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# The Role of Maternal Social Networks on the Outcomes of a Home-Based Childhood Obesity Prevention Pilot Intervention*

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## Abstract

**Background**. Despite evidence that obesity and related behaviors are influenced by social networks and social systems, few childhood obesity initiatives have focused on social network factors as moderators of intervention outcomes, or targets for intervention strategies. **Objectives**. This pilot study examines associations between maternal social network characteristics hypothesized to influence health behaviors and the target outcomes of a family-centered childhood obesity prevention initiative. The pilot intervention entailed the provision of healthy eating and activity components as part of an existing home visiting program (HVP) delivered to mothers and infants, to test the feasibility of this approach for improving mother diet, physical activity, and weight status, as well as infant diet and weight trajectory. **Methods**. Mothers and their infants (N=50 dyads) receiving services from our HVP partner were recruited and randomized to receive the HVP core curriculum with or without a nutrition and physical activity enhancement module for six

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months. Assessments of mothers' social network characteristics, mother/infant food intake and mother physical activity, and mothers' postpartum weight retention and children's growth velocity were conducted at baseline and post-intervention. **Results**. Several features of mothers' social networks, including the receipt of health-related social support, were significantly associated with the focal intervention outcomes ($p < .05$) at follow-up, controlling for study condition. **Conclusions**. Integrating childhood obesity prevention into HVPs appears promising. Future family-based interventions to prevent childhood obesity may be enhanced by including social network intervention strategies. For example, by addressing family network characteristics that impede healthy behavior change, or enhancing networks by fostering social support for healthy behavior and weight change.

**Keywords:** childhood obesity prevention; social networks; social support; Home Visiting Program; maternal and infant health

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# Introduction

Obesity is difficult to treat, and trajectories for biological and behavioral risk factors for excess weight are established early in life (Astrup, Dyerberg, Selleck, & Stender, 2008; Birch & Davison, 2001). The stability of obesity across the lifespan, and the physical, psychosocial and financial costs related to obesity for the individual and the larger society (Finkelstein & Bilger, 2012; Finkelstein, Graham, & Malhotra, 2014; Gooze, Hughes, Finkelstein, & Whitaker, 2012; Hoelscher et al., 2015) stress the importance of correcting weight trajectories in early childhood, before children become overweight or obese (Blake-Lamb et al., 2016; Taveras, 2016). In the United States (U.S.), children from low-income families and families of color (in particular, Hispanic and African American) are at the highest risk for developing overweight, and prevention efforts in the past decades have failed to address these disparities (Ogden et al., 2016). Childhood obesity prevention needs to target broad and multilevel mechanisms that extend beyond the parent-child context to other socioecological domains, such as extended family and community social contexts, and neighborhood environments (Campbell, 2015; Skinner & Foster, 2013). Initiating and maintaining healthy habits is difficult, especially for families that face a multitude of barriers, such as poverty, housing instability, food insecurity, and a lack of access to linguistically and culturally competent services (Flynn et al., 2006). Reducing risk factors and increasing protective factors in at-risk underserved families' *social* and *physical environments* may be critical for enabling long-term behavior change that would reduce childhood obesity and obesity inequities.

Few effective interventions to prevent obesity in early childhood exist, and existing programs typically focus on altering the behavior of a parent and/or child (Blake-Lamb et al., 2016). Parent weight and related health behaviors are important predictors of child weight and behaviors (Davison, Francis, & Birch, 2005; Wrotniak, Epstein, Paluch, & Roemmich, 2004), contributing to the intergenerational transmission of obesity risk. Family-centered obesity interventions, which target children and their parent(s), have proven more effective than interventions targeting children alone (Epstein, Paluch, Roemmich, & Beecher, 2007; Epstein, Valoski, Wing, & McCurley, 1994). However, families are themselves embedded in social networks and communities that can also influence family members' health behaviors. For example, multigenerational family members often share similar eating and physical activity behaviors (e.g., Munsch et al., 2007; Sallis, Patterson, Buono, Atkins, & Nader, 1988); and other relationships, such as friends and neighbors, can influence weight and related behaviors (Pachucki, Jacques, & Christakis, 2011; Salvy, Feda, Epstein, & Roemmich, 2017; Salvy, Feda, Epstein, & Roemmich, 2016; Zhang, de la Haye, Ji, & An, 2018). Broader social network influences on families' obesity and health behaviors operate through a complex set of interpersonal and socio-structural mechanisms, which include social influence, social support, and social capital (Ashida et al., 2011; Ashida, Wilkinson, & Koehly, 2012; Bauer, Neumark-Sztainer, Fulkerson, Hannan, & Story, 2011; Bauer, Laska, Fulkerson, & Neumark-Sztainer, 2011; Gorin et al., 2008). These social factors can promote or impede behavior change and intervention outcomes (Valente, 2010, 2012) and ultimately play an important role in family-based efforts to prevent obesity in early childhood.

# Home/Family-based Childhood Obesity Prevention

The current study draws on social influence and social network theories to identify features of family social networks that support or hinder the outcomes of a novel early childhood obesity prevention

program. This intervention, described in greater detail in Salvy, de la Haye, Galama, & Goran (2017) and de la Haye et al. (2018), involves the delivery of early childhood obesity prevention as part of the services provided by our home visiting program (HVP) partner. Annually, over 500 publicly and privately funded HVPs provide services to more than 650,000 low-income, underserved children and their families in the United States (U.S. Department of Health and Human Services, 2015). HVPs identify families pre-partum based on risk factors for poor child outcomes (e.g., low-income), and provide in-home services by trained home visitors for the first two to three years of the child's life. HVPs are successful in addressing maternal and infant psychosocial and physical health (Fergusson, Grant, Horwood, & Ridder, 2006; Gonzalez & MacMillan, 2008; Matone, O'Reilly, Luan, Localio, & Rubin, 2012), but they have not yet targeted obesity, or comprehensively addressed maternal and infant nutrition and physical activity. In response to this gap and pressing need for programs that reach at-risk populations to prevent childhood obesity in the first years of life, our team has developed a culturally-tailored curriculum to promote healthy eating and activity habits that can be incorporated into existing HVPs. The in-home delivery of obesity prevention makes it possible to guide parents as they implement changes in their family, home, and community, and address ecologically-relevant barriers to the formation of healthy eating and activity habits. The goal of the program is to promote a healthy weight in mothers and children, and healthy eating (increased fruit and vegetables; decreased sugar-sweetened beverages) and activity (increased steps) in mothers, to reduce children's obesity risk.

