Original Article
CLINICAL TRIALS AND INVESTIGATIONS

Obesity

Ripple Effects of a Community-Based Randomized Trial for Rural Women: Strong Hearts, Healthy Communities

Brian K. Lo [1], Meredith L. Graham[1], Galen Eldridge[2], Maria R. Donoso[1], Sara C. Folta [3], David Strogatz[4], Miriam E. Nelson[3], Lynn C. Paul[5], Stephen A. Parry[6], and Rebecca A. Seguin-Fowler [2]

Objective: This study aimed to examine (1) whether the Strong Hearts, Healthy Communities intervention (SHHC) improved social network members' (SNMs') weight, exercise, and diet and (2) whether SNMs' weight and behavioral changes were modified by their relationship closeness and/or spatial closeness with trial participants.

Methods: Eight towns received the SHHC intervention, which focused on building individual healthy behaviors and creating supportive social and built environments for exercise and healthy eating. Eight towns received an education-only control intervention. SNMs (n = 487) were recruited to complete a questionnaire at baseline and at 6 months that asked about demographics, weight, height, exercise, and eating habits.

Results: SHHC's effect on SNMs differed depending on their relationship closeness with trial participants. Among SNMs who had a very close relationship with trial participants, those associated with the intervention group lost more weight and decreased BMI more than those associated with the control group (weight [kilograms] between-group difference: Δ = −1.68; 95% CI: −3.10 to −0.25; P = 0.021; BMI between-group difference: Δ = −0.60; 95% CI: −1.16 to −0.04; P = 0.034). Spatial closeness did not modify any of SHHC's ripple effects.

Conclusions: Relationship closeness, rather than spatial closeness, played an important role in influencing a rural community–based intervention's ripple effects.

Obesity (2020) **28**, 1224-1234.

Study Importance

What is already known?

- People can influence their social network members' (SNMs') weight and health behaviors.
- No prior study has examined the ripple effects of rural behavior change interventions or how relationship closeness and/or spatial closeness influence(s) interventions' ripple effects.

What does this study add?

- Within the context of a rural community–based behavior change intervention, relationship closeness, rather than spatial closeness, plays an important role in promoting weight loss and exercise among trial participants' SNMs.

How might these results change the focus of clinical practice?

- Exploring ways to engage SNMs who are in close relationships with intervention participants might help improve reach and cost-effectiveness of these programs.

Introduction

In the United States, rural populations disproportionally experience higher levels of obesity in comparison with their nonrural counterparts (1). This could be partially due to the social challenges to active living and healthy eating faced by rural residents, including social isolation (2), limited social support (3-5), abundance of food-centric social events with unhealthy foods (6,7), limited organized outdoor activities (4,8), expectations on duties and caregiving responsibilities (5), and few role models for healthy living (9). Therefore, investigating ways to overcome social barriers to healthy living among rural residents might be an effective way to mitigate rural health disparities. One potential strategy is to engage and support rural residents' social network members (SNMs) in physical activity and healthy eating.

Increasing evidence has suggested that SNMs can exert influence on behaviors and weight status. Some review studies have found that individuals tend to exhibit concordance with their family members and friends in terms of health behaviors (10) and weight (11). A small but growing number of studies have also suggested that if individuals change their exercise or diet habits, family members might also adopt these new health behaviors (12-17).

[1] Division of Nutritional Sciences, Cornell University, Ithaca, New York, USA [2] Texas A&M AgriLife Research, Texas A&M University, College Station, Texas, USA [3] Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, USA [4] Bassett Research Institute, Bassett Healthcare Network, Cooperstown, New York, USA [5] College of Education, Health and Human Development, Montana State University, Bozeman, Montana, USA [6] Cornell Statistical Consulting Unit, Cornell University, Ithaca, New York, USA. Correspondence: Rebecca A. Seguin-Fowler (r.seguin-fowler@ag.tamu.edu).

