

# A Review of Modifiable Risk Factors for Severe Obesity in Children Ages 5 and Under

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## Abstract

Early-onset severe obesity in childhood presents a significant clinical challenge signaling an urgent need for effective and sustainable interventions. A large body of literature examines overweight and obesity, but little focuses specifically on the risk factors for severe obesity in children ages 5 and younger. This narrative review identified modifiable risk factors associated with severe obesity in children ages 5 and younger: nutrition (consuming sugar sweetened beverages and fast food), activity (low frequency of outdoor play and excessive screen time), behaviors (lower satiety responsiveness, sleeping with a bottle, lack of bedtime rules, and short sleep duration), and socio-environmental risk factors (informal child care setting, history of obesity in the mother, and gestational diabetes). The lack of literature on this topic highlights the need for additional research on potentially modifiable risk factors for early-onset severe obesity.

**Keywords:** children; nutrition; physical activity; screen time; severe obesity; sleep; social determinants

## Introduction

A 2011 report by the Institutes of Medicine (IOM) Committee on Obesity Prevention Policies for Young Children, “Early Childhood Obesity Prevention Policies,” focused on factors that influence the risk for obesity in a young child, drawing much needed attention to policy and prevention efforts in this area.<sup>1</sup> While the IOM report thoroughly described this population as a whole, it did not differentiate modifiable risk factors for young children with overweight, obesity, and severe obesity.<sup>1</sup> A paucity of literature exists on the nutrition, activity, behavioral, and socio-

environmental determinants of severe obesity in children 5 years and younger. Severe obesity is currently defined as a BMI  $\geq 120\%$  of the 95th percentile for BMI for children ages 2–18 and previously as a BMI  $\geq 99$ th percentile.<sup>2</sup> Among children under 2 years of age, overweight is defined as weight-for-length (WFL)  $\geq 95$ th percentile; however, there is no consensus on a definition for obesity or severe obesity.<sup>3</sup> In the United States, 8.1% of children under 2 years have overweight; 2% of 2- to 4-year olds enrolled in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) have severe obesity, with higher rates among Hispanic and American Indian/Alaska

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Native populations.<sup>4,5</sup> Growth patterns in children with severe obesity have been shown to diverge early in life (by 2–4 months) with a 2.5-fold risk of developing severe obesity by age 5 or 6 and high incidence of persistence into adulthood.<sup>6–8</sup> Studies have utilized various definitions of severe obesity for the purpose of stratifying risk and demonstrating persistence in children ages 5 and younger, including infancy.<sup>7,9,10</sup>

National guidelines encourage medical providers to screen for obesity and stratify care based on severity.<sup>3</sup> Despite these recommendations, less than half of providers reported using current BMI percentile cutoffs for diagnosing overweight, obesity, or severe obesity.<sup>11</sup> The guidelines do not provide direction to medical providers on screening for obesity in children <2 years of age despite the fact that only 1-in-5 children with severe obesity at age 2 will have improvement of their weight status by adulthood.<sup>8</sup> Recent studies indicate a continued increase in obesity rates, with significant increases in severe obesity in children ages 2–5.<sup>12</sup>

In 2014 the American Academy of Pediatrics Institute for Healthy Childhood Weight (IHCW) and the Children's Hospital Association (CHA) convened the Expert Exchange (EE), an interdisciplinary team of 40 participants from tertiary care obesity programs at 21 children's hospitals across the United States. A subgroup of the EE conducted a focused literature search to assist in identifying and defining behaviors associated with severe obesity in young children (5 years and younger). An additional subgroup focused on the medical and genetic risk factors for this same population.<sup>13</sup> This narrative review provides an overview of current literature specific to modifiable risk factors for severe obesity in children 5 years of age and younger, with a discussion of nutrition, activity, behaviors, and socio-environmental risks relevant for implementing targeted interventions. Due to a lack of research specific to severe obesity in children 5 and younger, the approach to the assessment and treatment of this population at high risk for subsequent morbidity is not well established in research or clinical practice. Selective supporting references to overweight/obesity were utilized as background in each risk factor category where evidence was weak or lacking in young children with severe obesity. Table 1 describes the studies with a specific focus on eating, activity, or behaviors in the young child (0–5 years) with severe obesity.<sup>7,9,10,14–19</sup>

## Defining Early-Onset Obesity

Significant emphasis has been put on early life risk for obesity. Blake-Lamb et al., describe an “early life obesity prevention program,” referring to the first 1000 days in the life of a child, recognizing the importance of intervention at this early stage.<sup>20</sup> The 2011 IOM report on early childhood obesity mentions “early onset of childhood obesity” and the 2016 National Academies report uses the term “obesity in the early years” both referring to children ages 5 and younger.<sup>21</sup> Using these reports as a stepping stone, “early onset” is used herein to expand on the highest risk

for children in this age group and describe children ages 5 years and younger with severe obesity.

