The STRONG Kids 2 Birth Cohort Study: A Cell-to-Society Approach to Dietary Habits and Weight Trajectories across the First 5 Years of Life

Barbara H Fiese,[1] Salma Musaad,[2] Kelly K Bost,[1] Brent A McBride,[1,3] Soo-Yeun Lee,[3,4] Margarita Teran-Garcia,[3,4,5] and Sharon M Donovan[3,4]

[1]Department of Human Development and Family Studies and [2]Biostatistics Core, the Interdisciplinary Health Sciences Institute, Urbana, IL; [3]Division of Nutritional Sciences, [4]Department of Food Science & Human Nutrition, and [5]UI Extension, University of Illinois at Urbana-Champaign, Urbana-Champaign, IL

ABSTRACT

Background: Dietary habits formed during the first 5 y of life portend lifelong eating patterns.

Objectives: The Synergistic Theory Research Obesity and Nutrition Group (STRONG) Kids 2 birth cohort study aimed to examine multilevel predictors of weight trajectories and dietary habits including individual biology, child socioemotional and behavioral characteristics, family environment, and child care environment over the first 5 y of life. This report describes recruitment strategies, an overview of survey measures, and basic descriptive statistics of the cohort.

Methods: The cohort includes 468 mothers and their offspring. A brief survey was completed at a 1-wk home visit including child's birth weight, intent to breastfeed, collection of an infant stool sample, and additional contact information should the family move. Mothers completed surveys including diet, child temperament, family environment, and child care when their child was 6 wk, 3, 12, 18, 24, 36, 48, and 60 mo of age. Height and weight of the mother and child were collected at each visit. Stool samples of the child were collected at each visit as well as saliva at 1 visit.

Results: Close to half of the mothers were either overweight (24.2%) or obese (25.2%) prepregnancy. At 6 wk of age, 32.9% of the children were overweight and 31.4% were obese based on direct measurement.

Conclusions: The STRONG Kids 2 research team has adopted a socioecological model that accounts for multiple influences on children's health including biological, child social and behavioral, family household organization, and community factors. The study is limited by a relatively educated and nondiverse sample. However, variations in maternal and child weight may inform future prevention programs and policy aimed at improving the diet and health of children under the age of 5 y. This trial was registered at clinicaltrials.gov as NCT03341858. *Curr Dev Nutr* 2019;3:nzz007.

Background

Recent epidemiology reports have indicated that 17% of children in the United States between 2 and 17 y of age are classified as obese (1). Dietary habits formed during the first 5 y of life portend lifelong eating patterns (2, 3). We know that beginning before 4 mo of age, infants and toddlers consume more calories than are required for healthy growth and development (3, 4). Of particular concern are the introduction of solids before 4 mo of age, the consumption of sugar-sweetened beverages before 2 y of age, and the low rates of consumption of green leafy vegetables across the first few years of life (5, 6). Thus, unhealthy weight and poor dietary habits in the first few years of life are a major public health concern. The Synergistic Theory Research Obesity and Nutrition Group (STRONG) Kids 2 (SK2): A Cells-to-Society Approach to Nutrition in Early Childhood

Keywords: pediatric obesity, birth cohort study, weight trajectories, nutrition, socioecological model

Manuscript received October 11, 2018. Initial review completed November 20, 2018. Revision accepted January 16, 2019. Published online January 18, 2019.
Supported in part by the National Dairy Council (to BHF), NIH grant 5R01DK107561-02 (to SMD), Gerber Foundation (to SMD), USDA Hatch grant 793-328 (to BHF), and Christopher Family Foundation (to BHF).
Author disclosures: BHF, SM, KKB, BAM, S-YL, and MT-G, no conflicts of interest. SMD serves on the Grant Advisory Board of the National Dairy Council.

Address correspondence to BHF (e-mail: bhfiese@illinois.edu).

Abbreviations used: SK2, STRONG Kids 2; SNP, single nucleotide polymorphism; STRONG, Synergistic Theory Research Obesity and Nutrition Group; WFLZ, weight-for-length *z* score.

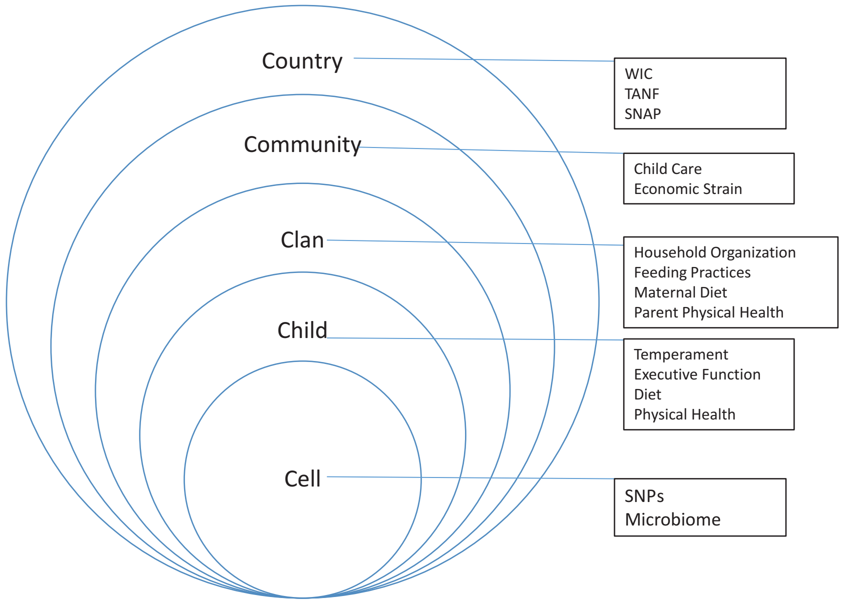

FIGURE 1 The Six C's theoretical model guiding the Synergistic Theory Research Obesity and Nutrition Group Kids 2 cohort study. SNAP, Supplemental Nutrition Assistance Program; SNP, single nucleotide polymorphism; TANF, Temporary Assistance to Needy Families; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

birth cohort study aimed to examine multilevel predictors of weight trajectories and dietary habits including individual biology, child socioemotional and behavioral characteristics, family environment, and child care environment over the first 5 y of life in a low-risk sample of children born in the United States. In this report we describe the theoretical foundations of the study, study design, recruitment procedures, and initial demographic and participant characteristics.