 Received: 22 September 2019; **Accepted:** 17 March 2020; **Published online 22 May 2020. doi:10.1002/oby.22817**

In addition, prior cross-sectional studies have shed light on the importance of relationship closeness, rather than spatial closeness, on associations with weight and related behaviors. For example, among spouses, friends, brothers, and sisters of Framingham Heart Study participants, only spouses showed strong concordance in eating patterns over time, despite other family members' living in the same household (18). Similarly, some studies found that close relationships, such as those with partners, friends, and family, have greater impacts on weight status than spatial relationships, such as those with neighbors and coworkers (19). Others also have suggested that, in comparison with perceived social ties, geographical proximity of networks might have limited influence on obesity status (20,21).

Given that rural populations tend to have closer relationships with others compared with nonrural populations (22), leveraging rural individuals' closer social ties to influence others' weight and health behaviors may be a cost-effective strategy to alleviate rural health disparities. However, none of the prior ripple effect studies has focused on rural populations, nor have they investigated how relationship closeness and spatial closeness might play a role in influencing ripple effects within the context of an intervention.

The aim of this study was to examine ripple effects on weight, exercise, and dietary patterns within Strong Hearts, Healthy Communities (SHHC), a rural community–based, randomized, behavior change intervention trial. We hypothesized that the intervention group's SNMs would have greater improvement in terms of weight, BMI, exercise, and diet quality, compared with the control group's SNMs. In addition, we further examined whether SNMs' weight and behavioral changes were modified by their relationship closeness and/or spatial closeness with trial participants. On the basis of findings from prior studies (18-21), we hypothesized that relationship closeness, but not spatial closeness, would have a significant interaction with the SHHC intervention. We further hypothesized that SNMs who had very close relationships with trial participants *and* were spatially close to these trial participants would have greater weight and behavioral changes.

Methods

Context

This secondary analysis examined ripple effects of a behavior change intervention trial, SHHC, which aimed to reduce cardiovascular disease risk factors among rural US women. From this point onward, women who participated in the original trial are referred to as *trial participants*. Study protocol, trial participants' flow, and trial participant characteristics have been described elsewhere (23,24). Between 2015 and 2016, 194 sedentary midlife and older women with excess weight or obesity participated as SHHC trial participants for 24 weeks in 16 medically underserved rural towns in Montana and New York. Our previous findings showed that in comparison with those in the control group, trial participants in the intervention group (SHHC) had statistically significant weight loss, BMI reduction, increased intake of fruit and vegetables combined, and increased walking metabolic equivalent (MET)-minutes per week (24,25). The study was approved by Cornell University and Bassett Healthcare Network institutional review boards.

Eight towns received the SHHC intervention (n = 101)—a 48-session (twice a week for 24 consecutive weeks) intervention with multiple components that were designed to increase physical activity and improve diet quality. These components included in-class exercise sessions, capacity-building activities, field-based learning, and other activities that were designed to promote positive behavioral changes through cultivating supportive social and built environments. In addition, intervention group participants were provided with tips and strategies to engage SNMs in exercise and healthy eating, such as inviting them to try new exercises and healthy foods, engaging them in decision-making, and offering support to and receiving support from each other. The other eight towns received an education-only control intervention, Strong Hearts, Healthy Women (SHHW), that only provided general information on healthy living (n = 93). Trial participants in the SHHW group met once every 4 weeks for 24 weeks for a total of six sessions.

Data collection

SNMs' recruitment. Family members, friends, coworkers, and/or other SNMs were nominated by trial participants on the baseline questionnaire to participate in pre- and postintervention questionnaires; trial participants provided contact information for each nominated SNM. Trial participants provided SNM nominations and completed baseline data collection prior to randomization. In other words, trial participants did not know their treatment assignment when they provided SNM nominations. All SNMs referred by trial participants were eligible to participate as long as they were at least 18 years old and provided consent. There were no BMI or weight eligibility criteria for SNMs. SNMs gave written consent on the first page of the SNM baseline online survey. Of the entire trial participant sample, the median number of social network referrals was 1 (interquartile range: 0-4). Figure 1 shows the SNMs' flow through the study.

Measures. The SNM questionnaire included questions about demographics, including address, weight, height, eating and exercise habits; relationship closeness to the trial participant; and psychosocial factors.