# Social Network Influences on Family Health Behavior Change and Child Obesity Risk

Children and adults are likely to have social connections whose risk for overweight is similar to their own (Christakis & Fowler, 2007; Koehly & Loscalzo, 2009; Zhang et al., 2018). This occurs in part because of social selection based on homophily and propinquity, whereby people are likely to establish social connections to others who share similar genetics (family), characteristics (e.g., demographics), and beliefs (McPherson, Smith-Lovin, & Cook, 2001). Similarity in weight status among social connections also occurs because obese individuals are socially marginalized, and in response are more likely to become socially connected to one another (Brewis, 2014; de la Haye, Robins, Mohr, & Wilson, 2011). In addition to these social selection processes, there is evidence that individuals' diet, activity, and weight status are *influenced by* their social connections and the characteristics of their social networks; and that obesity 'diffuses' through networks such that an individuals' risk for excess weight is greater when their social connections are obese (Zhang et al., 2018). Obesity appears to be influenced by our social networks because of multiple social functions that may or may not be provided by our social connections:

(a) *social support*, whereby social contacts provide various types of social support, such as informational support or encouragement, which can facilitate the adoption of healthy behaviors (Berkman, 2000; Thoits, 2011);

(b) *social influence* on beliefs about what constitutes a healthy weight (and thus weight management), and on eating and activity behaviors, through social learning, normative influence, and more automated processes such as imitation and mimicry (Salvy, de la Haye, Bowker, & Hermans, 2012); and

(c) *barriers* to healthy behavior change, whereby some social connections may be viewed as active barriers to adopting particular health behaviors or achieving health outcomes.

In sum, children and families with the highest risk for overweight and obesity are likely to be socially connected to others who are also at a higher risk for obesity, and these social environments can exert influences that are a barrier to healthy behavior change. Indeed, one study examining the influence of social networks on weight loss among Black and Hispanic adults who were overweight and enrolled in a weight loss trial, found that having obese network members who lived in the participants' home predicted weight gain, while support from children and coworkers predicted greater weight loss (Winston et al., 2015). Obesity prevention initiatives that identify social network influences on family behavior change, and then explicitly target families' social networks to either bolster relationships that provide positive influences, or alter connections that are barriers to change, have the potential to improve intervention adoption and effectiveness (Gest, Osgood, Feinberg, Bierman, & Moody, 2011; Valente, 2012). Close social connections that play a role in families' day-to-day lives will be particularly important to engage, as these social ties are key sources of support and social influence on obesity-related behaviors. Eating and physical activity are daily, habitual behaviors driven more by contextual and environmental cues (including social cues), than by exposure to information or individuals' beliefs (Gardner, 2015). Therefore, weak social ties, such as online acquaintances, may have minimal impact on promoting long-term changes to healthy eating and activity. Although online social connections may effectively diffuse information or influence simple health decisions or behaviors (e.g., Centola, 2010), a recent meta-analysis found limited evidence that online social network interventions lead to sustainable or meaningful change in key modifiable health behaviors including dietary intake and physical activity (Maher, Lewis, Ferrar, Marshall, De Bourdeaudhuij, & Vandelanotte, 2014).

Given the clustering of obesity risk in social networks and the need to engage close social ties, interventions that target *communal coping processes* are promising (Lyons, Mickelson, Sullivan, & Coyne, 1998), whereby health risks (e.g., obesity) are recognized as a *shared risk* by a social group, and this elicits interpersonal communication, support, and co-engagement in risk-reducing behaviors within the group. Family-centered interventions that have adopted a communal coping approach were found to be effective at increasing the density of health communication, encouragement, and health behavior co-engagement within family social networks, and these network changes were ultimately a mediating mechanism in healthy behavior change (Ashida et al., 2012; Koehly et al., 2011). Overall, social network intervention strategies have proven successful in other areas of public health (Valente, 2010), but to date have been underutilized in obesity prevention despite evidence that they are promising and needed.

# Study Aims

This pilot study examines whether characteristics of mothers' social networks are associated with the primary targets of a childhood obesity prevention initiative: namely, mother diet, physical activity, weight status, as well as infant diet and weight trajectory. Specifically, the aims were to identify how the following social network characteristics, which represent social functions that can support or interfere with behavior change, were associated with intervention targets: (a) sources of health-relevant social support, including informational support and encouragement, where we

expect that greater density of support relationships bolsters healthy behavior change; (b) co-engagement in dietary and activity behavior with social ties, which may provide key opportunities for social influence and communal coping; and (c) the presence of relationships that are perceived as barriers to health behavior change. A secondary aim is to explore whether the composition of mothers' social networks, based on the characteristics of network members (such as gender, social roles, frequency of contact), is associated with intervention outcomes.

# Methods

### *Participants and Procedure*

Mothers and infants who were receiving home visiting services from our HVP partner in Antelope Valley, CA, were recruited and invited to participate in the study. Mothers were enrolled in the existing HVP by our community partner via outreach and screening pre-partum at community health centers and hospitals. For mothers to be eligible to receive the existing HVP, they must meet a number of risk criteria (e.g., low-income, housing instability), and they begin receiving the program after the child's birth. Mothers and their infants were invited to participate in the study if they were actively receiving HVP services, and were excluded if they had current psychopathology or developmental disability; and/or if they were on medications or had conditions that could influence their mobility or their activity level. A total of 56 families were contacted for the study and 50 agreed to participate. Mothers provided informed consent in English or Spanish for their participation and their child's participation. Assessments of mothers' and children's anthropometrics, maternal and child diet, and maternal physical activity were conducted at baseline and after receiving six months of services. All study procedures were approved by the University of Southern California institutional review board.