Theoretical Foundation

The STRONG Kids program is grounded in a bio-ecological perspective proposing that child health outcomes are a result of multiple factors that extend across cell-to-society (7, 8). Although ecological models have been proposed to explain the complexities of childhood obesity (9, 10), they have rarely included the intersection of biological, family, and community processes. As originally proposed by Bronfenbrenner (11) and expanded by Bronfenbrenner and Evans (12), bio-ecological models suggest that individual biology is shaped by and expressed in an environmental context. The child's dietary habits and weight trajectories will be influenced by multiple factors including individual biology, temperamental characteristics of the child, psychosocial factors in the family, and availability of resources. The SK2 birth cohort study (NCT03341858; registered 14 November, 2017; data are available, upon reasonable request, from the authors) focuses on 4 ecologies that are proposed to interact or transact with each other to affect children's dietary habits and weight gain: cell, child, clan (family), and community (see **Figure 1**). Previous studies have identified a multitude of risk factors for unhealthy weight gain during the first 5 y of life including genetic risk and prenatal factors (13), maternal weight gain during pregnancy (5), breastfeeding practices (14), maternal feeding practices (15), and timing of entry into child care (5). What makes the SK2 study unique is the consideration of how these risk factors operate in concert with each other over time to predict weight trajectories as well as the cumulative effect of these factors in predicting dietary habits.

At the cellular level, variations in the maternal and child's genetic makeup as well as child and maternal microbiome are being examined using 16S ribosomal RNA sequencing and whole genome shotgun sequencing. Previous reports by our team have identified that candidate gene single nucleotide polymorphisms (SNPs) previously associated with an increased risk of overweight and obesity in adults (16, 17) also were associated with BMI in 2- to 3-y-olds (18). In the SK2 program, how route of delivery, maternal and child diet, maternal and child weight, and child growth trajectories affect the microbiome beginning at birth are being investigated. Importantly, changes in the microbiome during weaning and the introduction of solids are being documented and the microbiomes of infants who are exclusively breastfed, exclusively formula-fed, or fed both breast milk and infant formula are being compared and related to growth and health outcomes. For a subsample, breast milk samples have been collected alongside measurement of milk intake using a 24-h weighing procedure.

At the child level, child temperament, executive function, and how sleep characteristics interact with cellular and family factors to predict dietary habits and weight gain are being assessed. At the family level, the roles of feeding practices, parental and child emotion regulation, family routines (sleep and mealtime), and media use in establishing healthy dietary habits are being explored. In our earlier work, a relation between higher child weight status and unhealthy parental feeding practices was moderated by both parental responses to negative emotions and child genetic propensities for emotion reactivity (19). In addition, our data have shown that a combination of 4 household routines (mealtime, sleep, media use, and no TV during meals) predict child consumption of fruits and vegetables rather than a single routine, suggesting that multiple aspects of the family environment are important in understanding dietary habits (20).

Community contributions to child diet include the child's participation in child care, the timing of entry into child care, and type of child care. Because children under the age of 5 y may receive 2 meals (breakfast, lunch, or supper) and 1 or 2 snacks per day (https://www.fns.usda.gov/cacfp/why-cacfp-important), it is crucial to track participation in child care. Previous reports by our team documented that type of child care was important in determining early risk of obesity because some child care centers and early childhood programs, such as Head Start, may engage in more responsive feeding practices associated with healthy dietary habits (21).

In this report an overview of the recruitment procedures, collection of anthropometric and biological samples, and an overview of the panel survey are provided, as well as a description of the baseline demographic characteristics of the participants. The overall aim of the project was to identify predictors of weight trajectories during the first year and weight trajectories from 12 mo to 5 y. Our primary outcome measures included weight-for-length z scores (WFLZ) and weight trajectories. Secondary outcomes included infant feeding practices, maternal and child diet, stool sample microbiome, breast milk microbiome, and salivary SNPs. A complete listing of primary and secondary outcomes may be found at clinicaltrials.gov: NCT03341858.

Recruitment Strategy

Women were recruited in their third trimester of pregnancy from health care facilities (e.g., obstetrics and gynecology) and birthing classes in east-central Illinois. Notices were also placed on a university-based website. Exclusion criteria included premature birth (<37 wk), birth conditions precluding normal feeding (e.g., phenylketonuria and other inborn errors of metabolism), and low birthweight (<2.5 kg). At the time of recruitment, participants were provided with a timeline schema indicating the points at which project staff would contact them and expectations for each visit (see **Figure 2**). Recruitment began in May, 2013 and ended in January, 2017. Initially 539 pregnant women agreed to participate. See **Figure 3** for recruitment flow and loss of participants from study entry until first contact when the child was 1 wk of age.

Methods

This study was approved by the University of Illinois Institutional Review Board (# 13448). All participants completed online informed consent forms. The data set used in the current study is available from the corresponding author on reasonable request.

Participants

The final sample included 468 mothers and their offspring. Most caregivers were highly educated (72.9% college graduate/postgraduate degree), nonsingle (88.5%), employed (69.4%), and non-Hispanic/Latino white (76.1%). The mean ± SD age of the mothers was 30.8 ± 4.7 y at 6 wk postpartum. The mothers reported that 4.9% of their children were Hispanic/Latino, 83.1% were non-Hispanic/Latino white, 9.8% were African American/black, 9.4% were Asian, 1.1% were American Indian or Alaskan Native, and 1.1% preferred not to report. The majority of the children were first born (65.6%) and half were female (50%). A listing of participants' background demographic characteristics is shown in **Table 1**.

Power analysis

The null hypothesis was that there would be no difference in child weight trajectories over the first year, and between the first and fifth years. The alternative hypothesis was that there would be a significant difference between children who followed slow or gradual growth and those who followed rapid growth patterns during those durations.

Using developmentally appropriate child weight z scores (e.g., weight-for-length during the first 2 y of life), group sample sizes of 80 and 324 (total $n = 404$) achieved 80% power to detect a difference of ≥27% between 2 child weight trajectory groups in a repeated-measures design. Assumptions include ≥20% children in the slow or gradual growth trajectories, a minimum of 2 repeated measurements, a correlation coefficient (ρ) between observations on the same subject of 0.2, and a 5% α level.

