Interventions for Childhood Obesity in the First 1,000 Days
A Systematic Review

Tiffany L. Blake-Lamb, MD, MSc,[1,2] Lindsey M. Locks, MPH,[3] Meghan E. Perkins, MPH,[4]
Jennifer A. Woo Baidal, MD, MPH,[4,5] Erika R. Cheng, PhD, MPA,[4]
Elsie M. Taveras, MD, MPH[3,4]

Context: The "first 1,000 days"—conception through age 24 months—are critical for the development and prevention of childhood obesity. This study systematically reviews existing and ongoing interventions during this period, identifies gaps in current research, and discusses conceptual frameworks and opportunities for future interventions.

Evidence acquisition: PubMed, Embase, Web of Science, and ClinicalTrials.gov were searched to identify completed and ongoing interventions implemented during pregnancy through age 24 months that aimed to prevent overweight/obesity between ages 6 months and 18 years. English-language, controlled interventions published between January 1, 1980 and December 12, 2014, were analyzed between December 13, 2014 and March 15, 2015.

Evidence synthesis: Of 34 completed studies from 26 unique identified interventions, nine were effective. Effective interventions focused on individual- or family-level behavior changes through home visits, individual counseling or group sessions in clinical settings, a combination of home and group visits in a community setting, and using hydrolyzed protein formula. Protein-enriched formula increased childhood obesity risk. Forty-seven ongoing interventions were identified. Across completed and ongoing interventions, the majority target individual- or family-level changes, many are conducted in clinical settings, and few target early-life systems and policies that may impact childhood obesity.

Conclusions: Obesity interventions may have the greatest preventive effect if begun early in life. Yet, few effective interventions in the first 1,000 days exist, and many target individual-level behaviors of parents and infants. Interventions that operate at systems levels and are grounded in salient conceptual frameworks hold promise for improving future models of early-life obesity prevention.
(Am J Prev Med 2016;50(6):780–789) © 2016 American Journal of Preventive Medicine. Published by Elsevier Inc. All rights reserved.

From the [1]Department of Obstetrics and Gynecology, Massachusetts General Hospital, Boston, Massachusetts; [2]Kraft Center for Community Health Leadership, Partners Healthcare, Boston, Massachusetts; [3]Department of Nutrition, Harvard T. H. Chan School of Public Health, Boston, Massachusetts; [4]Division of General Academic Pediatrics, Department of Pediatrics, Massachusetts General Hospital for Children, Boston, Massachusetts; and [5]Division of Pediatric Gastroenterology, Hepatology, and Nutrition, Department of Pediatrics, Columbia University Medical Center, New York City, New York

Address correspondence to: Elsie M. Taveras, MD, MPH, Division of General Academic Pediatrics, Department of Pediatrics, Massachusetts General Hospital for Children, 125 Nashua Street, 8th Floor, Boston MA 02114. E-mail: elsie.taveras@mgh.harvard.edu.

Context

Obesity prevalence has reached historically high levels, affecting 35% of the U.S. adult population and sparing no age group across the life course.[1] Recent estimates show 8.1% of U.S. children younger than age 2 years have weight-for-length ≥ 95th percentile and 17% of children aged 2–19 years already meet criteria for obesity.[2]

The first 1,000 days of life—conception through age 24 months—represent an important period for the development and thus prevention of childhood obesity. Mounting evidence indicates that influences during pregnancy and infancy may alter lifetime risk of obesity.[3–5] An accompanying review

of modifiable risk factors for childhood obesity occurring in the first 1,000 days indicates strong evidence for risk factors in pregnancy (e.g., higher maternal prepregnancy BMI, prenatal tobacco exposure, excess gestational weight gain) and infancy (e.g., high infant birth weight, accelerated infant weight-for-length gain), as well as a smaller number of studies implicating gestational diabetes, child care attendance, low strength of maternal–infant relationship, curtailed infant sleep, inappropriate bottle use, introduction of solid food intake before age 4 months, and infant antibiotic exposure.[5] Identification of effective early-life interventions targeting these modifiable factors is critical for obesity prevention.