## Risk Factors: Nutrition

Infant weight gain has been shown to be a risk factor for obesity and severe obesity.<sup>6,7</sup> Evidence around rapid infant weight gain and overweight has been associated with bottle feeding, bottle size, weaning patterns, feeding to schedule, mode of milk delivery, timing of solid food introduction, and milk composition (breast milk vs. formula).<sup>22–26</sup> However, Colon and Ramey illustrate that the direct association between breastfeeding and improved child health (including BMI and obesity) is most likely multifactorial.<sup>27</sup> Current national recommendations for obesity prevention continue to support the use of exclusive breastfeeding for 6 months and breastfeeding in combination with complimentary foods for at least 1 year.<sup>1</sup> It has also been shown that eating patterns associated with increased risk of obesity (*e.g.*, high intake of sweets and grains; low intake of fruits and vegetables) are often developed by 12 months of age, entrenched by 2–4 years of age,<sup>28</sup> and predict lack of variety in fruit and vegetable preferences by age 8.<sup>29</sup>

When looking at differentiating factors for children 5 years old and younger with severe obesity, breastfeeding, fruit and vegetable intake, sugar sweetened beverage (SSB), juice, coffee/tea, and fast food consumption have all been examined. In a national sample of children ages 2–5 with severe obesity ( $N=123$ ) and normal weight ( $N=3907$ ), Tester et al., demonstrated that children who had never been breastfed had increased odds of severe obesity (odds ratio [OR] 1.9, 95% CI 1.3–2.8).<sup>19</sup> In a retrospective chart review of 67 one to 4-year olds presenting for overweight treatment, Welch et al., described children with severe obesity (defined as  $\geq 160\%$  of ideal body weight, without a control group), being significantly more likely to have never breastfed compared to breastfed >6 months (64% vs. 42%, respectively,  $p=0.037$ ).<sup>9</sup> In kindergarteners with ( $N=400$ ) and without severe obesity ( $N=6400$ ), Flores and Lin were able to demonstrate a significant difference in ages of early introduction to formula (2.5 months  $\pm$  0.2 months vs. 3.7 months  $\pm$  0.1 months, respectively,  $p<0.01$ ) and complimentary foods (4.1 months  $\pm$  0.1 months vs. 4.5 months  $\pm$  0.04 months, respectively,  $p=0.04$ ).<sup>17</sup>

Baughcum et al., provide a descriptive portrayal of 140 children ages 2–5 with severe obesity (without a comparison group) who present for tertiary care weight management treatment: 47% of parents reported no daily fruit intake, 61% reported no daily vegetable intake, and 29% reported daily consumption of SSBs.<sup>14</sup> In addition, Flores and Lin were able to demonstrate that the consumption of fruit, at least once a week in kindergarten-age children, offered a protective effect against severe obesity (OR 0.3, 95% CI 0.1–0.7).<sup>17</sup> Several studies show a strong relationship between SSB intake, excess adiposity, BMI, and BMI z-score.<sup>17,18</sup> For example, in a large retrospective chart review comparison of children ages 3–5 years with