Procedures

After recruitment into the study, project staff contacted the mother ~1 wk after the estimated due date. A home visit was conducted 1–2 wk after the child's birth. To encourage retention, the family specialist who enrolled the mother into the study conducted the initial home visit and the 6-wk home visit whenever possible. A brief survey was completed at the 1-wk visit including child's birth weight, intent to breastfeed, collection of an infant stool sample, and additional contact information should the family move. More extensive visits were made at 6 wk, 3, 12, 18, 24, 36, 48, and 60 mo (see Figure 2 for a description of procedures at each visit). Mothers also collected a sample of their own stool at the 6-wk visit. At each visit, mothers were asked to collect a stool sample from the infant/child, which was sent back to the project office via mail or was collected during the home visit. Detailed instructions were provided with each sample collection kit, which included a disposable collection pad (Dynarex Corporation), nitrile, powder-free and latex-free gloves, tubes (Dealmed), a sampling spoon (Bel-Art, SP-Scienceware), and storage box. For those infants not yet potty trained, a freshly voided stool sample was collected from the diaper or training pants by the mother. At 1 and 6 wk, the infant stool sample was placed into a sterile 3.0-mL screw-top tube (Thermo Fisher Scientific). A sterile 50-mL polyprophylene conical tube (Karter Scientific) was used for all subsequent infant stool samples. For stools from the mother and children after potty training, a sterile, single-use, Fisherbrand commode specimen collection system (Thermo Fisher Scientific) was placed into the commode before defecation. Subjects were asked to avoid passing urine into the specimen collection container. Approximately 10 g of stool sample was transferred to the sterile 50-mL polyprophylene conical tube and any remaining stool was flushed down the toilet. Mothers were instructed to wear gloves and use the sterile spoons to transfer the stool sample into the tube. Tubes were then placed into a storage box, which was placed into a sealable bag and stored in their home freezer (−20°C) until being picked up by the research staff. In addition, at the 6-wk visit, saliva samples were collected from both the mother and infant (18). However, in some cases insufficient amounts of saliva were obtained from the infant at 6 wk of age. Therefore, additional

Your Baby's Age	What Will Happen at This Visit?	Description
1-2 weeks		Home visit with birth height and weight record, stool sample from baby
6 weeks		Survey (breastfeeding, family health, maternal health, intent for childcare, household food security, economic strain) home visit with stool samples from mom and baby, saliva samples from mom and baby, weight and length for baby and height and weight for mom, breast milk/formula sample
3 months		Survey (breastfeeding, child health, family health, maternal health, food allergies, infant and parent sleep, sleep routines, infant temperament, child care intent, household income) home visit with length and weight for baby, stool sample from baby, food inventory, height and weight for mom
Introduction of solid food		Stool sample picked up after your baby begins solids
12 months		Survey (breastfeeding, child health, family health, maternal health, maternal food frequency, food allergies, infant and parent sleep, sleep routines, parent feeding practices, family routines, child care intent, child care hours, household income, food security), home visit with length and weight for baby, stool sample from baby, food inventory, height and weight for mom
18 months		Survey (food allergies, child health, maternal health, child and parent sleep, child temperament, parent feeding styles, child care intent/hours, household income) home visit with length and weight for baby, stool sample from baby, and height and weight for mom
2 years		Survey (child food frequency questionnaire, child health, family health, maternal health, maternal food frequency, food allergies, child and parent sleep, sleep routines, child and parent physical activity, parent feeding practices, family routines, media use, child care intent, child care hours, household income, food security, economic strain) home visit with length and weight for baby, stool sample from child, food inventory, height and weight for mom
3 years		Survey (child food frequency questionnaire, child health, family health, maternal health, maternal food frequency, food allergies, child and parent sleep, sleep routines, child and parent physical activity, parent feeding practices, family routines, media use, child care intent, child care hours, household income, food security, economic strain), home visit with length and weight for baby, stool sample from child, food inventory, height and weight for mom
4 years		Survey (child food frequency questionnaire, child health, family health, maternal health, maternal food frequency, food allergies, child and parent sleep, sleep routines, child and parent physical activity, parent feeding practices, family routines, media use, child care intent, child care hours, household income, food security, economic strain), home visit with length and weight for baby, stool sample from child, food inventory, height and weight for mom
5 years		Survey (child food frequency questionnaire, child health, family health, maternal health, maternal food frequency, food allergies, child and parent sleep, sleep routines, child and parent physical activity, parent feeding practices, family routines, media use, child care intent, child care hours, household income, food security, economic strain), home visit with length and weight for baby, stool sample from child, food inventory, height and weight for mom

FIGURE 2 Recruitment timeline.

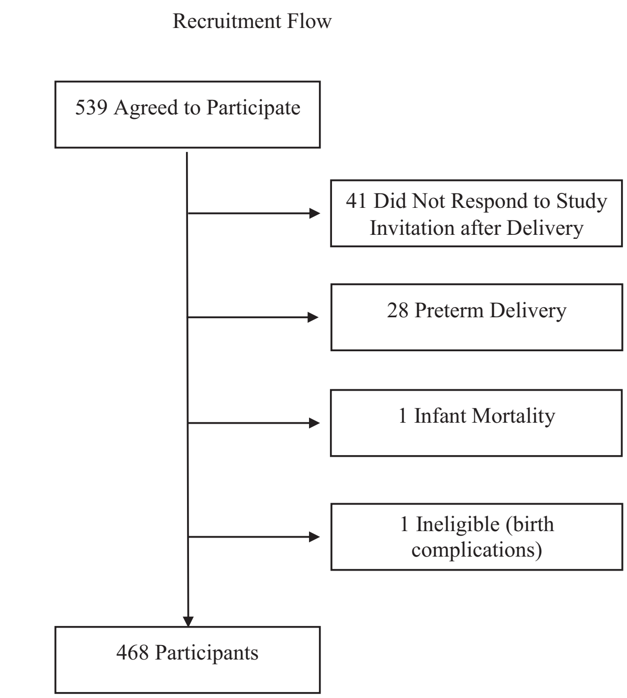

FIGURE 3 Recruitment flow.

saliva collections were made at a later date. Saliva and stool samples were stored at −80°C before analysis.