### *Intervention*

Home visitors at our HVP partner were randomly assigned to deliver the standard HVP curriculum with (intervention) or without (control) obesity prevention components as part of their weekly home visits for six months. Home visitors delivering the obesity prevention components received a two-day training by the primary investigators (see Salvy et al., 2017, for description of the training).

### *Control arm (standard HVP care)*

Our partner HVP, located in Antelope Valley, CA, is one of 400 nationwide *Healthy Families America* sites. The Healthy Families America model meets the U.S. Department of Health and Human Services criteria for an "evidence-based early childhood home visiting service delivery model" (See http://homvee.acf.hhs.gov). Their services begin prenatally and continue until children are 2 to 5 years old, depending on the HVP model. The curriculum is delivered by trained and accredited home visitors, who are matched to the mother/infant based on their ethnicity/race and language preferences to provide culturally sensitive services. Home visitors deliver the program to families during weekly (typically) visits to the home. The content focuses on strengthening parent-child relationships and family functioning, promoting positive child development, and linkage to community resources (e.g., medical providers, financial/housing assistance, childcare, substance abuse treatment, community programs).

### *Intervention arm*

The obesity prevention program is a culturally sensitive model to deliver evidence-based nutrition and activity components and behavioral strategies to at-risk families as part of existing HVP services, with the goal of preventing childhood obesity. Home visitors implementing the program are trained to gradually deliver the curriculum content during home visits, building healthier nutrition and lifestyle activity goals congruent to the families' preferences and cultural practices. Consistent with other family-based healthy lifestyle interventions (Birch & Doub, 2014; Institute of Medicine, 2011), nutrition goals include increasing intake of vegetables and fruits and limiting intake of high-saturated fat (for adults and children eating solid foods), eliminating intake of sugar-sweetened beverages and juice, and learning healthy portion sizes. The curriculum builds upon existing HVP material to promote sustained breastfeeding for the first two years and the gradual integration of complementary feeding that supports healthy eating for infants. Mothers also learn about feeding/eating developmental stages and transitions and healthy feeding practices.

Our program is also premised on accepted physical activity guidelines for children and adults, including specific recommendations for young children under the age of two (i.e., daily planned physical activities such as tummy time; 30 minutes of supervised unstructured physical activity; avoiding being sedentary for more than 60 minutes at a time; and limited screen time) (Barlow, 2007), and CDC guidelines for adults (e.g., 150 minutes of moderate intensity physical activity/week). Parents are taught to make activity and play a daily habit for their entire family by exploiting lifestyle activities (e.g., taking the stairs, walking to the shop). Home visitors help parents design activities around their local environment, schedule, and preferences, and suggest how to optimize their use of safe community spaces. The curriculum emphasizes the importance of parents co-engaging in activities with their children to set a good example through modeling and to provide opportunities for their children to be physically active.

### *Measures*

Baseline and post-intervention (six-month) assessments were conducted by home visitors who were trained by the study team to collect the survey and anthropometric data.

### *Maternal social networks*

Mothers' social networks were assessed using egocentric social network methods that capture subjective information about the social connections that surround mothers, and their perceptions of these contacts and relationships (Crossley et al., 2015). To measure mothers' close ties, a name generator was used (Crossley et al., 2015; McCarty, 2002), in which participants were asked to identify six adults whom they considered to be the most important people in their lives during the past six months, and with whom they had regular contact (they were instructed that contact could be face-to-face, by phone, or other online communication). The number of important social contacts was restricted to six because of the small scope of the pilot study.

Subsequently, participants reported on attributes of each person in their network, called "alters", including: gender (male/female), age (in years), their relationship to the alter (e.g., mother, father, sister, friend, etc.), where the alter lived in relation to them (1 = *the same house,* 2 = *the same*

*neighborhood*, 3 = *the same state*, 4 = *another state or country*), and their frequency of any type of contact in the previous three months (1 = *less than once a month*, 2 = *one to three times a month*, 3 = *one to three times a week*, 4 = *daily or almost daily*). Participants then reported on functional aspects of their relationships to these alters that are hypothesized to impact health behavior change: through the provision of social support, through co-engagement in health behaviors that provide opportunities for social influence, and by acting as a barrier to healthy outcomes (Ashida et al., 2012; de la Haye, de Heer, Wilkinson, & Koehly, 2012). Specifically, respondents indicated which alters, in the past six months, (1) they went to for information or advice about their health/their families' health, (2) helped or encouraged them to have a healthy lifestyle, eat healthy foods, or be active, (3) they ate meals or snacks with, or prepared food with, (4) they did physical activity with, and (5) made it difficult for them to have a healthy lifestyle (eat healthy foods and/or be active).

Finally, characteristics of alter-alter relationships were assessed by having respondents indicate whether each pair of alters they had nominated knew each other ("*Does Alter i and Alter j know each other?";* 1 = *yes*, 0 = *no*, 99 = *don't know*).

### *Social Network Predictor Variables*

Social network analysis (SNA) was used to compute statistics that represent the composition of mothers' close social networks based on this egocentric network data, which was treated as predictor variables in this study. We computed the density of functional relationships in the network by calculating the proportion of their nominated alters that: provided health information/advice, provided encouragement, they co-engaged in eating/food preparation with, they co-engaged in physical activity with, and they viewed as a barrier to health. We also computed the proportion of mothers' social network members that were female; that lived in their household or neighborhood; that were family members, a spouse/partner, or friends; and that they had daily contact with (average alter age was included in the models as a control). Finally, the overall connectivity of their personal network was summarized by a density statistic that represents the proportion of participants' alters that were socially connected (i.e., the number of alter-alter pairs who knew each other), relative to the total number of possible ties among all alters (i.e., the total number of alter-alter pairs), which was included as a control variable in the analyses.

### *Dependent Variables*

*Mother body mass index (BMI) and weight status.* Mother weight was measured using an electronic scale (Model BWB-800S, Tanita, Perspective Enterprises, Portage, MI), and height using a portable stadiometer; both according to standard procedures (Lohman, Roche, & Martorell, 1988). Mothers were asked to remove shoes, belts, and outerwear and empty their pockets. Mother BMI was computed based on their weight in kilograms divided by their height in meters squared, and BMI was used to classify mothers into the following three weight categories: not overweight = BMI less than 25.0, overweight = BMI of 25.0 to 29.9, and obese = BMI of 30.0 or more. Change in mother weight was computed as the difference in weight (kg) between pre- and post-intervention.