In a 2011 Cochrane review of 55 interventions for preventing obesity in children from birth to age 18 years, 71% targeted children aged 6–12 years and 78% occurred in school settings.[6] Although more than half of the reviewed studies showed improvement in children's nutrition or physical activity status, fewer (22/55, 40%) demonstrated an effect on improving childhood weight status. Other reviews have focused on interventions in children aged 5 years and younger, but the number of trials is limited and few have been shown to be effective in preventing childhood obesity.[7–9] A more recent review of RCTs during pregnancy and the first 2 years of life to reduce risk of overweight or obesity identified 27 trials, many of which improved feeding and lifestyle practices but few that impacted child growth.[10]

The current study has three aims. First, to systematically review existing evidence from interventions occurring in the first 1,000 days that included prevention of childhood overweight or obesity as an outcome. Second, to examine the distribution of intervention levels and the settings in which completed and ongoing childhood obesity interventions have been and are currently being studied, including identification of research gaps. Last, to discuss conceptual frameworks and intervention models that may inform and enhance the development of future interventions to prevent childhood obesity.

Evidence Acquisition

Search Strategy and Data Extraction

The methods are based on standards outlined by IOM and the Patient-Centered Outcomes Research Institute.[11,12] Included studies were published between January 1, 1980 and December 12, 2014, and analyzed between December 13, 2014 and March 15, 2015. PubMed, Embase, and Web of Science were searched for childhood obesity risk factors and interventions implemented during the first 1,000 days, as detailed in Woo et al.[5] From this larger review, any interventions that included prevention of childhood overweight or obesity as an outcome were identified and form the basis of the current review. To identify ongoing interventions, ClinicalTrials.gov was searched on March 2, 2015,

for nondrug, interventional trials with outcomes that included the terms *child* or *infant* or *childhood*, and *overweight* or *obese* or *obesity* or *weight*. Databases were then searched for any publications that have already resulted from the ongoing trials. Additionally, systematic reviews published in the past 3 years were examined and additional identified articles were reviewed for inclusion.

English-language studies were included if they had:

1. intervention designs that included a control group;
2. interventions implemented between conception and age 24 months; and
3. measures of childhood overweight or obesity as outcomes including weight-for-length, BMI, or age- and sex-specific BMI ≥85th percentile collected between age 6 months and 18 years.

Outcomes prior to age 6 months were excluded in order to focus on child weight status independent of birth weight. Studies in which growth measures were obtained only to assess safety of the intervention were excluded.

An initial screen of studies based on title and abstract was independently performed by all authors. Based on the initial screen, two authors independently reviewed full-text articles for inclusion based on eligibility criteria. If two authors did not agree, the senior author (EMT) reviewed the study to determine whether it should be included for full review. Data were extracted from full-text articles using a structured form. Methodologic quality of the completed interventions was assessed using established criteria developed by the Joanna Briggs Institute's Meta-Analysis of Statistics Assessment and Review Instrument critical appraisal checklist.[13] The criteria included an assessment of randomization, blinding, participant allocation concealment, equipoise at baseline across intervention arms, statistical analyses, valid and reliable outcome measurements, and attrition. Key findings were summarized qualitatively.

All completed and ongoing interventions that met inclusion criteria were classified according to the level of intervention (biological, individual, family, systems) and the setting (clinical, home, community, combination) in which the intervention takes place.

Evidence Synthesis

Completed Interventions

In the broader search of risk factors and interventions, 5,952 articles were identified. After screening and full-text review, a total of 34 published articles representing 26 unique interventions met criteria for inclusion and form the basis of the results (Appendix Figure 1, available online). The design, setting, level of intervention, and outcomes of these trials are summarized in Appendix Table 1 (available online). Nine of the 26 interventions demonstrated improvement in childhood weight status. Family-based interventions and those conducted in the home setting appear most effective, but results should be interpreted conservatively, given the small number of studies conducted at each level and setting (Figure 1).