Height and weight (for mother) and length and weight (for child) were collected by trained research assistants. Maternal weight was measured using a digital scale (HealthOmeter, Model 349KLX). Maternal height was measured on a Seca 213 portable stadiometer. Maternal measurements were taken twice at each visit and the mean was determined. If the difference in height was >0.5 cm a third measurement was taken. If the difference in weight was >0.1 kg a third reading was taken. Maternal BMI (kg/m^2) was classified as nonoverweight (0) consisting of underweight (BMI < 18.5) and normal weight (18.5 ≤ BMI < 25), overweight (1) (25 ≤ BMI < 30), and (2) obese (BMI ≥ 30) (22). Child length was obtained by measuring the distance from head to foot while the child lay flat on a scale (Seca, Model 728). Child weight was measured using a digital scale (HealthOmeter, Model 349KLX). A mean across 2 measurements was taken with adjustments for discrepancies, following the procedures outlined for maternal height and weight. Age- and gender-specific WFLZs were calculated using the 2006 WHO growth charts (23). Prepregnancy maternal weight was collected at study enrollment via maternal report. Although recall may be subject to bias, comparison of maternal recall of prepregnancy weight and clinical records indicates no significant differences except for women who are underweight (24).

A family food inventory was taken at the 3-, 12-, 24-, 36-, 48-, and 60-mo visits. Two trained research assistants used a structured checklist to ascertain the presence of foods in the family pantry, countertops, and refrigerator/freezer. Following a previously developed and validated approach, a healthy and obesogenic food index could be derived (25).

TABLE 1 Background demographics of study sample at 6 wk postpartum[1]

Characteristic	*n* (%) or mean ± SD	Range
Number of people living in the home	4 ± 1	2–11
At least 1 older sibling in the home	161 (34.4)	
Mother's education		
College graduate/postgraduate degree	341 (72.9)	
Some college/technical school	88 (18.8)	
Grade school/high school	32 (6.8)	
Unknown/missing	7 (1.5)	
Monthly household income		
≤$3000	137 (29.3)	
$3001–5000	123 (26.3)	
≥$5001	155 (33.1)	
Unknown/missing	53 (11.3)	
Marital status		
Not single	414 (88.5)	
Single	45 (9.6)	
Unknown/missing	9 (1.9)	
Employment status		
Employed	325 (69.4)	
Unemployed	37 (7.9)	
Stay at home	85 (18.2)	
Student	10 (2.1)	
Retired/disabled	1 (0.2)	
Unknown/missing	10 (2.1)	
Employment type[2]		
Professional and related occupations	126 (26.9)	
Office and administrative support	38 (8.1)	
Management, business, or financial	21 (4.5)	
Service occupation (e.g., food industry)	18 (3.9)	
Sales	8 (3.9)	
Production	5 (1.1)	
Transportation or materials moving	2 (0.4)	
Farming, fishing, and forestry	1 (0.2)	
Other	105 (22.4)	
Unknown/missing	144 (30.8)	
Health care coverage	453 (96.8)	
Participation in WIC (mother, child, or both)	97 (20.7)	
Participation in Childcare Assistance Program	7 (1.5)	
Received food stamps in last 30 d	48 (10.3)	
Mother's race/ethnicity		
Hispanic/Latino	19 (4.1)	
Non-Hispanic/Latino white	356 (76.1)	
Non-Hispanic/Latino nonwhite[3]	55 (11.8)	
African American	19 (4.1)	
Asian	30 (7.2)	
Alaskan Native or American Indian	1 (0.2)	
Unknown/missing	38 (8.1)	
Household food security		
Food secure	429 (91.7)	
Low food security	27 (5.8)	
Very low food security	5 (1.1)	
Unknown/missing	7 (1.5)	
Subjective social status[4]		
1 and 2 (low)	7 (1.5)	
3 and 4 (low–mid)	70 (14.9)	
5 and 6 (mid)	176 (37.6)	
7 and 8 (mid–high)	170 (36.2)	
9 and 10 (high)	28 (5.9)	

(*Continued*)

TABLE 1 (*Continued*)

Characteristic	*n* (%) or mean ± SD	Range
Unknown/missing	17 (3.6)	
Perceived economic hardship[5]		
Financial strain	1.1 ± 0.4	1.0–3.5
Make ends meet	2.0 ± 1.0	1.0–5.0
Not enough money	1.8 ± 0.8	1.0–4.7

[1] *n* = 468. Percentages may not add up to 100 because of rounding. Data that are unknown or missing were not provided by the mother. WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.
[2] Individuals who worked >1 job were asked to describe the job where they worked the most hours per week.
[3] Includes American Indians or Alaska Natives, Asians, and African Americans.
[4] The Subjective Social Status scale is depicted as a 10-rung ladder ranging from category 1 (lowest reported social ranking in terms of money, job, and education) to category 10 (highest reported social ranking). Categories were grouped in pairs for the purposes of tabulation. Groups 1 and 2 are considered low subjective status ranks, 9 and 10 are considered high ranks.
[5] A higher score indicates greater perceived economic hardship. The maximum possible score is 5.

Mothers completed an online survey that detailed dietary habits, sociodemographics, child health and personality characteristics, and family environment at each time point (Figure 2 provides an outline of procedures across all time points).

Measures

The online survey measures were selected with a focus on dietary habits, nutrient intake, and potential cell-to-community influences on early diet. Surveys were administered that were age- and developmentally appropriate for the child (6 wk, 3, 12, 18, 24, 36, 48, and 60 mo of age). We drew from pre-existing measures with established reliability and validity estimates. In this section, a general overview of the survey measures broken down by demographics, child diet, maternal diet, child health, child social and emotional behaviors, parental and family practices, child care, and economic strain is provided. We also provide a brief overview of the analysis of the stool and saliva samples.

Stool and saliva analysis

At this time, proposed analyses of the saliva samples include assessing SNPs for candidate genes associated with satiety and appetite control pathways with obesity-related traits as previously described (18). Data will be analyzed for individual associations with child outcomes as well as genetic predisposition scores (18). Future studies may also involve investigations of epigenetic changes between 6 wk and later time points and investigations into associations between microRNA and childhood obesity and growth trajectories (26, 27). Fecal microbiota composition of mothers and infants will be assessed by high-throughput sequencing of the V-3 to V-4 variable regions of the bacterial 16S ribosomal RNA gene (28). In addition, for the infant, microbiome metagenomics will be assessed by whole-genome shotgun sequencing (29) and the fecal metabolome by ultra-HPLC-MS (30). The impact of diet will be assessed in terms of the longitudinal development of the microbiome and its metabolic function. In addition, associations between the host microbiome and health outcomes will be investigated.

