unchanged risk of child obesity (Faith et al. 2004).

Physical Activity

Physical activity in the toddler years has been associated with characteristics of the home environment (e.g., availability of outdoor spaces) (Hager et al. 2017), digital media viewing, and parent role modeling (Lee et al. 2018). Greater physical activity in toddlers, which can be measured using accelerometry technology, is associated with better bone and skeletal health (Carson et al. 2017). Interventions to increase toddler engagement in physical activity have been shown to improve proximal risk factors for obesity, though evidence for a direct impact on child obese weight status has been inconsistent (Wang et al. 2015).

PRESCHOOL AGE

Autonomy over eating and food continues to increase in the preschool years (ages 3 to 5 years). Children are increasingly able to express preferences for and dislikes of different foods. During the preschool age range, marketing becomes increasing influential in shaping these preferences through packaging or digital media. Characters in children's media are omnipresent (Brunick et al. 2016) and are used to market foods and beverages, particularly those that are calorie-dense and nutrient-poor, to children. There is strong evidence that even associating a character with a food (by placing a sticker of that character on a food) increases the likelihood that a child will agree to try the food, prefer it over other foods, and consume more of the food (Kraak & Story 2015). Food commercials for unhealthy foods embedded in shows can increase preferences for and consumption of unhealthy foods in young children (Harris & Kalnova 2018). Children's exposure to digital media is no longer limited to television; in fact, targeted food and beverage marketing is also present on other media platforms, such as YouTube and Instagram, and through social media influencers (Coates et al. 2019, Smith et al. 2019). Food marketing has also been incorporated into children's mobile apps and games, many of which collect user data to further target their advertising through algorithms. These marketing strategies have repeatedly been found to be effective in changing children's attitudes toward, preferences for, and consumption of the advertised foods.

Preschooler Growth and Weight Gain

Researchers and clinicians in the United States generally plot and monitor children's growth from 24 months to 19 years of age using CDC growth charts (Kuczmarski et al. 2000). BMI is calculated and plotted against age- and sex-specific growth curves to generate a percentile, which allows categorization of children as overweight (BMI ≥ 85th percentile) or obese (BMI ≥ 95th percentile). Growth is often also reported in z-scores, which are the deviation of a growth measurement from the mean value of the reference population divided by the standard deviation. Z-scores can be converted into percentiles and vice versa. Analyses can be conducted using raw BMI if analyses are stratified on sex and either the children are all exactly the same age (to the month) or BMI is analytically transformed into trajectories. However, in almost all cases, it is most appropriate to use BMI z-scores or percentiles, given that both of these approaches standardize the measure for age and sex. Further, z-scores are preferred over percentiles when study cohorts include a significant number of children with BMIs above the 98th percentile, as z-scores prevent the compression of values at the extremes of the bell curve that occurs with percentiles.

The preschool age range is also marked by reaching the nadir of adiposity that occurs across the lifespan, referred to as adiposity rebound. Specifically, BMI declines to this nadir at some point between ages 3 to 7 years, with some evidence to indicate that the nadir occurring at a younger age predicts greater obesity risk (Péneau et al. 2016). This physiologically normal period of adiposity rebound can contribute to parental perceptions that children are not growing appropriately and lead to the parent excessively pressuring the child to eat beyond satiety, theoretically adversely impacting the ability to accurately self-regulate caloric intake.

Preschooler Eating Temperament

By preschool age, eating behaviors are generally conceptualized as food approach or food avoidant behaviors (Carnell et al. 2013). Food approach behaviors are suggested to include enjoyment of food, food responsiveness, emotional overeating, desire to drink, eating in the absence of hunger, and food reinforcement (Carnell et al. 2013). Parent reports of enjoyment of food, food responsiveness, desire to drink, and emotional overeating have been associated with higher weight status in almost all studies (French et al. 2012). Food reinforcement (the relative reinforcement value of food) reflects an individual's willingness to work to gain access to food when an alternative reinforcer is available (Epstein et al. 2007); preschoolers in laboratory protocols who demonstrate a greater relative reinforcing value of food have a higher BMI (Rollins et al. 2014b). Food avoidant behaviors have been suggested to include food fussiness, satiety responsiveness, slowness in eating, emotional undereating, and food neophobia (Carnell et al. 2013). Food avoidant behaviors have been consistently associated with lower diet variety and quality (Taylor et al. 2015), but their associations with BMI are less robust than for food approach behaviors (Dovey et al. 2008). Parent reports of satiety responsiveness and slowness in eating show negative associations with BMI, but food fussiness does not show consistent associations (Brown et al. 2016, French et al. 2012). In general, the effect sizes for associations of food avoidant behaviors with BMI are roughly half the magnitude of those observed for food approach behaviors. In summary, food approach behaviors show strong robust positive relationships with higher weight status, whereas food avoidant behaviors are consistently associated with poorer diet quality but weakly associated with weight status.