Interventions During Pregnancy

Two prenatal interventions were included; both were clinic-based and neither demonstrated an effect on offspring weight status. The Lifestyle in Pregnancy and Offspring intervention included dietary advice, coaching, and exercise for women during pregnancy. At approximately 3 years of age, BMI z-score of offspring was not substantially different from that of children in the control group.[14] In the Australian Carbohydrate Intolerance Study in Pregnant Women, offspring of women who were treated for mild gestational diabetes during pregnancy did not have improved BMI at age 4−5 years compared to the offspring of those who were untreated.[15]

## Interventions Starting in Pregnancy and Continuing After Birth

Six interventions began in pregnancy and continued into infancy. The Promotion of Breastfeeding Intervention Trial, a cluster RCT involving 31 clinical sites in Belarus, studied a systems-level implementation of hospital policies and practices to promote breastfeeding based on the "Baby-Friendly Hospital Initiative" developed by WHO and the UN Children's Fund.[16] The intervention resulted in significantly improved breastfeeding rates at 3 months postpartum (43.3% vs 6.4%, $p < 0.001$); however, at ages 6.5 years and 11.5 years, there were no differences in child BMI or other anthropometric measures.[17,18] The Vaasa Childhood Obesity Primary Prevention Study provided education on maternal and child diet and physical activity at prenatal visits, group sessions, and well-child visits, but did not demonstrate an effect on child growth measures through age 12 months.[19]

Two interventions that utilized home visiting were found to be effective in improving child BMI. In the Healthy Beginnings trial, eight educational home visits focusing on infant diet, feeding, and activity were conducted by community nurses prenatally through age 24 months.[20] At 24 months, intervention children had a BMI that was 0.29 kg/m^2 lower than those in the control group ($p=0.04$). Another intervention in which community health workers provided education around maternal diet and infant feeding practices at a combination of home and group visits successfully reduced child BMI z-score by 0.31 ($p=0.001$) and reduced risk of overweight by 57% ($p=0.005$) at 13−24 months.[21]

Two interventions examined the effect of dietary supplements. The Impact of Nutritional Fatty Acids During Pregnancy and Lactation for Early Human Adipose Tissue Development (INFAT) trial of fatty acid supplementation from 15 weeks gestation to 4 months postpartum did not show a difference in offspring fat mass at age 12 months.[22,23] A Finnish trial of a Lactobacillus supplement for 4 weeks prior to delivery through 6 months after delivery did not demonstrate a difference in BMI, overweight, or obesity status between offspring through 10 years of follow-up.[24]

Interventions Starting After Birth

Eighteen interventions occurred between birth and age 24 months. Two interventions examined the effect of fish oil supplementation. One trial randomized women to receive fish oil supplementation during the first 4 months of lactation and found no difference between groups in child BMI at 9 months[25] or 7 years[26]; however, the fish oil group had a higher mean BMI (0.81 [SD=0.28], $p=0.006$) at 2.5 years.[25] A second trial randomized
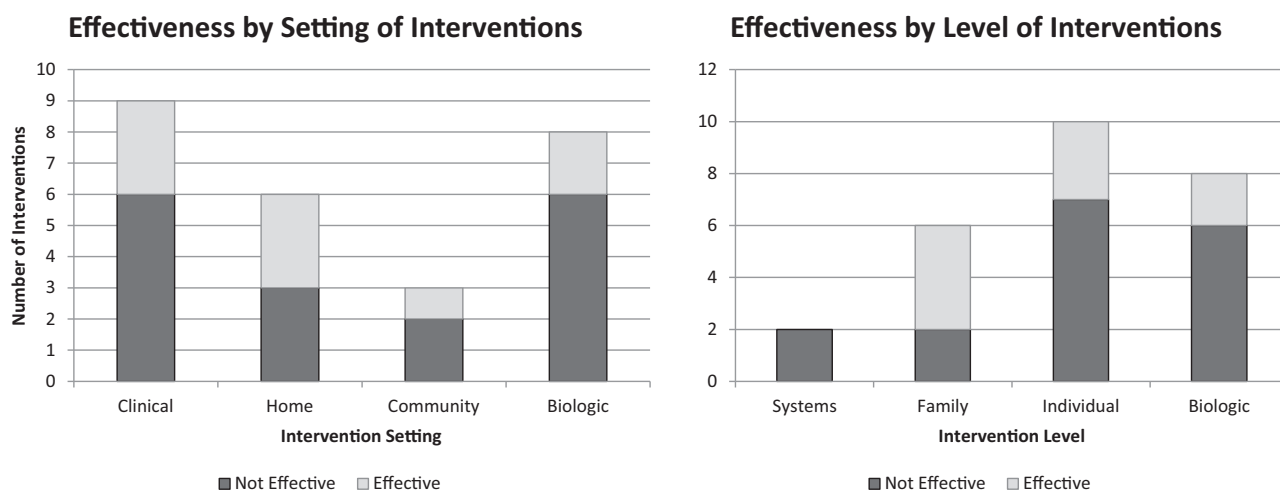
Figure 1. Effectiveness by setting and level of obesity-prevention interventions in the first 1,000 days.