Demographics

Mothers responded to general questions about marital status, highest level of education, race/ethnicity, household income, and employment status.

Child diet

During the first year of life, mothers completed survey items drawn from the CDC Survey on Infant Feeding Practices Study II (31). Information about method of feeding, formula use, dietary supplements, infant health, use of medicines, stool characteristics, breastfeeding cessation, pumping and expressing milk, food allergy, and infant sleep quality and sleeping arrangements was collected. From 2 y onward, mothers completed the Child Block FFQ for Ages 2–7 developed by Nutrition Quest to ascertain the child's consumption of fruits and vegetables, fats, proteins, and dairy (32). This is a 90-item questionnaire that parents complete in response to their child's "usual eating habits in the past 6 months." It takes ∼30 min to complete and parents completed an online version that was analyzed by Nutrition Quest. The food list was developed from NHANES III dietary recall data and the nutrient database was drawn from the USDA Nutrient Database for Standard Reference (http://www.nutritionquest.com/assessment/list-of-questionnaires-and-screeners/).

Maternal diet

Maternal dietary habits associated with breastfeeding were included in the CDC Infant Feeding Practices questionnaire (31). In addition, mothers completed the validated full-length Block 98 FFQ provided by Nutrition Quest at the 12-, 24-, 36-, 48-, and 60-mo points (33, 34). Mothers' consumption of fruits and vegetables, fats, proteins, and dairy and dietary supplements was analyzed.

Child health

Overall general health was ascertained from the Short Form of the Medical Outcomes Study Health Survey (35). In addition, survey questions included items pertaining to allergies and allergic reactions to food. Beginning at 2 y of age, 25 items were included about physical activity (36). These items included types of physical activity that the child and other family members engaged in such as walking and playing ball. Parents were also asked whether they provided opportunities for their child to engage in physical activity such as providing transportation to parks or taking lessons such as swimming. Beginning at 3 mo of age, survey items were included about sleep including time that the child went to bed, time that the child woke up, and nighttime waking (37). Parents were asked to report, on average, how many hours they had slept each night during the past 4 wk. Although self-report assessments of sleep duration are subject to bias they provide a cost-effective approach to understanding this important health factor (38).

Child behavioral style, executive function, and eating behaviors

During the first year, mothers completed survey items pertaining to child temperament (39). During the second year, mothers completed survey items designed to assess children's executive function in everyday activities (40), emotional eating (41), and picky eating (42).

Parental feeding practices

In addition to detailed information regarding breastfeeding practices, we assessed caregiver feeding styles including restrictive practices and pressure to eat (43) and parenting styles associated with feeding (44).

Maternal physical health

The Short Form of the General Health Survey was collected beginning at the 6-wk visit (35). Alcohol and tobacco use were surveyed as single items, respectively. Beginning at 2 y of age, physical activity was surveyed annually including participation in family physical activity such as walking and running (36). Amount of sleep experienced per night was collected at every survey period (37).

Household organization

Several aspects of household organization were surveyed at most time points. Sleep routines were monitored beginning at 3 mo of age (45). Family routines including mealtime, weekends, and special celebrations were surveyed on an annual basis (46). Family chaos, reflecting the lack of planning and disorganization in the household (47), was also measured on an annual basis. Media use in the household was also assessed beginning in the second year of life. This included type of media that the child was exposed to as well as the amount of time engaged with media (48).

Child care

Beginning at 1–2 wk, mothers were asked about their intent to use child care and the planning and support surrounding child care. Once their child was enrolled in child care, the type of child care (e.g., home-based care, center-based care, Head Start) was monitored, along with the number of hours enrolled in child care.

Economic strain

Although the sample was highly educated, we did track perceived economic strain and the family's ability to make ends meet (49). In addition, we assessed the mother's perceived social status to track her perception of relative economic worth (50). This approach is more sensitive than socioeconomic status alone. We also tracked participation in the Supplemental Nutrition Assistance Program; Women, Infants, and Children Program; Temporary Assistance to Needy Families Program; and household food security status as assessed by the USDA (51).

TABLE 2 Child health characteristics[1]

Characteristic	*n* (%) or mean ± SD	Range
Weight (pounds)		
Birth	7.7 ± 1.0	4.6–10.6
Week 6	10.7 ± 1.4	7.1–16.7
Length (inches)		
Birth	20.1 ± 1.0	16.8–23.5
Week 6	22.0 ± 1.2	8.5–24.9
WFLZ		
Birth	−0.4 ± 1.3	−4.8 to 3.5
Week 6	0.0 ± 1.1	−3.8 to 3.4
Maternal report of child physical health at 6 wk		
Excellent	338 (72.2)	
Very good	112 (23.9)	
Good	14 (2.9)	
Fair	2 (0.4)	
Poor	1 (0.2)	
Unknown/missing	1 (0.2)	
Feeding method[2] at 1 wk		
Exclusive breastfeeding	330 (70.5)	
Exclusive formula feeding	33 (7.1)	
Combined	101 (21.6)	
Unknown/missing	4 (0.9)	
Feeding method[2] at 6 wk		
Exclusive breastfeeding	317 (67.7)	
Exclusive formula feeding	65 (13.9)	
Combined	84 (17.9)	
Unknown/missing	2 (0.4)	

[1]*n* = 468. Percentages may not add up to 100 because of rounding. Data that are unknown or missing were not provided by the mother. WFLZ, child weight-for-length *z* score.
[2]Feeding method was determined based on responses to the question, "Did you feed your baby formula, breast milk, or both in the past 7 days?"