Child temperament and self-regulation abilities in the preschool age range have received a great deal of interest as a potential contributor to obesity risk and target for intervention. Overall, temperamental qualities of surgency (high impulsivity, pleasure and novelty seeking, activity level) and negative affectivity (high lability, reactivity, negative emotion) predict greater food responsiveness and higher BMI in preschoolers (Leung et al. 2014, 2016). By contrast, the temperamental quality of effortful control (ability to refrain from a behavior, maintain attention, and resist distraction) has not been found to predict obesity-promoting eating behaviors or BMI in preschoolers (Leung et al. 2014, 2016). There is much ongoing research examining the roles of various types of self-regulation or executive function (inhibitory control, attention control/shifting, working memory, delay of gratification, and affective decision-making) in contributing to child obesogenic eating. Ongoing work is also continuing to examine whether associations between self-regulation abilities and obesogenic eating vary depending on whether the stimulus is a food or a nonfood reward (Tan & Lumeng 2018).

Parental Feeding Behaviors

The family food environment continues to play an important role in children's obesity risk in the preschool years. Family routines around mealtime and food, including parental offering of foods, food availability in the household, mealtime routines, and modeling, have been associated with healthier child intake and have been proposed as a modifiable target for obesity interventions. However, interventions targeting these potentially modifiable targets have shown mixed efficacy (Bekelman et al. 2017). Parental controlling feeding behaviors, in contrast to responsive feeding behaviors, have been the subject of much research in the preschool age group. Parental pressuring and restriction have been associated with child weight status, although results have been mixed. Most studies have found greater pressuring to eat to be associated with lower child weight and greater restriction to be associated with greater child weight. These relationships are likely bidirectional in nature, as maternal feeding behaviors are likely shaped by their concerns for their child's weight and eating behaviors, which are in turn shaped by maternal feeding behaviors (Zhou et al. 2020).

Feeding behaviors occur within the context of the dyad and are likely shaped by the parent-child relationship. Mother-child attachment is fundamental in children's early relationships. The attachment behavioral system signals individuals to seek proximity to someone who can provide support, comfort, and help when distressed. Securely attached children display attachment behaviors, such as seeking comfort and soothing from their caregivers when distressed, while insecurely attached dyads demonstrate behaviors that can interfere with the development of supportive caregiver-child relationships (Ainsworth et al. 2015). Extensively studied in relation to other outcomes, attachment has only recently begun to receive attention as a possible pathway to obesity in early childhood. Recent studies have found associations between a measure of attachment and child obesity in the preschool years (Bergmeier et al. 2020). Maternal representations are a related construct and refer to mothers' affective and cognitive perspectives regarding their children and their subjective experiences of their relationships with their children. In our own work, we found that mothers with more optimal representations of their children (e.g., balanced) were most likely to report optimal feeding practices. Mothers with less optimal representations (e.g., disengaged) were less invested in child feeding (Leung et al. 2015). Further, mothers with more parenting reflectivity, the degree to which mothers are able to perceive and understand their own and their children's mental states (including feelings), had more optimal feeding practices, including more positive affectivity, sensitivity, and engagement during an observed feeding (Leung et al. 2015).

During the preschool age range, maternal feeding also evolves in response to changing views of children's overweight status. When children are younger, parents often perceive excess adiposity as something the child will grow out of. However, as they enter the preschool age range, parental concern about children's overeating increases (Pesch et al. 2016a), and parents can sometime begin to express hostility toward their child's overeating. Parents sometimes begin to express frustration with attempts to restrict the child's eating and may begin to distance themselves from the child as they begin to experience growing societal disapproval of their child's overeating (Pesch et al. 2019b).

Physical Activity

Over the preschool years, settings outside the home become more important for physical activity, including preschool and child care. In addition, as children acquire greater gross motor skills, organized sports begin to emerge as a contributor to children's physical activity. Correlates of lower physical activity in preschoolers include higher digital media use, female sex, urban neighborhood environment, and home-based (versus center-based) childcare setting (Hodges et al. 2013). Preschool and child care settings become increasingly important venues for promoting physical activity during this age range.