9-month-old infants to receive daily fish oil supplementation but did not demonstrate a difference in BMI z-score at age 18 months.[27]

Four infant-formula trials showed opposing results, with hydrolyzed protein formulas (hypothesized to promote greater infant satiety) stemming early childhood growth and enriched formulas promoting childhood obesity (Appendix Table 1, available online).[28–33] As shown in Appendix Table 1 (available online), interventions using high-protein formula[28,31] and nutrient-enriched formula[32] resulted in higher risk of obesity at age 6 years and higher fat mass at age 5–8 years, respectively.

Three of five clinic-based interventions in infancy reduced childhood weight or BMI status. One intervention targeting mothers' physical activity and diet during the first year of the infant's life resulted in a slower rise in child BMI z-score between ages 2 and 4 years compared with controls, although effect sizes were small (−0.034 to −0.002, p=0.028).[34] In another, the Special Turku Coronary Risk Factor Intervention Project for Children (STRIP) trial, behavioral counseling on diet and physical activity was directed at the entire family and continued intermittently from age 7 months to 10 years. STRIP demonstrated a lower prevalence of overweight among daughters at age 10 years (10.2% vs 18.8% in controls, p=0.04), but not among sons.[35] Third, the positive feeding practices and food preferences in an early childhood (NOURISH) trial in Australia used a cognitive behavioral approach and focused on parenting practices that mediate children's early feeding experiences during two 3-month group education sessions. At age 13–15 months, children in the intervention group had lower BMI z-scores compared with the control group (0.23 vs 0.42; p=0.009)[36]; however, this was not sustained at age 2 years.[37] Two clinic-based interventions—one focused on parenting practices to improve infant sleep[38] and one providing anticipatory guidance around either maternal or infant diet[39]—did not find an effect on childhood weight status.

Four infancy interventions included a home-visiting component; however, only one demonstrated a significant effect. The Sleeping and Intake Methods Taught to Infants and Mothers Early in Life trial randomized mothers to receive either, both, or neither of "soothe/sleep" and "introduction of solid foods" curriculums delivered by nurses during two home visits. Infants of mothers receiving both curriculums, but not those receiving only one curriculum, demonstrated a lower weight-for-length at age 12 months compared with the control group.[40] Another home-based intervention using indigenous peer educators to deliver a 16-week program for improving parenting skills around infant feeding and activity in a Native American community showed a trend toward decreasing BMI z-scores up to age 3 years, but was limited by a small sample size.[41] Two additional interventions assisting mothers to improve infant feeding practices did not demonstrate an effect of offspring overweight status at age 4–5 years[42] or age 7–8 years.[43]

One of three community-based interventions during infancy showed an effect on weight status. The study utilized child daycare centers to promote healthy food choices and increase physical activity among families of children aged 9–24 months.[44] During the year-long intervention, the infants' mean BMI z-score decreased in both the intervention and control daycare centers but decreased more in those implementing the intervention (p≤0.05). Another intervention based in the Supplemental Nutrition Program for Women, Infants, and Children (WIC) that focused on bottle weaning did not impact risk of overweight at age 2 years.[45] In the Melbourne Infant Feeding, Activity, and Nutrition Trial, first-time parents participating in community-based parenting groups led by a nutritionist did not alter child BMI z-scores.[46,47]