**Table 1. Studies Exploring Severe Obesity in Children Ages 5 and Under**

Study	Design	SO criteria	Study population/Age/N	Results		
				BMI/Demographic	Eating/Activity	Parenting/Behavioral
Gittner et al. <sup>7</sup>	RCR: 1997–2001	SO Definition: WHO BMI = 99th%	Midwestern Health Maintenance Organization Ages birth–5 N = 72 with SO	SO compared to normal, overweight, obese <ul style="list-style-type: none"> <li>Mothers BMI: 24.8 ± 4.5; 28.3 ± 6.8; 28.3 ± 7.0; 31.4 ± 7.0***</li> <li>BMI values consistently differ between normal weight and SO cohorts after 1 week for girls*; after 2 months for boys*</li> <li>Earliest BMI correlation to 5 year SO: 4 months***</li> </ul>	SO compared to normal, overweight, obese: <ul style="list-style-type: none"> <li>No relationship between breastfeeding/formula feeding and later weight status</li> <li>No difference in introduction of timing of solid foods; all cohorts were introduced to solid food before 6 months</li> </ul>	N/A
Welch et al. <sup>9</sup>	RCR: 2000–2006	SO Definition: % IBW ≥ 160% (McLaren Method)	Obesity Treatment Referral Clinic Ages 1–4 years N = 67 with SO 12%: BMIz ≥ 5.0	SO: Common Characteristics: <ul style="list-style-type: none"> <li>Mother with obesity*</li> <li>Obese parent or sibling***</li> <li>Medicaid/uninsured**</li> <li>Birth weight ≥ 4 kg*</li> </ul>	Common Characteristics: <ul style="list-style-type: none"> <li>Breastfeeding—Never (64%) or &lt; 6 months (39%)*</li> <li>Juice ≥ 9 oz/day (62%)*</li> </ul>	N/A
Satkunam et al. <sup>10</sup>	CS: 2009–2016	SO Definition: WHO zBMI = > 3 CDC BMI = 1.2 × 95%	The Applied Research Group for Kids (TARGET Kids!) and BORN Ontario Ages: 17–24 months N (TARGET Kids! & BORN) = 4481 (1.1% with WHO SO definition and 0.3% with CDC SO definition)	SO: Common Characteristics: <ul style="list-style-type: none"> <li>Maternal prepregnancy BMI OR 1.04 (95% CI 0.94–1.15)</li> </ul>	N/A	N/A
Baughcum et al. <sup>14</sup>	RCR: 2009–2011	SO Definition: BMI ≥ 99th%	Obesity Treatment Referral Clinic Ages 2–5 years N = 140 with SO 11%: BMIz ≥ 5.0	Maternal BMI was correlated with child's BMI z-score** <ul style="list-style-type: none"> <li>BMI z-score decreased from 3.51 to 3.37 at 2nd visit***</li> </ul>	Common Characteristics: <ul style="list-style-type: none"> <li>Daily fruit 53% and vegetables 39%</li> <li>Fast food ≥ 1 × per week 61%</li> <li>SSB several times a week 50%</li> <li>Screen time &gt; 2 hours 44%</li> <li>Sleep duration ~ 10 hours/night (range 7–12.5 hours)+sleep problems</li> </ul>	Common Characteristics: <ul style="list-style-type: none"> <li>Problem eating patterns 68% (snacks too much, eats too fast, eats at wrong time of day, skips meals, eats at night)</li> <li>Mindless eating 51% (in front of TV/computer, eating when bored, food as reward)</li> <li>Self-control problems 76% (large portions, loves sweets, can't stay away from food, eats ≥ 2 servings, not sure when full)</li> <li>Parental degree of concern was highly correlated with BMI*</li> </ul>

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**Table 1. Studies Exploring Severe Obesity in Children Ages 5 and Under continued**