To assess relationship closeness at baseline, SNMs responded to the question, "How would you describe your relationship with the Strong Hearts Study participant?" with the response options "very close," "somewhat close," and "not very close." These three levels of relationship closeness were based on the Convoy Model of Social Relations that suggests social relationships could be divided into three layers: inner circle, middle circle, and outer circle (26). After data collection, we found that 53.9% of the SNMs selected the "very close" option, 37.2% selected the "somewhat close" option, and only 8.8% selected the "not very close" option at baseline. Therefore, SNMs were dichotomized as having a relationship with trial participants that was either "very close" or "somewhat or not very close" to allow easier interpretation of findings.

To assess spatial closeness, we dichotomized SNMs into "spatially close" and "not spatially close." Those in the spatially close category included SNMs who lived in the same household as trial participants, coworkers, and those who lived within a 10-mile driving distance from trial participants. Coworkers were included as being spatially close because people spend a considerable amount of time at work, and the work environment has been shown to be related to individuals' physical activity and diet (27,28). The shortest driving distance between trial participants and their SNMs' contact addresses was calculated using Google Maps. The 10-mile driving

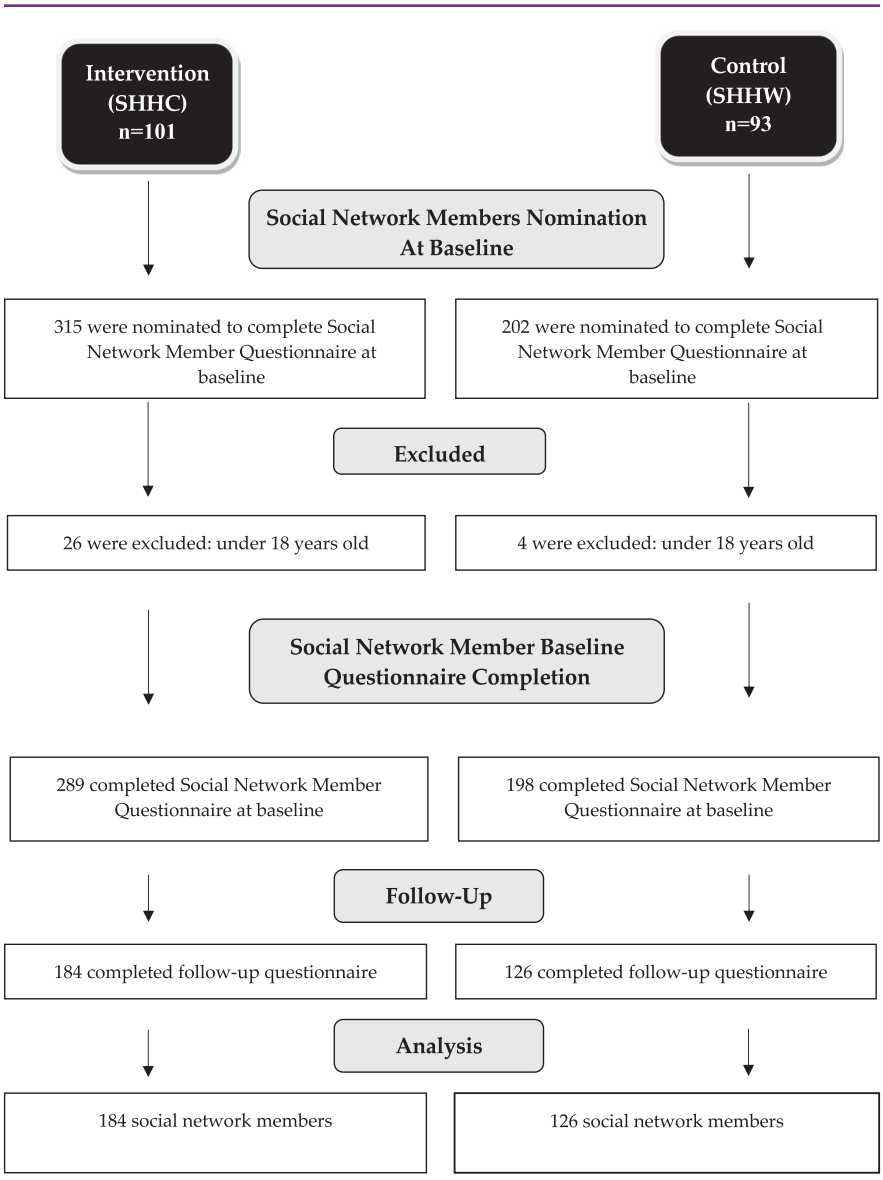

Figure 1 Flow of social network members in the SHHC trial. Abbreviations: SHHC, Strong Hearts, Healthy Communities; SHHW, Strong Hearts, Healthy Women

distance cutoff has been used by governmental and social agencies as a proxy to define reasonable travel distance to service amenities in rural communities (e.g., grocery stores, hospitals, banks) (29-31). Such a cutoff was also the median driving distance between trial participants and their SNMs. Relationship and spatial closeness could be classified for 463 of the 487 SNMs at baseline. There was a modest but significant (P = 0.008) inverse association between the two measures of closeness: being spatially close to trial participants was somewhat less common for SNMs with a very close relationship (134/246 = 54.5%) than for SNMs with a somewhat/not very close relationship (145/217 = 66.8%).

The International Physical Activity Questionnaire–Short Form was used to assess SNMs' physical activity (32). Standard scoring protocol was used to calculate SNMs' weekly walking MET-minutes, moderate-to-vigorous physical activity (MVPA) MET-minutes, and total MET-minutes (33).