Quality of Completed Intervention Study Designs

The study quality of completed interventions was generally suboptimal, with only two trials—the NOURISH trial[36] and the German Infant Nutritional Intervention study[29]—meeting all quality criteria. Two other trials met nine of ten criteria for high-quality interventions: In the Promotion of Breastfeeding Intervention Trial,[18] the pediatricians performing outcome measurements were not able to be blinded to participant randomization status, and a hydrolyzed protein formula trial[33] used complete case analysis rather than intention to treat. Details of randomization were included in all 26 interventions. Nine of the interventions had allocation concealed to participants[24,26–29,32,33,36,39] and in 16 interventions, participant allocation was concealed to researchers and data collection was blinded.[15,20,23,24,26–29,32–34,36,38,39,42,43] The remaining trials inadequately reported allocation concealment or were not able to conduct study blinding. Of the 34 published follow-up studies from the 26 trials, one-quarter had dropout rates that were <20% at follow-up points.[17,18,27,29,33,36,41,46,47] Retention rates for the remaining studies ranged from 44% to 78% at follow-up. Thirteen follow-up studies used intention-to-treat analyses.[14,17,18,20,29,32,36–38,43,45–47]

Ongoing Interventions

Forty-seven ongoing trials testing interventions occurring in the first 1,000 days and with plans to monitor child obesity outcomes between age 6 months and 18 years were identified. Appendix Table 2 (available online) provides a

summary of each study design and sample, the intervention setting and level, and the planned duration of child follow-up. Of the 47 ongoing trials, 23 are based in clinical settings, 40 are focusing on individual- or family-level behaviors of mothers or infants, three are systems-based, and four are maternal or infant supplement trials.

Intervention Levels, Settings, and Current Research Gaps

Figure 2 illustrates the distribution of completed and ongoing trials by the level and setting of intervention. Across both completed and ongoing interventions, the majority target individual-level biological and behavioral factors of mothers and infants and many are being conducted in clinical settings. Forthcoming intervention studies focus less on dietary supplementation than do currently published studies, while there has been a surge among the ongoing trials in individual-oriented, clinically based intervention designs. Systems-level interventions and those utilizing community-based settings to interface with families in the first 1,000 days are under-represented amid both the completed and ongoing studies.

Discussion

In this systematic review of interventions occurring in the first 1,000 days that aimed to prevent childhood obesity, 26 completed interventions and 47 ongoing interventions were identified. Of the completed interventions, seven demonstrated a beneficial effect on children's growth status using interventions focusing on individual- or family-level behavior changes through counseling provided within a clinical setting, at home

visits, in the community, or using a combination of home and group visits; two interventions using hydrolyzed protein formula curtailed infant growth, whereas enriched formulas increased risk of childhood obesity. Only two of the published interventions met all criteria for high-quality study design.

The finding of only a small number of effective early-life interventions for childhood obesity prevention is not uncommon. Prior reviews of interventions in the first years of life have also revealed small numbers of published studies, most of which employ suboptimal study designs and demonstrate minimal or no impact on child growth measures.[6–8,10] Among evidence-based modifiable risk factors for childhood obesity prevention in the first 1,000 days identified in the current authors' literature review, higher maternal prepregnancy BMI, prenatal tobacco exposure, SES, and infant antibiotic exposure are not addressed by any published or forthcoming intervention studies in the current review.[5]