Baseline Description of Child and Maternal Health

Child and family health characteristics

Child health characteristics are presented in **Table 2**. The WFLZs of the children at 6 wk lie 0 SDs around the reference median value, hence they follow the age- and gender-adjusted growth pattern of the WHO reference population at 6 wk. The majority of the children were reported by their parent to be in excellent health at 6 wk (72.2%) and were exclusively breastfed at 1 wk (70.5%) and 6 wk (67.7%). Only 47 (10%) of the children received newborn care in an intensive care unit or premature nursery. At 6 wk postpartum, a low prevalence of problems was reported for the previous 2 wk, including cough (7%), colic (6.4%), diarrhea (4.7%), eczema (1.9%), fever (1.3%), and food allergy (0.4%). Notably, 223 (47.7%) of the children were reported to be fussy or irritable and 70 (14.9%) had reflux. At 6 wk, only 79 (16.9%) of the children had regular child care, including care by a family member (9.4%), in-home child care (6.6%), and center-based child care (1.9%).

In terms of family health history, there were low rates of reported diabetes, dyslipidemia, stroke, heart disease, Alzheimer disease, autism spectrum, anxiety, cancer, and asthma. The highest reported family history rates were 28.2% for hypertension (maternal grandfather) and 24.6% for environmental allergies (biological mother).

Maternal health characteristics

Maternal health characteristics are summarized in **Table 3**. Close to half of the mothers were overweight (24.2%) or obese (25.2%) prepregnancy, based on self-report. When the child was 6 wk of age, 32.9% were overweight and 31.4% were obese based on direct measurement. Fewer than 6% had gestational diabetes, hypertension, or pre-eclampsia. The majority of mothers delivered their infants vaginally (73.3%) and self-reported excellent or very good physical health (69.9%).

Discussion

The SK2 birth cohort study aims to examine predictors of weight trajectories and dietary habits across the first 5 y of life. Our research

TABLE 3 Maternal health characteristics[1]

Characteristic	n (%) or mean ± SD	Range
Mother's age at 6 wk postpartum, y	30.8 ± 4.7	18.0–46.2
Gestational diabetes	27 (5.8)	
Pre-eclampsia	25 (5.3)	
Gestational hypertension	27 (5.8)	
Delivery method		
Vaginal	343 (73.3)	
Cesarean delivery	120 (25.6)	
Unknown/missing	5 (1.1)	
Maternal report of self physical health at 6 wk		
Excellent	109 (23.3)	
Very good	218 (46.6)	
Good	109 (23.3)	
Fair	17 (3.6)	
Poor	3 (0.6)	
Unknown/missing	12 (2.6)	
Alcohol use at 6 wk postpartum		
Never	165 (35.3)	
Rarely	154 (32.9)	
1–2 times a month	61 (13.0)	
Some days	74 (15.8)	
Every day	6 (1.3)	
Unknown/missing	8 (1.7)	
Smoking at 6 wk postpartum		
Not at all, I've never smoked	365 (77.9)	
Not at all, I've quit	77 (16.5)	
Some days	8 (1.7)	
Every day	11 (2.4)	
Unknown/missing	7 (1.5)	
Mother's BMI[2]		
Prepregnancy[3]		
Nonoverweight	217 (46.4)	
Overweight	113 (24.2)	
Obese	118 (25.2)	
Unknown/missing	20 (4.3)	
Study entry[3]		
Nonoverweight	75 (16.0)	
Overweight	175 (37.4)	
Obese	198 (42.3)	
Unknown/missing	20 (4.3)	
Week 6 postpartum		
Nonoverweight	156 (33.3)	
Overweight	159 (33.9)	
Obese	147 (31.4)	
Unknown/missing	6 (1.3)	

[1] $n = 468$. Percentages may not add up to 100 because of rounding. Data that are unknown or missing were not provided by the mother.
[2] Mother's BMI (in kg/m^2) was classified as nonoverweight [underweight (BMI < 18.5) and normal weight (18.5 ≤ BMI < 25)], overweight (25 ≤ BMI < 30), and obese (BMI ≥ 30).
[3] Based on self-reported weight. Mothers were recruited during the third trimester, hence BMI values at study entry are interpreted with caution.

team has adopted a socioecological model that accounts for multiple influences on children's health including biological, child social and behavioral, family household organization, and community factors. We aim to add to the literature by examining how individual biology of the child and mother transacts with the social environment over time to predict child dietary habits and weight trajectories over the first 5 y of life. We build on previous reports that have predicted weight trajectories based on single predictors of infant weight (52) or maternal weight (5), early introduction of solids (4), and breastfeeding practices (14). Rather than focus on single predictors of risk we hope to inform practice and policy that will take a richer approach to the complex origins of dietary habits and weight gain in the early years to include child socio-emotional development, family organization, and child care as they provide an environmental context in support of individual variations in biology.

In this descriptive report, we have outlined our recruitment procedures and the baseline health characteristics of the mother and child. Even though the sample is relatively well-educated, there were some indicators of risk for children being classified as overweight in this sample. Close to half of the mothers reported being overweight or obese prepregnancy and at 6 wk postpartum >65% of the mothers were overweight or obese. Prepregnancy BMI has been linked to adiposity rebound in early childhood (53) and risk of childhood obesity in the first 1000 d (5). We will be able to provide a nuanced examination of this potential risk factor in terms of the potential contribution of changes in the maternal and child microbiome before the introduction of solids and its interaction with characteristics of the family environment, including delivery mode, antibiotic use, pets in the home, siblings, daycare use, etc. (54).

We also note the relatively high incidence of breastfeeding in our sample. At 6 wk of age, close to 67% of the mothers reported breastfeeding exclusively and an additional 17% reported combined breastfeeding and formula feeding. The national average of exclusive breastfeeding at 3 mo is 46.9% (55). Although our sample may not be representative of all mothers across the nation, we will be able to look at not only risk factors associated with later dietary habits but also protective factors such as early feeding practices, transitions to solids, and the relationship between mother and child. Further, once the children enter child care we will be able to track community influences on diet and weight trajectories.

We recognize that this study is not without limitations. The relatively homogeneous nature of our sample will not allow us to address racial and ethnic variations, an important consideration in untangling health disparities in the early years of life (1). Our sample is also limited geographically and is relatively well-educated, which also raises concerns about representativeness.