The Rapid Eating and Activity Assessment for Patients (REAP)–Shortened Version (REAP-S) was used to assess SNMs' diet quality (34). This 13-item questionnaire contains questions related to frequency of eating out, skipping breakfast, low consumption of high fiber foods, and consumption of processed foods, meats, oil, sweets, and soda. Responses for each question included the following: 1 point = "usually/often," 2 points = "sometimes," and 3 points = "rarely/never." Food items that were skipped (or answered "not applicable to me") were coded as "rarely" or "never." Possible sum scores ranged from 13 to 39, and higher scores indicated better diet quality (35).

BMI was calculated using SNMs' self-reported weight and baseline height. Implausible weight values were excluded for one SNM who had a baseline weight of 234.3 kg (BMI = 83.4) and had a weight of 101.6 kg at 6 months (BMI = 36.2). Without any medical procedure, it is unrealistic for a normal person to lose more than 100 kg in 6 months through physical activity and diet changes only; therefore, we removed this SNM's weight and BMI values and treated them as missing values.

Analysis

Baseline characteristics by treatment group were compared for the entire SNM sample, the very-close-relationship sample, and the spatially close sample. We used *t* tests to examine normally distributed continuous variables and Wilcoxon rank sum tests to examine non-normally distributed continuous variables. Baseline demographic differences for categorical variables were examined using Fisher exact tests. In cases in which the Fisher exact test was not able to be run, Monte Carlo estimates were used to examine categorical-variable differences.

Linear mixed models were used to assess the change of outcomes from baseline to 6 months in weight, BMI, exercise, and diet between the intervention (SHHC) and control (SHHW) groups' SNMs (Δ outcome of interest = treatment group + control variables + baseline value of outcome). To test whether relationship closeness moderated the effects of the treatment on body-weight and behavior outcomes, an interaction term was used between treatment group (intervention vs. control) and relationship closeness (very close vs. somewhat or not very close) (Δ outcome of interest = treatment group + treatment group*relationship closeness + relationship closeness + control variables + baseline value of outcome). Similarly, to test whether spatial closeness moderated the effects of the treatment on body-weight and behavior outcomes, an interaction term was used between treatment group (intervention vs. control) and spatial closeness (spatially close vs. not spatially close) (Δ outcome of interest = treatment group + treatment group*spatial closeness + spatial closeness + control variables + baseline value of outcome).