*Infant weight-for-length and weight status.* Infant weight was measured on a digital scale (Model BWB-800S, Tanita, Perspective Enterprises, Portage, MI) accurate to the nearest 5g using standard procedures. Length was measured to the nearest 0.1 cm using an infanto-meter using the

standardized WHO approach, which included the use of staff training modules. Weight and length were used to calculate weight-for-length z-scores (WLZ) (WHO Standards) for baseline and post-intervention, as recommended by the CDC for children less than 24 months of age. Infants' weight status was measured by WLZ and classified as at-risk for overweight or overweight (WLZ > 1SD) or not at-risk for overweight (WLZ ≤ 1SD).

*Mother and infant diet.* Multi-pass dietary recalls were completed by mothers as a respondent for their infant's food intake, and as a respondent for their own food intake. Participants completed two weekdays and one weekend day in-person dietary recall. With the help of the home visitor doing the assessment, mothers listed all foods/beverages their infant consumed, identified omissions in the initial list, and provided details for each item (portions, brands). The Nutrition Data System for Research software (2011 version), developed by the Nutrition Coordinating Center, University of Minnesota (Schakel, Buzzard, & Gebhardt, 1997; Schakel, Sievert, & Buzzard, 1988; Sievert, Schakel, & Buzzard, 1989) was used for analyses of macronutrients and food groups. Outcomes included in the current analyses were mothers' consumption of fruits and vegetables, and mothers' and infants' consumption of sugar-sweetened beverages and juices (SSB). Although subjective dietary assessments are known to have bias, multi-pass dietary recalls are currently the gold standard in survey-based research.

*Mother physical activity.* Mother step count was assessed using Ozeri Sport Pocket 3D Pedometers, worn on the hip for seven (or more) consecutive days. Average daily steps were computed for participants who recorded a minimum of two days of data.

### *Analytic Approach*

First, our analyses explored correlations between infant and mother health outcomes (post-intervention, and change from pre- to post-intervention) with distal (baseline) and proximate (post-intervention) characteristics of the mother's social network. Social network variables that were significantly ($p < .05$) or marginally significantly ($p < .10$) correlated with infant and mother outcomes were included in regression models to predict these infant/mother outcomes, controlling for mother demographics (age, race/ethnicity, household income), infant age, and alter age. Logistic regression models were used to predict infant post-intervention weight category. Because the purpose of the pilot study was to evaluate the acceptability and feasibility of the intervention, it was not powered to test for main effects of the intervention on mother and infant outcomes. As such, we report descriptive statistics for change in these outcomes, and then control for study arm (intervention/control) in the regression models that explore associations between maternal social network characteristics and the key weight and behavior targets of the intervention.

# Results

### *Descriptive Characteristics of Mother/Infant Outcomes and Maternal Social Networks*

Fifty of the mothers and infants who were enrolled in the study completed the baseline assessments, and 26 completed the post-intervention assessment. Attrition was largely due to mothers dropping out of the HVP, and interestingly, retention rates were somewhat higher in the intervention arm (57%) than in the control arm, who received the standard HVP (45%). There were

**Table 1.** Descriptive statistics of mother and infant demographics and outcomes (N = 26 dyads)

| Mother or infant characteristic | Baseline *M* (SD) / N (%) | Post-intervention *M* (SD) / N (%) |
|---|---|---|
| *Mother demographics* | | |
| *M* (SD) age in years at baseline | 28.4 (7.6) | |
| Race/ethnicity (%)[a] | | |
| Hispanic/Latina | 21 (80.1) | |
| Black/African American | 2 (7.7) | |
| White, non-Hispanic | 6 (23.1) | |
| Annual household income (%)[b] | | |
| $9,999 or less | 8 (30.8) | |
| $10,000 - $29,999 | 12 (46.2) | |
| $30,000 - $49,999 | 4 (15.4) | |
| $50,000 - $69,999 | 1 (3.8) | |
| Marital status (%)[b] | | |
| Single | 13 (52.0) | |
| Married | 7 (28.0) | |
| Divorced | 1 (4.0) | |
| Living with spouse | 4 (16.0) | |
| *Infant demographics* | | |
| *M* (SD) age in months at baseline | 3.8 (2.7) | |
| Female (%) | 16 (61.5) | |
| Intervention arm (%) | 17 (65.4) | |
| *Mother health outcomes* | | |
| *M* (SD) BMI[c] | 29.2 (5.9) | 29.1 (6.5) |
| N (%) overweight/obese | 18 (69.2) | 19 (73.1) |
| *M* (SD) SSB[d] serves/day | 1.0 (1.0) | 1.5 (2.3) |
| *M* (SD) fruit serves/day | 1.0 (1.6) | 0.9 (2.2) |
| *M* (SD) vegetable serves/day | 0.7 (0.9) | 1.0 (1.5) |
| *M* (SD) steps/day | 3996 (1713) | 4162 (2922) |
| *Infant health outcomes* | | |
| *M* (SD) WLZ[e] | -0.46 (2.3) | 0.70 (2.3) |
| N (%) at risk for overweight | 5 (29.4) | 6 (25.0) |
| *M* (SD) SSB[d] serves/day | 0.04 (0.2) | 0.4 (1.0) |

[a]Multiple response permitted
[b]N = 25
[c]BMI = body mass index; calculated as $kg/m^2$
[d]SSB = sugar-sweetened beverage
[e]WLZ = weight-for-length Z-score

no significant differences between mother participants who did and did not complete follow-up for mean BMI ($p$ = .36), network density ($p$ = .20), or the proportion of females in their network ($p$ = .34) (data not shown). Thus, the analytic sample for this study included 26 mothers/infants who completed both assessments (Table 1). These mothers were between 16 and 44 years of age