This complex observational longitudinal birth cohort study should provide valuable information about growth trajectories and dietary habits in the first 5 y of life. We have amassed a transdisciplinary team of investigators that includes expertise in pediatric nutrition, human genetics, the gut microbiome, sensory science, human development and family science, and early care and education. Each investigator brings their own unique disciplinary perspective. Collectively the STRONG Kids team provides an opportunity to integrate these approaches across biological, family, and community systems. Ultimately, the results of the SK2 cohort study have the potential to inform practice and policy in the interest of improving children's health from birth.

Acknowledgments

Each member of the STRONG Kids 2 team has made a significant contribution to the intellectual content of the study. The authors' responsibilities were as follows—BHF, KKB, BAM, and SMD: made substantial contributions to the conception and design of the study;

SM: made substantial contributions to the acquisition and analysis of the data; S-YL and MT-G: participated significantly in the drafting and review of the manuscript; and all authors: read and approved the final manuscript.

References

1. Ogden CL, Carroll A, Lawman H, Fryar C, Kruszon-Moran D, Kit BK, Flegal KM. Trends in obesity prevalence among children and adolescents in the United States, 1988–1994 through 2013–2014. JAMA 2016;315:2292–9.
2. Rose CM, Birch LL, Savage JS. Dietary patterns in infancy are associated with child diet and weight outcomes at 6 years. Int J Obes 2017;41:783–8.
3. Saavedra JM, Deming DM, Dattilo A, Reidy K. Lessons from the Feeding Infants and Toddlers Study in North America: what children eat, and implications for obesity prevention. Ann Nutr Metab 2013;62(Suppl 3): 27–36.
4. Wang J, Wu Y, Xiong G, Chao T, Jin Q, Liu R, Hao L, Wei S, Yang N, Yang X. Introduction of complementary feeding before 4 months of age increases the risk of childhood overweight or obesity: a meta-analysis of prospective cohort studies. Nutr Res 2016;36:759–70.
5. Baidal JAW, Locks LM, Cheng ER, Blake-Lamb TL, Perkins ME, Taveras EM. Risk factors for childhood obesity in the first 1,000 days. Am J Prev Med 2015;50:761–79.
6. Deming DM, Reidy KC, Fox MK, Briefel RR, Jacquier E, Eldridge AL. Cross-sectional analysis of eating patterns and snacking in the US Feeding Infants and Toddlers Study 2008. Public Health Nutr 2017;20:1584–92.
7. Harrison K, Bost KK, McBride BA, Donovan SM, Grigsby-Toussaint DS, Kim J, Liechty JM, Wiley AR, Teran-Garcia M, Jacobsohn GC. Toward a developmental conceptualization of contributors to overweight and obesity in childhood: the Six-C's model. Child Dev Perspect 2011;5:50–8.
8. Fiese BH, Bost KK, McBride BA, Donovan SM. Childhood obesity from cell to society. Trends Endocrinol Metab 2013;24:375–7.
9. Birch LL, Anzman SL. Learning to eat in an obesogenic environment: a developmental systems perspective on childhood obesity. Child Dev Perspect 2010;4:138–43.
10. Kitzman-Ulrich H, Wilson DB, St., George SM, Lawman H, Segal M, Fairchild A. The integration of a family systems approach for understanding youth obesity, physical activity, and dietary programs. Clin Child Fam Psychol Rev 2010;13:231–53.
11. Bronfenbrenner U. Toward an experimental ecology of human development. Am Psychol 1977;32:513–31.
12. Bronfenbrenner U, Evans GW. Developmental science in the 21st century: emerging questions, theoretical models, research designs, and empirical findings. Soc Dev 2000;9:115–25.
13. IOM (Institute of Medicine). Examining a developmental approach to childhood obesity: the fetal and early childhood years: workshop summary. Washington (DC): The National Academies Press; 2015.
14. Carling SJ, Demment MM, Kjolhede CL, Olson CM. Breastfeeding duration and weight gain trajectory in infancy. Pediatrics 2015;135:111–19.
15. Haszard JJ, Russell CG, Byrne RA, Taylor RW, Campbell KJ. Early maternal feeding practices: associations with overweight later in childhood. Appetite 2019;132:91–6.
16. Chung WK, Patki A, Matsuoka N, Boyer BB, Liu N, Musani SK, Goropashnaya AV, Tan PL, Katsanis N, Johnson SB, et al. Analysis of 30 genes (355 SNP's) related to energy homeostasis for association with adiposity in European-American and Yup'ik Eskimo populations. Hum Hered 2009;67:193–205.
17. Wheeler E, Huang N, Bochukova EG, Heogh JM, Lindsay S, Garg S, Henning E, Blackburn H, Loos RJ, Wareham NJ, et al. Genome-wide SNP and CNV analysis identifies common and low-frequency variants associated with severe early-onset obesity. Nat Genet 2013;45:513–17.
18. Wang Y, Wang A, Donovan S, Teran-Garcia M; The STRONG Kids Team. Individual genetic variations related to satiety and appetite control increase risk of obesity in preschool-age children in the STRONG Kids Program. Hum Hered 2013;75:152–9.
19. Bost KK, Teran-Garcia M, Donovan SM, Fiese BH. Child body mass index, genotype, and parenting in the prediction of restrictive feeding. Pediatr Obes 2018;13:239–46.
20. Jones BL, Fiese BH; The STRONG Kids Team. Parent routines, child routines, and family demographics associated with obesity in parents and preschool-aged children. Front Psychol 2014;5:374.
21. Dev DA, McBride BA, Speirs KE, Donovan SM, Cho HK. Predictors of Head Start and child-care providers' healthful and controlling feeding practices with children aged 2 to 5 years. J Acad Nutr Diet 2014;114:1396–403.
22. National Institutes of Health, National Heart Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. NIH Publication No. 98-4083. Rockville, MD: NHLBI; 1998.
23. Grummer-Strawn LM, Reinold C, Krebs NF. Use of World Health Organization and CDC growth charts for children aged 0–59 months in the United States. MMWR Recomm Rep 2010;59:1184.
24. Lederman SA, Paxton A. Maternal reporting of prepregnancy weight and birth outcome: consistency and completeness compared with the clinical record. Matern Child Health J 1998;2:123–6.
25. Fulkerson JA, Nelson MC, Lytle LA, Moe S, Heitzler C, Pasche KE. The validation of a home food inventory. Int J Behav Nutr Phys Act 2008;28:55–65.
26. Ouyang S, Tang R, Liu Z, Ma F, Li Y, Wu J. Characterization and predicted role of microRNA expression profiles associated with early childhood obesity. Mol Med Rep 2017;16:3799–806.
27. Thompson MD, Cismowski MJ, Serpico M, Pusateri A, Brigstock DR. Elevation of circulating microRNA levels in obese children compared to healthy controls. Clin Obes 2017;7:216–21.
28. Berding K, Holscher HD, Arthur AE, Donovan SM. Fecal microbiome composition and stability in 4- to 8-year old children is associated with dietary patterns and nutrient intakes. J Nutr Biochem 2018;56: 165–74.
29. Schwartz S, Friedberg I, Ivanov I, Davidson LA, Goldsby JS, Dahl DB, Herman D, Wang M, Donovan SM, Chapkin RS. A metagenomic study of diet-dependent interaction between gut microbiota and host in infants reveals differences in developmental and immune responses. Genome Biol 2012;13:R32.
30. Bazanella M, Maier TV, Clavel T, Lagkouvardos I, Lucio M, Maldonado-Gomez MX, Autran C, Walter J, Bode L, Schmitt-Kopplin P, et al. Randomized controlled trial on the impact of early-life intervention with bifidobacteria on the healthy infant fecal microbiota and metabolome. Am J Clin Nutr 2017;106:1274–86.
31. Shealy KR, Scanlon KS, Labiner-Wolfe J, Fein SB, Grummer-Strawn LM. Characteristics of breastfeeding practices among US mothers. Pediatrics 2008;122:S50–5.
32. Nutrition Quest. Block questionnaire for ages 2-7—kids 2-7 FFQ; 2014 [Internet]. Available from: http://www.nutritionquest.com/assessment/list-of-questionnaires-and-screeners/. Accessed January 8, 2019.
33. Block G, Woods M, Potosky A, Clifford C. Validation of a self-administered diet history questionnaire using multiple diet records. J Clin Epidemiol 1990;43:1327–35.
34. Boucher B, Cotterchio M, Kreiger N, Nadalin V, Block T, Block G. Validity and reliability of the Block98 food-frequency questionnaire in a sample of Canadian women. Public Health Nutr 2006;9:84–93.
35. McHorney CA, Ware JE, Rogers W, Raczek AE, Lu JFR. The validity and relative precision of MOS Short- and Long- Form Health Status Scales and Dartmouth COOP charts: results from the Medical Outcomes Study. Med Care 1992;30:253s–65s.
36. McKenzie TL, Sallis JF, Rosengard P. Beyond the stucco tower: design, development, and dissemination of the SPARK physical education programs. Quest 2009;61:114–27.
37. Mindell JA, Meltzer LJ, Carskadon MA, Chervin RD. Developmental aspects of sleep hygiene: findings from the 2004 National Sleep Foundation *Sleep in America poll*. Sleep Med 2009;10:771–9.
38. Sadeh A. Sleep assessment methods. Monogr Soc Res Child Dev 2015;80:33–48.