Study	Design	SO criteria	Study population/Age/N	Results		
				BMI/Demographic	Eating/Activity	Parenting/Behavioral
Clifford et al. <sup>15</sup>	PS	Weight status: Median BMI = 99th% Mean BMIz = 2.36	Family-Based Obesity Treatment Intervention Study Ages 2–5 years N = 41	N/A	<ul style="list-style-type: none"> <li>Each hour of nocturnal sleep associated with 186 fewer calories consumed<sup>d**</sup></li> </ul>	<ul style="list-style-type: none"> <li>Each hour of nocturnal sleep associated with 0.14 unit lower BMI z-score*</li> </ul>
Lo et al. <sup>16</sup>	RCR: 2007–2010	SO Definition: BMI = 1.2 × 95th%	Northern California Kaiser Clinic Ages 3–5 years N = 688 with SO N “biologically implausible BMI/Wt values” = 223	<p>SO: Common Characteristics:</p> <ul style="list-style-type: none"> <li>Male gender (1.9%)<sup>***</sup></li> <li>Hispanic boys (3.3%)<sup>**</sup></li> <li>Hispanic girls (2.2%)<sup>*</sup></li> <li>Black girls (1.7%)<sup>*</sup></li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>
Flores and Lin <sup>17</sup>	LS: 2001–2008	SO Definition: BMI ≥ 99th%	Early Childhood Birth Cohort Ages: 9 months–kindergarten (K) N = 400 with SO 5.7% in K	<p>Factors predicting SO at Kindergarten (K):</p> <ul style="list-style-type: none"> <li>Crossing 85th% BMI at 9 months (2 × odds)<sup>**</sup> or 2 years (8 × odds)<sup>**</sup></li> <li>Higher weight for gestational age<sup>**</sup></li> <li>Latino, multiracial/ethnic, non-English primary language<sup>**</sup></li> <li>Poverty, lower parental education, increased number of adults in household, nonrelative child care<sup>**</sup></li> <li>Gestational DM (3 × odds), maternal SO before pregnancy, maternal age<sup>**</sup></li> </ul>	<p>Factors predicting SO at K:</p> <ul style="list-style-type: none"> <li>Younger introduction to formula<sup>**</sup> and solids<sup>*</sup></li> <li>Sleep with bottle at 9 months<sup>**</sup></li> <li>Higher screen time<sup>**</sup></li> <li>Higher SSB (2 × odds SO at K)<sup>**</sup></li> <li>Fast food in K more than 3 days/week<sup>**</sup></li> <li>Drinking tea/coffee between meals/late (3 × odds)</li> </ul> <p>Factors protecting from SO:</p> <ul style="list-style-type: none"> <li>Consumption of fruit (3 × less likely SO)</li> <li>Drinking milk with meals at 2 years<sup>*</sup></li> </ul>	<p>Factors predicting SO at K:</p> <ul style="list-style-type: none"> <li>No bedtime rules (79% SO vs. 35% SO if bedtime rules)<sup>*</sup></li> <li>Maternal agreement that toilet training should occur before 1 year<sup>**</sup></li> </ul> <p>Factors protecting from SO:</p> <ul style="list-style-type: none"> <li>Attending center-based child care (3 × lower SO)<sup>*</sup></li> </ul>

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**Table 1. Studies Exploring Severe Obesity in Children Ages 5 and Under continued**

Study	Design	SO criteria	Study population/Age/N	Results		
				BMI/Demographic	Eating/Activity	Parenting/Behavioral
Ford et al. <sup>18</sup>	RCR: 2012–2013	SO Definition: BMI = 1.2 × 95th% Moderate Obesity: BMI = 100%– 119% × 95th%	Kaiser Permanente Northern California, Get Health Action Plan Program Ages 3–5 N = 355	SO: Common Characteristics: • Low income (39.3%)* • Racial/ethnic differences compared to non-Hispanic white: • Black (37.6%)* • Hispanic (34.0%)*	SO compared to moderate obesity • Eating breakfast <6 × /week* • Hispanic (33.3%)* • Asian/PI (37.6%)* • ≥2 Sugary Drinks/Day* • Black (67.2%)* • Hispanic (64.3%)* • Asian/PI (57.1)* • 60 minutes exercise outside <5 × /week* • Black (50.9%)* • Hispanic (47.0%)* • Asian/PI (50.8%)* • 60 minutes exercise outside <3 × /week • Hispanic (19.1%)* • Asian/PI (23.5%)*	SO compared to moderate obesity • Sleep (<8 hours/day), including naps* • Black (17.0%)* • TV, computer, or video games ≥3 hours/day • Black (43.5%)* • Asian/PI (36.6%)*
Tester et al. <sup>19</sup>	CS: 1999–2012	SO Definition: BMI = 1.2 × 95th%	NHANES Ages: 2–5 years N = 157 (2.1%) with SO	Common Characteristics: • Income below FPL OR 2.1 • African American OR 1.7 • Hispanic OR 2.3* • Single parent OR 2.0* • Parent ≤High School completion OR 2.4*	Common Characteristics: • >4 hours of screen time/day (2.0 × odds SO)* • Never breastfed (1.9 odds SO)* • No association with Healthy Eating Index • No association with daily calorie intake	N/A

Significant association: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

Study design: CS, Cross-sectional Study; LS, Longitudinal Study; PS, Prospective Study; RCR, Retrospective Chart Review.