**Table 2.** Descriptive statistics of change in the mother and infant outcomes by study condition (N = 26 dyads)

| **Change score** (post - baseline) | **Intervention** | | | **Control** | | |
|---|---|---|---|---|---|---|
| | ***M*** | **SD** | **N** | ***M*** | **SD** | **N** |
| *Mother* | | | | | | |
| weight in kg | -0.53 | 3.83 | 16 | 0.00 | 3.08 | 8 |
| BMI | -0.07 | 1.46 | 14 | -0.04 | 1.16 | 8 |
| SSB serves/day | 0.22 | 2.43 | 17 | 0.92 | 2.75 | 9 |
| fruit serves/day | -0.14 | 0.92 | 17 | -0.19 | 4.38 | 9 |
| vegetable serves/day | 0.47 | 1.49 | 17 | 0.09 | 2.17 | 9 |
| steps/day | -977 | 4028 | 8 | -3467 | 3536 | 2 |
| *Infant* | | | | | | |
| WLZ | 1.58 | 2.61 | 13 | -0.29 | 1.23 | 7 |
| SSB serves/day | 0.11 | 0.30 | 16 | 0.94 | 1.45 | 8 |

at baseline (*M* age 28.4, and 80% identified as Hispanic/Latina. The majority lived in households with annual incomes below $30,000 and were single. Infants were, on average, 3.8 months old at baseline and 62% were female. Two-thirds (65%) of mother-infant dyads in our analytic sample were in the intervention condition (i.e., receiving the standard HVP curricula + nutrition and physical activity enhancement module).

Table 1 also provides descriptive statistics for mother and infant weight and health behavior outcomes pre- and post-intervention. Mothers' average BMI was 29.1 and 73% of mothers were overweight or obese. Mothers reported consuming, on average, one and a half servings of SSB per day, and approximately one serving of fruit and one serving of vegetables per day. Their average daily step count was just over 4000. Among infants, about 1 in 4 had WLZ that classified them at risk for overweight, and they consumed on average half a serving of SSB per day.

Because this pilot study was designed to test the feasibility and acceptability of the intervention, it was not powered to identify main effects of the intervention on the mother and infant outcomes. Therefore, descriptive statistics that summarize change in these outcomes for the intervention and control participants are presented in Table 2. Overall, there were positive trends for both mothers and children in the intervention: compared to mothers in the control group (standard HVP), mothers in the intervention showed trends for greater weight loss (an average of 0.5 kg weight loss in the intervention vs. 0.0 kg in the control group) and declines in BMI; greater uptake of vegetable consumption (an average increase of 0.5 daily servings in the intervention vs. 0.1 daily servings in the control group); and less uptake of SSB (an average increase of 0.2 daily servings in the intervention vs. an increase of 0.9 daily servings in the control group). There were negligible differences in mothers' fruit intake between study conditions, and the difference in daily steps could not be interpreted due to the small number of participants with valid data in each arm. Infants in the intervention, compared to those in the control group, showed a trend for greater WLZ increase, but also a trend for less uptake of SSB servings (an average increase of 0.1 daily servingss in the intervention vs. an increase of 0.9 daily servings in the control group).

The characteristics of mothers' social networks are summarized in Table 3, where we report on the proportion (%) of the mother's total social network with particular characteristics (e.g., the %

**Table 3.** Characteristics of mothers' egocentric social networks at baseline and post-intervention

| **Mother network characteristic (% of mothers' social network ties that are…)** | **Baseline *M* (*SD*)** | **Post-intervention *M* (*SD*)** |
|---|---|---|
| Health influence relationships (%) | | |
| Provides health information/advice | 74.3 (28.2) | 66.7 (31.8) |
| Encourages health | 68.8 (34.9) | 73.9 (30.1) |
| Eat/prepare food with | 47.2 (24.9) | 49.3 (24.3) |
| Do physical activity with | 42.4 (30.3) | 42.0 (25.1) |
| Health barrier | 19.6 (25.8) | 12.3 (15.3) |
| Female (%) | 59.6 (21.8) | 60.9 (20.5) |
| Relationship type (%) | | |
| Family | 64.9 (26.8) | 66.7 (24.6) |
| Friend | 19.7 (23.6) | 23.2 (24.0) |
| Spouse/boyfriend | 8.5 (8.7) | 10.1 (9.7) |
| Location (%) | | |
| Same household | 25.1 (21.9) | 29.0 (15.3) |
| Same neighborhood | 31.0 (33.9) | 24.6 (25.6) |
| Contact daily or almost daily (%) | 40.4 (30.6) | 50.0 (20.7) |
| Network density | 0.77 (0.28) | 0.85 (0.17) |

*Note.* Network members' age was included in the models as a control when it was significantly correlated with the outcome variable. At baseline, 20% of network ties were <25 years, 47% were 25-44 years, 27% were 45-64 years, and 2% were 65+ years, on average.

of the total network that provide health information/advice), as well as the density of her personal network. These statistics are summarized across all mother social networks (i.e., *M* and *SD* of each characteristic).

When considering relationships that support health behaviors and weight maintenance, the majority of network members (between two-thirds to three-quarters, on average) provided mothers with health information and advice, and a similar proportion helped or encouraged them to be healthy. Mothers ate or prepared food with approximately half of their network members and did physical activity with 42%. On average, fewer than one in five network members were perceived to be a barrier to adopting a healthy lifestyle. With regards to demographic characteristics, on average, mothers' networks were comprised of more females than males, and the majority of their social ties were 25 to 44 years old. About two-thirds of their social ties were family members, with the remaining social ties largely comprised of friends and spouse/partner. On average, one in five of their social network members resided in the same household as the mother, and approximately