Conceptual Frameworks and Intervention Models

Interventions that are explicitly grounded in a sound theoretic framework and that adequately attend to social context can substantially increase the likelihood that an intervention will be effective.[48] However, in a prior review of early-life obesity prevention interventions, Bluford et al.[7] noted that less than half of interventions utilize a theoretic framework to guide their work. In the current review, only one completed intervention explicitly referenced a conceptual model for child growth—notably, this intervention resulted in decreased odds of child overweight[21]—while four studies alluded to a life-course conceptual framework for obesity,[26,32,33,40] and six
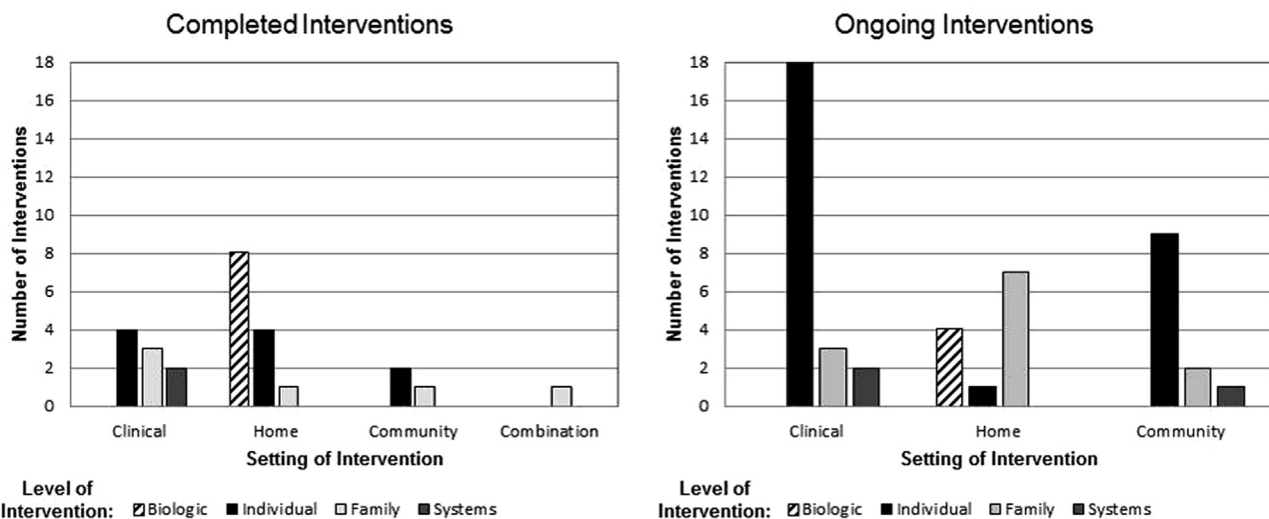

Figure 2. Distribution of completed and ongoing obesity-prevention interventions in the first 1,000 days by intervention level and setting.

studies reported that a model or theory guided the intervention design[20,21,35,36,44,46] (Appendix Table 1, available online). The following is a discussion of how conceptual frameworks could be utilized to optimize prevention of childhood obesity in the first 1,000 days, as well as consideration of intervention models that can appropriately complement the chosen conceptual framework.

A life-course conceptual framework intuitively lends itself to describing early-life obesity risk with the notion of "critical periods" during which adverse exposures can result in lifelong deleterious health effects.[49] For example, the idea that in utero exposures may "program" the developing fetal biology such that the offspring has an altered risk of obesity in later life[50,51] underlies childhood obesity prevention interventions that target mothers during pregnancy, such as the Australian Carbohydrate Intolerance Study in Pregnant Women,[15] Lifestyle in Pregnancy and Offspring,[14] and INFAT[22,23] trials. This framework additionally describes "chains of risk"—the accumulation of risk factors over the life course—that would argue for repeated risk-reducing interventions over time, such as the STRIP trial, in which diet and exercise counseling were provided to families intermittently during a 10-year span.[35]

An ecosocial conceptual framework offers the concept of "embodiment" to represent pathways through which the natural environment (eco) and the structure of society (social) are incorporated into biology (embodied) to become determinants of population health.[52] An ecosocial framework for obesity would highlight the risk factors within and among various social levels and sectors that influence population-level behavioral patterns and would suggest that interventions targeting these existing pathways of embodiment are necessary to reduce the prevalence of and disparities in obesity. The concept that social context influences health motivates studies, such as the Finnish RCT that intervened on mothers' health behaviors during the infants' first year of life and resulted in a slower rise in child BMI between ages 2 and 4 years.[34]