For outcomes in which SHHC intervention group participants had statistically significant improvements in the original trial in comparison with the control group (i.e., weight, BMI, weekly walking MET-minutes, and diet quality), we conducted sensitivity analyses among (1) SNMs who had a very close relationship to trial participants (Δ outcome of interest = treatment group + treatment group*spatial closeness + spatial closeness + control variables + baseline value of outcome) and (2) those who were spatially close to trial participants (Δ outcome of interest = treatment group + treatment group*relationship closeness + relationship closeness + control variables + baseline value of outcome).

All linear mixed models controlled for SNMs' age, sex, education, relationship status, employment status, self-rated health, and baseline value of outcome of interest (see Table 1). We also controlled for trial participants' program attendance. Trial program sites and trial participants' unique identification numbers were also included in all models and were treated as random effects to control for the clustering effects of trial program sites and the possible correlation between SNMs referred by the same trial participant. Model assumptions were checked and met. Collinearity diagnostics indicated no violations among the independent variables in the present study, in which all variance inflation factors were under 2.

Examination of missing data revealed that the proportion of missing data of our dependent variables (i.e., changes in weight [kilograms], BMI, weekly walking MET-minutes, weekly MVPA MET-minutes, weekly total MET-minutes, and REAP score) ranged between 37.2% and 48.0%. This was largely due to SNMs being lost to follow-up (36.3%). This was not surprising, as SNMs were not our primary target audience in the original SHHC trial. SNMs might have been less motivated to complete follow-up data-collection activities.

We examined differences between SNMs who completed the follow-up survey and those who did not. We found similar demographic characteristics between them in terms of their baseline BMI, relationship status, education level, employment status, and self-rated health (all $P > 0.05$). However, those who returned for follow-up surveys were younger than those who did not (mean age: 46.2 vs. 49.8, $P = 0.020$). Without responses from non-respondents, it was challenging to distinguish whether our missing data were missing at random or were missing not at random. As we found no major demographic differences between SNMs that had available dependent variables and those who did not, we used a multiple imputation approach that assumed responses were missing at random.

SAS Software Version 9.4 (PROC MI; SAS Institute, Cary, North Carolina) was used to handle missing data with an imputation model that included the variables used in the analysis, including the interaction terms, to impute SNMs' baseline demographic variables (i.e., covariates). Thirty data sets were imputed, and SAS PROC MIANALYZE was used to pool the estimates from individual data sets. We did not impute the dependent variables (i.e., changes in weight [kilograms], BMI, weekly walking MET-minutes, weekly MVPA MET-minutes, weekly total MET-minutes, and REAP score) because imputing dependent variables without knowing useful auxiliary variables would not provide useful information but would add uncertainties to our data, which would in turn increase the SEs (36,37).

All tests were two-sided, and $P < 0.05$ was used as the cutoff for statistical significance.

Results

Table 1 shows SNMs' baseline characteristics.

Of the 487 SNMs, 289 (59.3%) were referred by intervention group participants, and 198 (40.7%) were referred by control group participants; 135 (27.7%) were family members (child, spouse, or parent), and 352 (72.3%) were friends and others.

There were differences between groups at baseline in the entire social network sample as well as within the two sensitivity-test subsamples. Among the entire social network sample, although the intervention group's SNMs were older (49.1 vs. 45.1, $P = 0.007$), a higher proportion of the control group's SNMs were employed than those related to the intervention group (77.2% vs. 67.1%, $P = 0.018$). For baseline physical activity and diet, intervention-group SNMs had higher weekly MVPA MET-minutes (1,440.7 vs. 1,142.6, $P = 0.017$), weekly total MET-minutes (2,151.0 vs. 1,792.1, $P = 0.026$), and REAP-S sum scores (30.0 vs. 28.4, $P = 0.001$). For those in the very-close-relationship sample, a greater proportion of the control