**Table 4a.** Correlations between mothers' social network characteristics (B = baseline and P = post-intervention) and mother and infant health outcomes post-intervention

| | Mother outcomes | | | | | Infant outcomes | |
|---|---|---|---|---|---|---|---|
| **Mother network characteristic** | **BMI** | **SSB serves/ day** | **Fruit serves/ day** | **Veg serves/ day** | **Step count/ day** | **WLZ** | **SSB serves/ day** |
| Health relationships (%) | | | | | | | |
| Provides health info/ advice | | | | .41* (B) | | | |
| Encourages health | -.42$^{+}$ (P) | | | .50* (B) | | | |
| Eat/prepare food with | | -.38$^{+}$ (B) | | -.39$^{+}$ (P) | | | |
| Do physical activity with | | | | | | | |
| Health barrier | | | | .37$^{+}$ (B) | | | |
| % female | -.50* (P) | .37$^{+}$ (P) | | | -.64* (P) | | |
| Relationship type (%) | | | | | | | |
| Family | | -.46* (P) | | .47* (B) | | | |
| Friend | | .64* (P) | | | | | |
| Spouse/boyfriend | | | | | | | |
| Location (%) | | | | | | | |
| Same household | | -.39$^{+}$ (P) | | | | .41$^{+}$ (P) | |
| Same neighborhood | | | | | | | |
| Same household *or* neighborhood | | | .42* (P) | | | | .43$^{+}$ (P) |
| Contact daily/almost daily (%) | | -.43*(B) | | | | | .53* (P) |
| Network density | | | -.61* (B) | | | | |

$^{+}$ $p$ <.10 * $p$ <.05; ** $p$ <.001

*Note*: No social network characteristics were associated with infant weight category post intervention, and so this variable is excluded from the table.

one-quarter lived in the same neighborhood. They had contact with approximately half of these network members daily or almost daily. The average density of social connections (who knows whom) among the members in their network was 77%-85%.

***Relationships between Maternal Social Networks and Mother and Infant Outcomes***

*Mother outcomes*

Characteristics of mothers' social networks were correlated to several mother health outcomes post-intervention (Table 4a), as well as *change* in mother health outcomes pre-to-post intervention (Table 4b). Social network characteristics associated with mothers' healthier weight outcomes (i.e., lower BMI post-intervention, or greater weight loss during the intervention) included having a greater proportion of relationships that helped/encouraged the mothers to be healthy, and a greater proportion of ties who were female.

**Table 4b.** Correlations between mothers' social network characteristics (B = baseline and P = post-intervention) and *change in* mother and infant health outcomes

| | Mother outcomes | | | | | Infant outcomes | |
|---|---|---|---|---|---|---|---|
| **Mother network characteristic** | **Change in kg** | **Change in SSB serves/ day** | **Change in Fruit serves/ day** | **Change in vegetable serves/ day** | **Change in step count/ day** | **Change in WLZ** | **Change in SSB serves/ day** |
| Health relationships (%) | | | | | | | |
| Provides health info/advice | | | | | | | |
| Encourages health | | | | .39$^{+}$ (P) | | | |
| Eat/prepare food with | | | | | | | |
| Do physical activity with | | | | | -.56$^{+}$ (P) | | |
| Health barrier | | | | .41* (P) | | | |
| % female | | .37$^{+}$ (P) | | | .75* (P) | | |
| Relationship type (%) | | | | | | | |
| Family | .39$^{+}$ (P) | -.38$^{+}$ (B)<br>-49* (P) | | | | | |
| Friend | | .61* (P) | | | | | |
| Spouse/boyfriend | | | | | | .45$^{+}$ (P) | |
| Location (%) | | | | | | | |
| Same household | | -.55* (P) | | | | .48* (B) | |
| Same neighborhood | | | .49* (P) | .34$^{+}$ (P) | | | .50* (P) |
| Contact daily/almost daily (%) | | -.48* (B) | | | | .68**(B) | .48* (P) |
| Network density | | -.43* (P) | | | | | -.53* (B) |

+ $p$ <.10 * $p$ <.05; ** $p$ <.001

Social network characteristics associated with healthier *behavior* outcomes (i.e., lower/decreased intake of SSB, higher/increased intake of fruits and vegetables, and greater/increased step count) included having more network members who provided health information and advice, who encouraged mothers to be healthy, *and* who were perceived to be barriers to being healthy. Although the latter association may be counterintuitive, mothers who are trying to adopt healthy behaviors may perceive more social barriers to this change. Healthier mother behaviors were also associated with having a greater proportion of network members who: were female, were family members, lived in the same household or same neighborhood, and they had daily contact with.

**Regression models.** Regression models were specified to identify mother social network characteristics (baseline and post-intervention) that significantly predicted mother health outcomes (post-intervention, and change in outcomes), controlling for mother demographics (age, Hispanic/Latina, household income), infant age, alter age, study arm (intervention, control), and network density. Results indicated that mothers had significantly lower BMI scores post-

intervention if they had a *greater* proportion of network members post-intervention who helped or encouraged them to be healthy ($b$ = -.41, $p$ = .02) and who were female ($b$ = -.56, $p$ < .01). Mother's change in weight (in kg) between baseline and post-intervention was not significantly predicted by these variables.

In terms of dietary behaviors, mothers had significantly lower intake of SSB post-intervention if they had a *smaller* proportion of friends in their network post-intervention ($b$ = .53, $p$ < .01). Mothers had a greater increase in fruit intake if they had a *greater* proportion of network members who lived in their neighborhood post-intervention ($b$ = .50, $p$ = .02). Mothers had greater intake of vegetables post-intervention if their network had a greater proportion of network members who helped or encouraged them to be healthy at baseline ($b$ = .48, $p$ = .02). No network characteristics significantly predicted change in vegetable intake pre-to-post intervention.

Mothers had a higher average step count post-intervention if they had a *greater* proportion of females in their network at baseline ($b$ = -.54, $p$ = .02). No network characteristics significantly predicted change in average step count pre-to-post intervention.

*Infant outcomes*

Correlation analyses also indicated that there were relationships between several characteristics of mothers' social networks and their infants' health outcomes post-intervention (Table 4a), as well as *change* in infant health outcomes from pre- to post-intervention (Table 4b). Social network characteristics that were associated with healthier weight outcomes (i.e., lower WLZ post-intervention, and a slower increase in WLZ from pre-to-post intervention[1]) included having a *smaller* proportion of network members who lived in the same household, and who had daily contact with the mother. In other words, mothers who had frequent and proximate contact with more of their close social ties may have experienced greater challenges to achieving healthy weight trajectories for their infants. Mothers' social network characteristics were not associated with infant weight status category (overweight vs. non-overweight) post-intervention.