Glass and McAtee[53] propose a conceptual framework that combines the tenets of life-course and ecosocial theories into a graphical metaphor that describes an individual's life course as a stream of water on a horizontal axis with a vertical axis comprised of three levels. There is an "underwater" level of biological/physiologic factors, a "waterline" that represents individual behavior, and an "above water" level that is subdivided into micro and macro influences, which in turn shape the factors at the "underwater" and "waterline" levels. Applying this framework to childhood obesity prevention highlights the focus to date on interventions targeting the "underwater" level (e.g., dietary supplements) and "waterline" level (e.g., dietary and physical activity behaviors), and as such reveals opportunities for future interventions in the "above water" sphere (e.g., built environment, fast food chains) as described in Woo and colleagues.[5]

The traditional clinical model of prenatal care and well-child visits offers a venue for interventions targeting individual-level health behaviors for mother—infant dyads—as seen in seven of the nine clinical-based interventions identified in the current review.[14,19,34–36,38,39] However, behavior change counseling provided in the clinical setting is necessarily limited in its impact on individual and family lifestyles by manifold nonmedical, but health-critical, influences from the social and physical environment—factors that are highlighted by the ecosocial[52] and Glass and McAtee[53] conceptual frameworks discussed here.

Alternatively, linking clinical care with community and public health resources is supported by the chronic care model.[54] Chronic care model innovations include case-management services, community partnerships, and advocacy for policies that impact the healthcare delivery system, which, in combination, have been found to be effective at improving clinical measures around chronic disease.[55] Elements similar to those utilized in the chronic care model were implemented in several interventions that engaged community and public health programs, such as child care centers,[44] parenting groups,[46] and WIC,[45] to influence families outside of the traditional clinical setting.

Finally, the collective impact model, a population-level intervention model, encourages multi-level and cross-sector collaborations to create multiple, integrated, and mutually reinforcing interventions organized through a backbone support organization.[56] The collective impact model has been used effectively in systems change programs outside of health care and has potential to aid in addressing the obesity epidemic.[57] The strength of a collective impact intervention model lies in its ability to target multiple obesity risk factors simultaneously using systems change across multiple sectors and settings. Figure 3 proposes how the collective impact model could be applied to obesity prevention in the first 1,000 days by bringing together otherwise disparate sectors across multiple levels of social organization and implementing simultaneous systems-level interventions that are coordinated in their impact on modifiable risk factors for childhood obesity.[5] As examples, training and educational materials about healthy lifestyles can be standardized across clinical care, WIC, and home-visiting programs; child care facilities and community centers can be engaged to promote healthy practices around infant feeding and activity; and partnerships can be created with worksites to encourage maternal smoking cessation and support physical activity for women before and during pregnancy. The collective impact model allows for this variety of
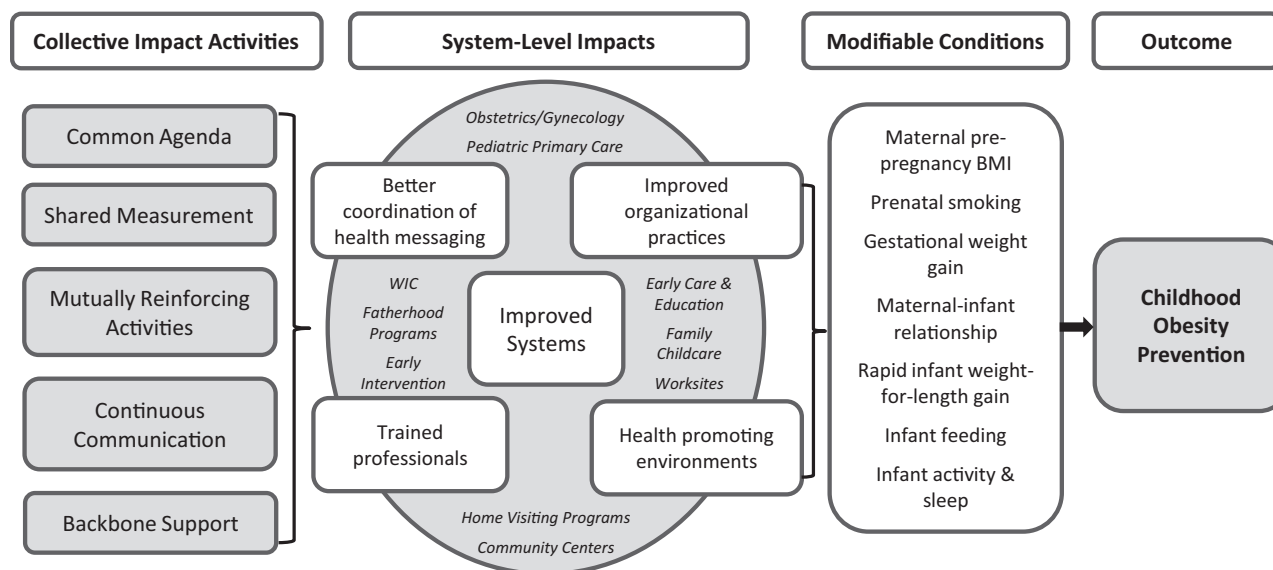
Figure 3. A collective impact model for designing systems-change obesity interventions in the first 1,000 days.
Note: WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