TABLE 1 Baseline characteristics of trial participants' SNMs

	Overall					Very close relationship					Spatially close				
	Intervention		Control			Intervention		Control			Intervention		Control		
	n	Mean (SD) or %	*n*	Mean (SD) or %	*P* value	*n*	Mean (SD) or %	*n*	Mean (SD) or %	*P* value	*n*	Mean (SD) or %	*n*	Mean (SD) or %	*P* value
Age, y	270	49.1 (16.6)	186	45.1 (14.0)	**0.007**[a]	155	47.6 (17.5)	88	44.7 (15.3)	0.202[a]	138	50.9 (16.4)	124	46.7 (14.2)	**0.027**[a]
Weight, kg	273	81.0 (19.3)	188	83.3 (19.1)	0.202[b]	160	81.3 (19.7)	88	87.0 (20.7)	0.051[b]	139	82.9 (19.5)	128	84.2 (19.3)	0.667[b]
BMI	244	29.2 (6.6)	155	29.9 (6.7)	0.286[b]	142	28.8 (6.3)	76	30.5 (7.1)	0.119[b]	126	29.5 (6.2)	106	30.3 (6.8)	0.486[b]
Sex															
Male	50	17.9	32	16.6	0.805[c]	40	24.5	25	27.5	0.654[c]	30	21.4	26	19.8	0.766[c]
Female	229	82.1	161	83.4		123	75.5	66	72.5		110	78.6	105	80.2	
Education															
High school or less	107	38.2	63	32.6	0.657[c]	71	43.3	32	35.2	0.218[c]	63	44.4	43	32.8	0.256[c]
Associate degree	64	22.9	47	24.4		36	22.0	17	18.7		34	23.9	36	27.5	
Bachelor's degree	63	22.5	49	25.4		36	22.0	31	34.1		25	17.6	27	20.6	
Postgraduate degree	46	16.4	34	17.6		21	12.8	11	12.1		20	14.1	25	19.1	
Relationship status															
In a relationship	204	72.6	150	77.7	0.237[c]	121	73.8	73	80.2	0.285[c]	103	72.5	101	77.1	0.406[c]
Not in a relationship	77	27.4	43	22.3		43	26.2	18	19.8		39	27.5	30	22.9	
Employment status															
Employed	188	67.1	149	77.2	**0.018**[c]	99	61.1	69	75.8	**0.019**[c]	97	67.8	101	77.1	0.105[c]
Not employed	92	32.9	44	22.8		63	38.9	22	24.2		46	32.2	30	22.9	
Self-rated health status															
Excellent or very good	157	55.9	89	46.1	0.106[c]	90	54.9	43	47.3	0.484[c]	80	55.9	57	43.5	0.115[c]
Good	86	30.6	74	38.3		50	30.5	34	37.4		43	30.1	52	39.7	
Fair or poor	38	13.5	30	15.5		24	14.6	14	15.4		20	14.0	22	16.8	
Walking MET-min/wk	277	702.0 (907.6)	196	660.9 (928.0)	0.171[b]	159	708.8 (880.6)	90	676.4 (910.2)	0.391[b]	140	778.6 (1,023.1)	132	631.9 (938.4)	0.126[b]
MVPA MET-min/wk	264	1,440.7 (2029.0)	196	1,142.6 (1,851.9)	**0.017**[b]	154	1,540.3 (1932.6)	90	1,478.5 (2,426.2)	**0.041**[b]	133	1,566.2 (2,225.3)	133	1,114.0 (1944.0)	**0.012**[b]
Total MET-min/wk	260	2,151.0 (2,406.1)	194	1,792.1 (2,305.1)	**0.026**[b]	150	2,244.5 (2,241.9)	88	2,137.9 (2,921.5)	0.057[b]	132	2,356.0 (2,649.0)	132	1,718.0 (2,385.0)	**0.015**[b]
REAP-S sum score	289	30.0 (4.7)	198	28.4 (5.3)	**0.001**[a]	170	29.9 (4.6)	92	28.3 (5.3)	**0.010**[a]	146	29.4 (5.3)	133	28.4 (5.3)	0.095[a]
Relationship type between trial participants and SNMs															
Spouse	24	8.3	15	7.6	0.074[d]	24	14.1	15	16.3	0880[c]	19	13.0	14	10.5	0.722[c]
Parent	13	4.5	13	6.6		13	7.6	11	12.0		7	4.8	6	4.5	

TABLE 1 (continued).