Mothers' social network characteristics that were associated with lower or decreased intake of SSB in infants included: having a smaller proportion of network members who lived in the same neighborhood; and having a smaller proportion of network members with whom they had daily/almost daily contact.

**Regression models.** Regression analyses predicting infant outcomes, which controlled for mother demographics, infant age, alter age, study arm (intervention/control), and network density, indicated that infant WLZ post-intervention was not significantly predicted by mothers' social network characteristics. However, change in infant WLZ from pre- to post-intervention was predicted by the proportion of mothers' social ties with whom she had daily contact at baseline ($b$ = .57, $p$ = .02). This indicates that infants had significantly *slower increases* in their WLZ score if their mothers had frequent contact with a smaller number of their network members.

[1] A slower increase in WLZ in infants can be positive if it results in a WLZ that is not defined as at-risk for overweight or overweight, however it can also be indicative of a failure to thrive and so should be interpreted with caution.

Regression analyses also indicated that infants had significantly lower intake of SSB post-intervention if their mothers' social network had a *smaller* proportion of network members post-intervention who: they had contact with daily/almost daily ($b = .60$, $p < .01$), and lived in the same household or neighborhood ($b = .51$, $p < .01$). Regression analyses also indicated that infants had significantly less uptake in SSB intake pre-to-post intervention if their mothers' social network post-intervention had a *smaller* proportion of network members with whom they had contact with daily/almost daily ($b = .38$, $p = .02$).

# Discussion

Mothers and infants exposed to this pilot study showed trends for positive changes in healthy eating and weight (for mothers), compared to those receiving the standard HVP, suggesting that the intervention shows promise for reducing childhood obesity among at-risk children. Changes in mother and infant health outcomes were also associated with characteristics of mothers' social networks. Mothers participating in this pilot study had social networks that were largely comprised of family members who were densely connected to one another; the majority of whom lived in the same household or neighborhood as the mother. Mothers regularly ate or prepared food with about half of these social ties and did physical activity with approximately one-quarter of ties. Overall, this suggests that the close-knit social networks measured in this study could be important sources of influence, either positive or negative, on mother and infant weight, diet, and activity, particularly via the co-engagement in these behaviors. Indeed, the results of this pilot study indicate that some characteristics of low-income mothers' social networks may be protective (e.g., associated with better mother and infant health outcomes), while other characteristics may be barriers to health behavior change (i.e., related to poorer mother and infant health outcomes), in the context of a family-based childhood obesity prevention intervention.

Characteristics of mothers' social networks at baseline or post-intervention that predicted one or more *positive health outcomes* in mothers and/or children included: (1) having a greater proportion of network members who helped or encouraged the mother to have a healthy lifestyle; and (2) having a greater proportion of social ties that were female. Social network characteristics at baseline or post-intervention associated with one or more *negative health outcomes* included having: (1) a greater proportion of network members who had daily or almost daily contact with the mother; and (2) a greater proportion of network members who were friends. One network characteristic was not clearly protective nor risky: having a greater proportion of network members that lived in the same neighborhood was associated with an increase in fruit intake in moms, but higher SSB intake in infants. It is difficult to interpret this last finding because we did not measure network members' food intake. However, because health risk behaviors cluster in social networks and neighborhoods, we might expect neighborhood-based social ties to be similar in their eating habits and as such may be a barrier to behavior change unless they are also engaged in the change process.

Of the functional relationships hypothesized to be sources of social influence, only "the receipt of help and encouragement to have a healthy lifestyle, eat healthy foods, or be active" was found to significantly predict positive intervention outcomes, suggesting this may be a particularly important type of social influence needed to adopt healthy lifestyles in this population (see Figure 1). We did not find evidence that other potential sources of social influence predicted the