wide-reaching interventions to operate in parallel and synergistically, as well as potentially expand to partner with industry and to influence local, state, and national policies to promote healthy environments and tackle "above water" structural influences.

Limitations

The strengths of the current review include a broad search of academic databases and clinical trial registrations. Given the restriction of the review to interventions during pregnancy and the first 2 years of life, the results provide what limited evidence exists for obesity prevention efforts in the earliest life periods. Summarizing identified studies by intervention level and setting (Figure 2) highlights where research efforts have been concentrated to date and where gaps persist.

Nearly all of the completed interventions identified by the current search were RCTs, which minimize confounding factors but may limit generalizability. Other intervention study designs may have been missed owing to publication bias. Some intervention studies may have been missed if the results were not published in English or if child overweight or obesity was not explicitly stated as an outcome of interest; indeed, all seven included studies that were missed in the original search lacked PubMed Medical Subject Headings pertaining to childhood growth measures. By default, the search for ongoing interventions through ClinicalTrials.gov identified controlled trials only.

There are two potential limitations of the review findings. First, the majority of included studies utilized BMI or an equivalent outcome rather than, or in addition

to, prevalence of overweight or obesity, with seven of the nine successful interventions showing a decrease in BMI or weight-for-length only and two interventions demonstrating a decrease in proportion of overweight.[21,35] However, though none of the interventions demonstrated reduced obesity prevalence, a downward shift in BMI within the study population may translate to prevention of obesity if upscaled to larger populations. Second, there is a wide range in follow-up duration—most of the effective interventions measured proximal outcomes, and several of those that had later follow-up did not demonstrate sustained effects, likely indicating dilution by future influences.

Conclusions

The intractability of the obesity epidemic lies in the complexity of its risk profile, with an interplay of biological and social susceptibilities across population groups, environments, and the life course. In early life, most current intervention designs are limited to a focus on individual-level diet and activity behaviors, rather than trying to impact the social context that gives rise to these behaviors and upstream influences on obesity, such as government policies (e.g., food subsidies) and private-sector practices (e.g., fast-food marketing).

Future early-life intervention designs for prevention of obesity will need to concurrently address multiple obesity risk factors across several levels of influence and a variety of social sectors, guided by an appropriate conceptual framework. The collective impact model is one potential example of how to accomplish such a complex intervention design.

Novel intervention designs, such as policy changes and private-sector collaborations, may not be amenable to randomization and blinding, but instead may necessitate quasi-experimental designs. As such, research quality measures traditionally applied to RCTs will likely be less useful, in turn, emphasizing the importance that intervention designs be grounded in a sound conceptual framework as well as the need for rigorous evaluation of intervention impact.[58]

Current evidence supports the use of a systems-level approach to obesity prevention in pregnancy and early life.[59] IOM and NIH have identified a priority for obesity prevention interventions to be conducted at systems and policy levels.[60,61] Additionally, the WHO Commission on Ending Childhood Obesity has called for low- and high-income countries to develop multi-sector approaches to reducing childhood obesity across the life course and emphasizes that preconception, pregnancy, and early life are critical periods for prevention.[62] The challenge now is to create population-level obesity prevention interventions that are cost effective and sustainable.[58,63] Novel approaches will be critical to the prevention of obesity in the first 1,000 days.

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Appendix

Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2015.11.010.