BMIz, body mass index z score; BORN, Better Outcomes Registry &amp; Network; CDC, US Centers for Disease Control; FPL, federal poverty level; IBW, ideal body weight; PI, Pacific Islander; SO: Severe obesity; SSB, sugar sweetened beverage; WHO, World Health Organization.

obesity ( $N=775$ ) versus severe obesity ( $N=355$ ), Ford et al., found that those with severe obesity were significantly more likely to drink  $\geq 2$  SSB/day.<sup>18</sup> Findings from Flores and Lin support this showing that consumption of at least one SSB per week in kindergarteners was associated with double the odds of severe obesity (OR 2.3, 95% CI 1.4–3.7).<sup>17</sup> Welch et al., also showed that children ages one to four with severe obesity presenting for nutrition evaluation were significantly more likely to drink  $\geq 9$  ounces of juice per day than drink no juice (62% vs. 45%, respectively,  $p=0.037$ ).<sup>9</sup> In addition to SSB and juice, Flores and Lin found that 2-year-old children who drank coffee or tea between meals or at bedtime had triple the odds (OR 3.3, 95% CI 1.3–8.5) of severe obesity by kindergarten.<sup>17</sup> Finally, among those presenting for tertiary care weight management in a descriptive study without a control group, Baughcum et al., describe 61% of families with children 5 years and younger with severe obesity report consuming fast food once per week or more.<sup>14</sup>

## Risk Factors: Eating Behaviors

Infants who have larger appetite ratings, greater enjoyment of food, faster rate of eating, and lower satiety responsiveness tend to have higher body weight and more rapid weight gain over 6- and 12-month periods during infancy.<sup>30</sup> Food seeking behavior driven by hyperphagia is a well-recognized behavioral characteristic in syndromic or genetic obesity disorders in childhood, such as Prader–Willi Syndrome.<sup>31</sup> Food seeking and hyperphagia can also be seen in children ages 8–12 without identified genetic abnormalities and are associated with reduced satiety responsiveness and greater “loss of control” when eating.<sup>32</sup> A systematic review of 41 studies suggested no association between food neophobia and overweight or obesity, while a statement could not be made about the association between picky eating and weight status, possibly due to varied definitions of picky eating.<sup>32,33</sup>

Little research has addressed eating behaviors in children 5 years old and younger with severe obesity. Baughcum’s descriptive study of 140 children ages 2–5 years with severe obesity presenting to a tertiary care multidisciplinary obesity center examined parental responses to an intake questionnaire completed prior to their initial appointment: 68% of parents reported at least one problematic child eating behavior, with “child snacks too much” as being the most frequently reported (51%), followed by “child eats too fast” (34%). Approximately half of parents endorsed their child engaging in mindless eating (51%), with 32% reporting eating in front of a TV or computer and 31% endorsing boredom eating. There were no comparison groups, so it is unknown what the frequency of maladaptive eating behaviors would be for children in other weight categories.<sup>14</sup> Gross et al., described eating behaviors in children with ( $N=108$ ) and without severe obesity ( $N=41$ ).<sup>34</sup> This study was inclusive of children 5 and younger and reported that children with severe obesity ages 2–12 years old who presented for weight management had lower “Satiety

Responsiveness” on the Child Eating Behavior Questionnaire compared to children with obesity.<sup>34</sup> In addition, girls aged 2–12 with severe obesity reported higher “Enjoyment of Food” and measured lower on “Slowness of Eating,” compared to girls with obesity.<sup>34</sup>

## Risk Factors: Household Routine, Sleep, Activity, and Screen Time

Structured family routines (*e.g.*, bedtime, screen time, and family meals) have been shown to decrease the odds of a preschooler having obesity.<sup>35,36</sup> Shorter sleep duration and less physical activity are associated with higher risk of overweight/obesity in children.<sup>37–39</sup>

Sleep, screen time, and physical activity have been studied in children 5 years and younger with severe obesity. Flores and Lin found that lack of bedtime rules and taking an infant (9 months old or less) outside less than a few times per month were associated with increased risk of severe obesity in kindergarten (79% vs. 35% and 80% vs. 33%, respectively) in those with a cluster of common risk factors (crossing BMI percentiles at an early age, low education level, and higher maternal age).<sup>17</sup> In a cross-sectional study of 2- to 5-year olds with severe obesity compared to normal weight counterparts, Tester et al., found that those with severe obesity were more likely to have three or more hours of screen time (OR 1.7, 95% CI 1.1–2.7), and 27.1% of children with severe obesity had four or more hours of screen time compared to 14.7% of children with normal weight ( $p<0.05$ ).<sup>19</sup> Baughcum et al., describes activity among 2- to 5-year olds with severe obesity presenting for tertiary care weight management, with 74% reported playing outside for more than 1 hour per day and 27% were in an organized sport, while only 56% reported  $<2$  hours of screen time daily.<sup>14</sup> In a bivariate analysis, Flores and Lin showed that kindergarteners with severe obesity (BMI  $\geq 99$ th%) compared to those without severe obesity (BMI  $\leq 99$ th%) were less likely to participate in organized athletic activities outside of school (32.6% vs. 44.5%, respectively,  $p=0.01$ ),<sup>17</sup> and Ford et al., demonstrated that children ages 3–5 years with severe obesity (vs. those without severe obesity) are more likely to get 60 minutes of activity outside of physical education (PE)  $<5$  times per week (53% vs. 40.7%,  $p<0.05$ ).<sup>18</sup>