39. Gartstein MA, Rothbart MK. Studying infant temperament via the Revised Infant Behavior Questionnaire. Infant Behav Dev 2003;26:64–86.
40. Gioia GA, Espy KA, Isquith PK. Behavior rating inventory of executive function—pre-school version. Lutz, FL: Psychological Assessment Resources, Inc.; 2003.
41. Lewinsohn PM, Denoma JM, Gau JM, Joiner TE, Striegel-Moore R, Bear P, Lamourex B. Problematic eating and feeding behaviors of 36-month-old children. Int J Eat Disord 2005;38:208–19.
42. Boquin M, Smith-Simpson S, Donovan SM, Lee SY. Mealtime behaviors and food consumption of perceived picky and nonpicky eaters through home use test. J Food Sci 2014;79:S2523–32.
43. Musher-Eizenman D, Holub S. Comprehensive feeding practices questionnaire: validation of a new measure of parental feeding practices. J Pediatr Psychol 2007;32:960–72.
44. Hughes SO, Power TG, Fisher JO, Mueller S, Nicklas TA. Revisiting a neglected construct: parenting styles in a child-feeding context. Appetite 2005;44:83–92.
45. Henderson JA, Jordan SS. Development and preliminary evaluation of the Bedtime Routines Questionnaire. Journal Psychopathol Behav Assess 2010;32:271–80.
46. Fiese BH, Kline CA. Development of the Family Ritual Questionnaire: initial reliability and validation studies. J Fam Psychol 1993;6:1–10.
47. Matheny A, Wachs TD, Ludwig J, Philips K. Bringing order out of chaos. J Appl Dev Psychol 1995;16:429–44.
48. Common Sense Media. Zero to eight: children's media use in America 2011 [Internet]. San Francisco, CA: Common Sense Media; 2011. Available from: http://www.commonsensemedia.org/research/zero-to-eight-childrens-media-use-in-america.
49. Barrera M, Caples H, Tein J. The psychological sense of economic hardship: measurement models, validity, and cross-ethnic equivalence for urban families. Am J Community Psychol 2001;29:493–517.
50. Adler NE, Boyce T, Chesney MA, Cohen S, Folkman S, Kahn RL, Syme SL. Socioeconomic status and health: the challenge of the gradient. Am Psychol 1994;49:15–24.
51. Bickel G, Nord M. Measuring food security in the United States: guide to measuring household food security. Rev 2000. Alexandria, VA: US Department of Agriculture, Food and Nutrition Services, Office of Analysis, Nutrition and Evaluation; 2000.
52. Bichteler A, Gershoff ET. Identification of children's BMI trajectories and prediction from weight gain in infancy. Pediatr Obes 2018;26:1050–6.
53. Linares J, Corvalan C, Galleguillos B, Kain J, Gonzalez L, Uay R, Garmendia ML, Mericq V. The effects of pre-pregnancy BMI and maternal factors on the timing of adiposity rebound in offspring. Obesity 2016;24:1313–19.
54. Zimmermann P, Curtis N. Factors influencing the intestinal microbiome during the first year of life. Pediatr Infect Dis J 2018;37:e315–35.
55. Centers for Disease Control and Prevention. Breastfeeding report card. United States, 2018 [Internet]. Atlanta, GA: CDC; 2018. Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.