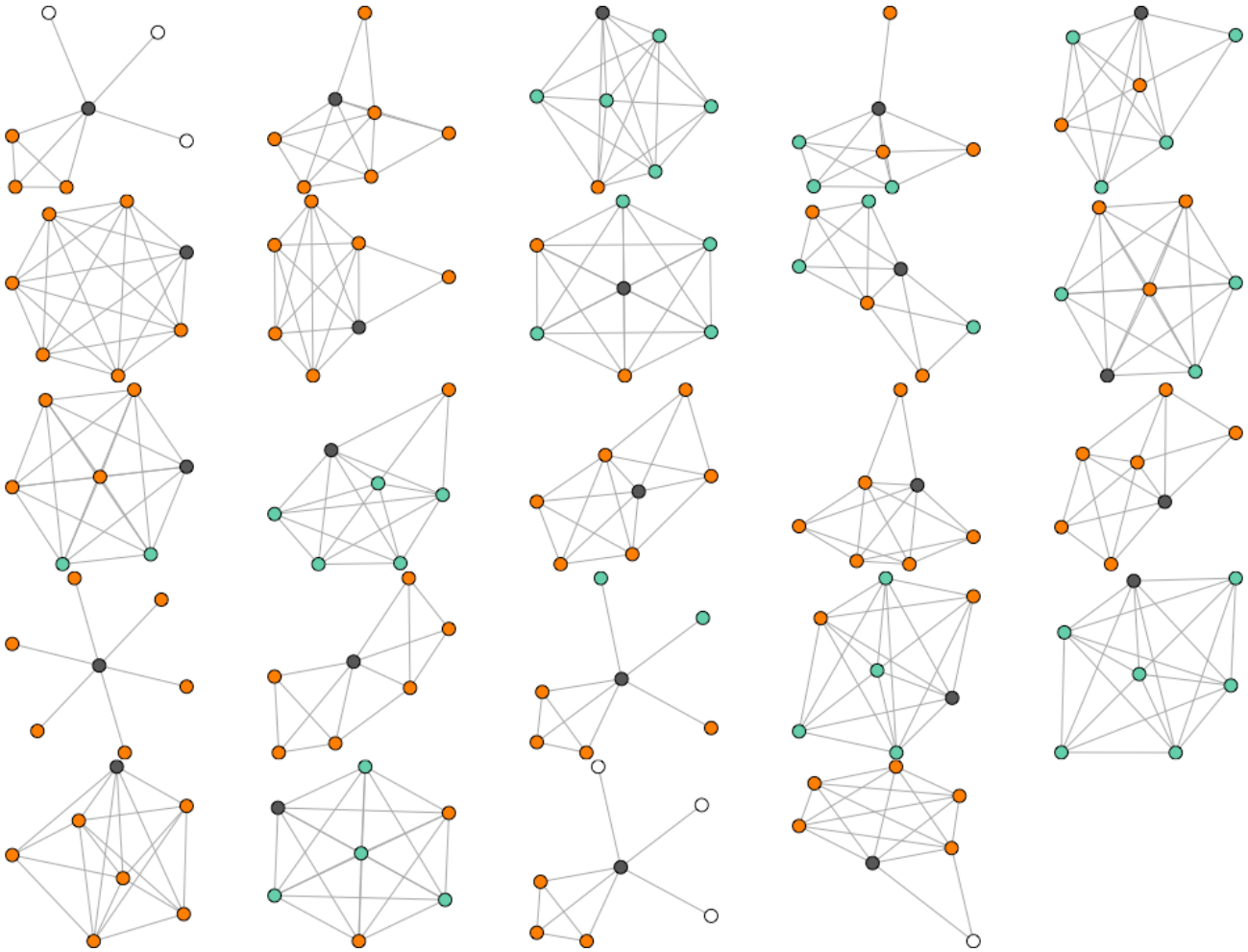

**Figure 1.** *Help and encouragement to be healthy within mothers' personal networks*. Each network represents the personal network of the participating mothers pre-intervention (baseline), where nodes represent the mother (black node) and her named alters, and ties represent social connections. Alters that provided the mother with "help or encouragement to have a healthy lifestyle, eat healthy foods, or be active" are colored orange, and alters that did not provide this type of support are colored blue (white nodes = missing data). Personal network data from two mothers was missing at baseline.

intervention outcomes, including the proportion of network members with whom mothers ate or prepared food, did physical activity, provided health advice/information, or were perceived to be barriers to adopting a healthy lifestyle. This may be because the impact of these relationships is dependent on whether or not the person providing the information and/or influence is themselves engaging in healthy eating or activity behaviors or has a healthy weight. Unfortunately, these alter health attributes were not measured in the current study, but should be the focus of future work. Social influence theory would suggest that receiving information from, or engaging in, health behaviors with "healthy" social ties can bolster healthy behavior change, while these same relationships with "unhealthy" people may be a barrier to change.

Of note, some social network characteristics appeared to have a negative influence on infant outcomes. For instance, mothers who interacted more frequently (i.e., daily) with a greater number

of their social ties, or who had greater proportion of relationships who lived in their neighborhood, had infants that consumed more SSB post-intervention and had greater increases in SSB intake over the intervention period. Frequency of contact with a greater number of ties and neighborhood proximity were also associated with greater increases in infant weight (WLZ). Having more face-to-face and neighborhood-based social ties could be a barrier to healthy changes for these mothers if the influence of these social contacts conflicts with the healthy behaviors mothers are trying to adopt (e.g., if they encourage or provide SSB for the infants). This is likely given the clustering of health risk behaviors, such as poor diet, inactivity, and obesity, within families and communities. Engaging multiple family members and close neighborhood contacts as part of interventions may be an important extension to family-focused interventions. A communal coping approach that can foster increased communication, encouragement, and co-engagement in healthy eating and activity is a promising strategy to engage multiple members of these close-knit social networks in behavior change and positive social influence (Ashida et al., 2012; Koehly et al., 2011). The benefits of targeting the family as part of lifestyle interventions are well established (Epstein, Paluch, Roemmich, & Beecher, 2007; Skelton, Buehler, Irby, & Grzywacz, 2012; St Jeor, Perumean-Chaney, Sigman-Grant, Williams, & Foreyt, 2002). The rationale underlying family-centered approaches is that modification of children's social and physical environments is necessary to change and maintain children's healthy habits. These findings extend the literature on the benefits of family-centered lifestyle interventions and emphasize that prevention programs should explicitly address the influence of wider social systems to help prevent unhealthy eating habits and promote children's healthier lifestyle trajectories.

Although this pilot study has numerous strengths, including the diversity of the sample, the comprehensive measures of adiposity and associated behaviors in mothers and infants, and the use of objective measures for anthropometrics and physical activity, there are also several limitations. The small sample size limits the power to identify social network factors that predict the outcomes of interest in this six-month intervention. Additionally, because of the small scope of this study, only six social network ties were enumerated from mothers, and future work should assess a larger sample (e.g., 20) of social contacts to capture more variability in social network characteristics. The use of home visitors to gather the subjective measures (dietary intake and social network structures) is also a limitation. Overall, the results of this pilot study should be considered suggestive and verified in future larger-scale interventions.

# Conclusion

This pilot study suggests that HVPs are a promising context for childhood obesity prevention. The results also indicate that family-based interventions seeking to promote healthy weight and related behaviors among mothers and infants may benefit from explicitly trying to increase the help and encouragement mothers receive from the people in their social networks for adopting a healthy lifestyle, eating healthy foods, or being active. Mothers in our pilot study who received more of this type of health-related support from their social networks had significantly lower BMIs post-intervention, and significantly greater intake of vegetables post-intervention. The findings also suggest that interventions may need to engage multiple social network members who have regular contact with mothers and/or who live in the same neighborhoods as mothers to help establish

healthy goals and healthy lifestyles for the family, as these connections may be a barrier to change if they provide conflicting norms or messages.

There is evidence that health behavior change interventions can be designed to collectively engage social network members, elicit communal coping responses, and enhance relationships that provide health-related social support, to boost the adoption of targeted health behaviors (Valente, 2010; Valente & Pitts, 2017). Network intervention strategies to engage and elicit support from multiple social network members may also benefit family-based obesity interventions in low-income populations, to enhance protective factors in mothers' social networks that bolster efforts to prevent childhood obesity.

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