Baughcum et al., also assessed for sleep patterns in her study of a treatment-seeking population of preschoolers with severe obesity and found that 58% of families reported at least one sleep problem, including snoring, interrupted sleep, or difficulty sleeping.<sup>14</sup> Ford et al., utilized a large health system to perform a retrospective chart review on children who had been identified to have obesity. Among this population, children ages 3–5 with severe obesity (BMI  $\leq 120$ % of 95th%;  $N=353$ ) had shorter sleep duration ( $<8$  hours/night) more frequently compared to children with moderate obesity (BMI 100%–119% of 95th%;  $N=762$ ) (9.4% vs. 5.4%, respectively,  $p<0.05$ ).<sup>18</sup> Clifford et al., report on a behavioral intervention study of 41 young children (ages 2–5) with a mean BMI  $z$ -score of

2.36 consistent with severe obesity.<sup>15</sup> They showed that each additional hour of sleep per night was associated with a 0.14 unit decrease in BMI *z*-score and in 186 fewer calories consumed.<sup>15</sup>

## Risk Factors: Socio-Environmental Determinants

Food insecurity, geographic areas with higher priced fruits/vegetables, nonparental child care, and greater time spent in child care have shown an association with obesity and increased BMI in young children.<sup>40–42</sup>

Socio-environmental determinants seem to influence prevalence of severe obesity in children 5 years and younger. Lower parental education, poverty, and a higher number of adults in the household predicted severe obesity in preschool-aged children and kindergarteners.<sup>17,18</sup> Specifically, Welch et al., reported that among 1- to 4-year-old children presenting to a multidisciplinary hospital-based nutrition evaluation clinic, children with severe obesity were more likely to have public versus private insurance ( $p=0.0004$ ).<sup>9</sup> In a nationally representative longitudinal study that followed children from birth to kindergarten entry, with severe obesity compared to those without severe obesity at kindergarten entry, Flores and Lin demonstrate that severe obesity was associated with family income ever below the poverty threshold ( $p=0.01$ ), lower parental educational attainment ( $p<0.01$ ), and more adults in the home ( $p<0.01$ ).<sup>17</sup> Similarly, in an analysis of children ages 2–5 from a large NHANES dataset, Tester et al., revealed that lower parental educational attainment was associated with greater odds (compared to children without severe obesity) of having a child with severe obesity (OR 2.4, 95% CI 1.5–3.9) and children from a single caregiver household had twice the odds of severe obesity (OR 2.0, 95% CI 1.3–3.0).<sup>19</sup> Finally, Flores and Lin found that attending a formal child care center was protective with an odds of severe obesity in kindergarten being thrice lower for center-based child care attenders versus nonattenders (OR 0.3, 95% CI 0.1–0.9).<sup>17</sup>

## Risk Factors: Maternal Health

Much attention has focused on maternal factors that may be associated with obesity and severe obesity in the young child, including maternal weight status, gestational weight gain, and gestational diabetes. While many studies have demonstrated the correlation between maternal obesity and childhood adiposity,<sup>43–45</sup> few have stratified this risk for young children with severe obesity. Several studies report that high maternal BMI (obese or severely obese) is often associated with early-onset severe obesity in the offspring. Welch et al., found that 1- to 4-year-old children with severe obesity presenting to a nutrition evaluation clinic more frequently had a mother with obesity.<sup>9</sup> In a separate study evaluating characteristics of preschoolers presenting for tertiary care obesity treatment, Bauchcum et al., reported