STRESS, POVERTY, AND CHILD OBESITY RISK

Early-life poverty confers enduring risk for obesity later in the lifespan (Lee et al. 2014). In 2019, 14% of US children were living below the federal poverty line and 25% were living below 150% of the federal poverty line. Growing up in poverty is often characterized by early-life stress exposure to both acute and chronic stressors. There are many potential mechanisms explaining the association between psychosocial stress and obesity in children (Miller & Lumeng 2018). Mothers living in poverty describe feeding goals aligned with public health recommendations, including restricting unhealthy foods, promoting autonomy around eating, preventing obesity, and promoting fruit and vegetable intake (Goulding et al. 2015). However, these mothers find implementing their goals around promoting vegetable intake to be more achievable than implementing goals to restrict junk food or other unhealthy behaviors (Pesch et al. 2016b). Psychosocial stress is also associated with less physical activity (Roemmich et al. 2003, Walton et al. 2014). Finally, child sleep is increasingly recognized as important for obesity prevention and is adversely affected by stress (Lundahl et al. 2013). Stress alters stress hormones, which lead to less satiety responsiveness, to more emotional overeating, and sometimes to obesity (Doom et al. 2020, Lumeng et al. 2014, Miller et al. 2013a). Body fat, in a feedback loop, alters the functioning of these same stress hormones (Doom et al. 2020) and produces other hormones linked with poor emotion regulation (Miller et al. 2013b). In summary, psychosocial stress confers increased risk for obesity in young children through a number of pathways, emphasizing the importance of focusing obesity prevention efforts within communities most in need of support.

CONCLUSIONS

The childhood obesity epidemic emerged 30 years ago and has persisted in the face of myriad public health interventions. Research early in the epidemic initially focused intensively on parenting (Baumrind 1971; Costanzo & Woody 1985; Iannotti et al. 1994; Klesges et al. 1983, 1986). The early focus on parenting is consistent with how science commonly evolves in addressing health problems that we do not yet understand—early efforts often focus on personal behaviors. It was hypothesized that parents being overly indulgent, forcing children to clean their plates, and generally being overly controlling and intrusive or unresponsive to the child's cues was the cause of childhood obesity (Birch et al. 1987). Decades of research have shown, however, that although these dynamics are causal for some children, they do not explain a large proportion of the variance in the majority of children. It was also hypothesized that parents were lacking knowledge and that nutrition education was needed (Epstein et al. 1980). However, as is true with most public health challenges, behavior change does not result from education alone (Epstein et al. 1998).

Efforts focused on behavior have also evolved over the last 30 years. There was initially a strong focus on promoting emotional and behavioral self-regulation and encouraging children to inhibit the impulse to eat. As it became clear that strategies involving self-control were only modestly effective, the focus of behavioral research began to turn toward food approach behaviors—specifically, individual differences in the drive to eat. Behaviors related to the drive to eat arguably have been more robustly associated with obesity than behaviors related to self-control of eating and therefore are increasingly the focus of research (Birch et al. 2007, Fisher & Birch 2002, Kininmonth et al. 2021).

The last 30 years of research has also seen an evolution with regard to the life stage at which interventions have been focused. In the late 1990s, the first behavioral prevention trials focused on school-age children. In the early-to-mid-2000s, efforts increasingly turned to preschool age. In the past decade, researchers have been focusing on early infancy. Most recently, as interventions even in the first months of life have been found to have modest effects (Savage et al. 2016), researchers have begun to focus on prenatal prevention, with a focus on understanding the biological mechanisms linking the intrauterine environment with postnatal growth (Patel et al. 2017, Peaceman et al. 2018). This work is especially challenging with respect to the need to traverse disciplines to include biological and behavioral expertise in pregnancy as well as in early childhood.

The focus of research into the biological mechanisms of obesity has also evolved substantially over the last 30 years. Scientists early in the epidemic focused on identifying genetic causes of obesity by conducting large genome-wide association studies, which ultimately identified only a small proportion of the variance in heritability (Ingelsson & McCarthy 2018). Work has now turned toward the epigenome on the premise that epigenetic modifications are shaping gene expression, which in turn confers obesity risk (Sharma et al. 2020). The scientific understanding of the biology of obesity also evolved to shift from focusing on metabolism to focusing on the brain as researchers increasingly understood the complexities of the gut-brain axis and the impact of the metabolic milieu on hunger and satiety signaling in the brain (Torres-Fuentes et al. 2017). After decades of work and multiple failed efforts, in the last 5 years, effective medications to treat obesity have been identified and approved for children as young as 12 years (Chadda et al. 2021, Shoemaker et al. 2020).

Policy change to address obesity continues to be a challenge. Efforts have ranged from state policies requiring schools to notify parents of their child's BMI to local regulations requiring calorie labeling on menus and imposing a tax on sugar-sweetened beverages (Fletcher et al. 2010, Frongillo et al. 2017, Thompson & Madsen 2017). Change at the federal level involving the food industry has been more difficult to accomplish but is an important area for future work. As is true with most public health problems, social policies that support families are also likely to reduce rates of childhood obesity through multiple mechanisms and must continue to be a long-term advocacy goal.

In summary, childhood obesity is a complex and multifactorial condition with causes spanning from biology to federal policy. In addition, there are substantial individual differences in risk and unique risks specific to each developmental stage in childhood. Understanding the mechanisms underlying these differences across childhood is a critical area of focus in developmental science.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

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