that maternal BMI was associated with child BMI *z*-score.<sup>14</sup> Flores and Lin demonstrated that maternal severe obesity before pregnancy was associated with triple the odds of the child having severe obesity by kindergarten (OR 3.4, 95% CI 1.9–5.8).<sup>17</sup> Similarly, in a retrospective chart review, Gittner et al., reported that maternal prepregnancy BMI was on average lowest in the normal weight cohort and highest in the cohort of children with severe obesity.<sup>7</sup> Flores and Lin found that maternal gestational diabetes was associated with a three-fold adjusted odds of severe obesity by kindergarten (OR 2.9, 95% CI 1.5–5.5).<sup>17</sup> A recent report by Satkunam et al., looking at two large cross-sectional Ontario datasets, supports these findings, with maternal prepregnancy BMI associated with increased odds of severe obesity (WHO BMI<sub>z</sub> >3) in 17- to 24-month-old children (OR 1.04, 95% CI 0.94–1.15).<sup>10</sup> Mirza et al., as a part of the same EE Workgroup, recently reviewed the genetic and medical risk factors in children 5 years and younger and found supporting evidence around prenatal factors and severe obesity in young children.<sup>13</sup>

## Discussion

Nutrition, activity, and behavioral and socio-environmental factors clearly influence infant and early childhood excess weight gain; however, many of the existing studies have focused on overweight/obesity without distinguishing those with severe obesity. Differing definitions for severe obesity in the young child, lack of a definition for severe obesity among children younger than 2 years, and emerging studies recommending a change in current practice (using WHO BMI vs. WFL) all contribute to this lack of data.<sup>6,46</sup> Without a consistent definition, primary care providers are unable to identify those children <2 years old who already have severe obesity or those at most risk of developing severe obesity, and epidemiologists are unable to consistently capture data and risks. Consistent terminology and measures of severe obesity are needed for screening, identification, and understanding outcomes/national changes.<sup>47</sup>

Rates of obesity and severe obesity in children 5 and under have continued to trend upward.<sup>12</sup> Children with early-onset severe obesity display more pronounced obesogenic behaviors/risk factors compared to their peers with overweight or obesity. In those presenting for treatment, parents of children with severe obesity note behaviors of decreased satiety, greater enjoyment of food, and faster eating speed compared to children with obesity in observational studies.<sup>34</sup> Shorter sleep duration, lack of bedtime rules, increased screen time, less involvement in team sports, and less frequent time outside in infancy are all observed in children ages 5 and under with severe obesity. Observational studies on children ages 5 and under with severe obesity presenting for treatment of weight suggest never being breastfed; decreased fruit and vegetable consumption, increased SSB, juice, coffee/tea, and fast food consumption are seen at increased frequency in this population.<sup>7,9,14–19</sup> An infant presenting to their pediatric

primary care provider with a cluster of socio-environmental risk factors (poverty, maternal gestational diabetes or obesity, or multiple adults in the household) and WFL or BMI >85th percentile may warrant increased involvement and support for the family,<sup>48</sup> before the child reaches the threshold of severe obesity in infancy or early childhood. Further research is needed to identify potential modifiable intervention targets, such as eating/feeding behaviors and parenting practices/strategies, and identify ways to mitigate the impact of poverty on obesity early in life.

There are several limitations to this narrative review. First, there is a limited body of literature on this topic area. The studies listed in Table 1 have small sample sizes of children with severe obesity ( $N=41-688$ ), variable definitions of severe obesity (five different definitions), and primarily utilize cross-sectional study designs (including two observational studies without control groups), which limit the ability to draw causal inferences or determine conclusive priorities for treatment. In addition, there are significant gaps in the literature, including those related to child behaviors (e.g., tantrums, oppositional behaviors, and food restriction), prenatal exposure and the intrauterine environment, including pre-conception BMI/pregnancy weight gain and gestational diabetes, and early nutritional habits (breastfeeding and early solid food introduction) in the child with early-onset severe obesity. While several studies describe factors associated with severe obesity, most have focused on older age groups.

## Conclusions

This narrative review provides a summary of the literature on nutrition, activity, and behavioral and socio-environmental risk factors associated with severe obesity in children 5 years and younger and highlights the need for stratification of samples by obesity severity in studies where possible, additional research on potentially modifiable risk factors, and clear definitions of obesity and severe obesity in children 2 years and younger. Ultimately, a better understanding of these risk factors will inform the development of assessment tools and targeted interventions for this vulnerable subgroup of young children.

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