	Overall					Very close relationship					Spatially close				
	Intervention		Control			Intervention		Control			Intervention		Control		
	n	Mean (SD) or %	*n*	Mean (SD) or %	*P* value	*n*	Mean (SD) or %	*n*	Mean (SD) or %	*P* value	*n*	Mean (SD) or %	*n*	Mean (SD) or %	*P* value
Child	48	16.6	22	11.1		45	26.5	20	21.7		17	11.6	10	7.5	
Other relative	42	14.5	19	9.6		29	17.1	14	15.2		12	8.2	8	6.0	
Friend	90	31.1	65	32.8		31	18.2	15	16.3		43	29.5	40	30.1	
Coworker	29	10.0	36	18.2		7	4.1	4	4.3		29	19.9	36	27.1	
Other[e]	43	14.9	28	14.1		21	12.4	13	14.1		19	13.0	19	14.3	

Significant *P* values indicated in bold.
[a]*t* test.
[b]Wilcoxon rank sum test.
[c]Fisher exact test.
[d]Monte Carlo estimate for Fisher exact test.
[e]Included those who indicated two or more relationship types with trial participants.
MET, metabolic equivalent; MVPA, moderate-to-vigorous physical activity; REAP-S, Rapid Eating and Activity Assessment for Patients–Shortened Version; SNM, social network member.

group's SNMs were employed (75.8% vs. 61.1%, *P* = 0.019); the intervention group's SNMs had higher baseline weekly MVPA MET-minutes (1,540.3 vs. 1,478.5, *P* = 0.041) and REAP-S sum scores (29.9 vs. 28.3, *P* = 0.010) than those related to the control group. For those in the spatially close sample, the intervention group's SNMs were older (50.9 vs. 46.7, *P* = 0.027) and had higher baseline levels of weekly MVPA MET-minutes (1,566.2 vs. 1,114.0, *P* = 0.012) and total MET-minutes (2,356.0 vs. 1,718.0, *P* = 0.015).

Weight, BMI, physical activity, and dietary changes among SNMs

Overall, we did not observe any difference between the intervention and control groups' SNMs in weight (between-group difference [kilograms]: Δ = −0.96; 95% CI = −2.34 to +0.42; *P* = 0.172), BMI (between-group difference: Δ = −0.40; 95% CI = −0.99 to +0.19; *P* = 0.184), walking MET-minutes (between-group difference: Δ = +88.26, 95% CI = −155.49 to +332.02; *P* = 0.478), MVPA MET-minutes (between-group difference: Δ = −173.74; 95% CI = −690.6 to +343.14 *P* = 0.510), total MET-minutes (between-group difference: Δ = −242.13, 95% CI = −878.74 to +394.48; *P* = 0.456), or REAP-S score (between-group difference: Δ = +0.15; 95% CI = −1.16 to +1.47; *P* = 0.821).

Interaction-terms testing

Table 2 summarizes findings of the interaction-terms testing.

Weight and BMI

Among the entire SNM sample, the interaction between relationship closeness and treatment group was statistically significant for weight change (kilograms, *P* = 0.030) and marginally statistically significant for BMI change (*P* = 0.050); the interaction between spatial closeness and treatment group was not statistically significant for either weight change (kilograms, *P* = 0.132) or BMI change (*P* = 0.208, Table 2). Between-group comparisons revealed that among those who had a very close relationship with trial participants, the intervention group's SNMs lost more weight and decreased BMI more than those associated with control group participants (weight [kilograms] between-group difference: Δ = −1.68; 95% CI = −3.10 to −0.25; *P* = 0.021; BMI between-group difference: Δ = −0.60; 95% CI = −1.16 to −0.04; *P* = 0.034) (Table 3).

The interaction between spatial closeness and treatment group was only marginally statistically significant within the very-close-relationship sample for weight change (kilograms, *P* = 0.046) but was not statistically significant for BMI change (*P* = 0.097, Table 2). Among those who were not spatially close but had a very close relationship with trial participants, the intervention group's SNMs lost weight and decreased BMI, whereas weight and BMI increased for those associated with control group participants (weight [kilograms] between-group difference: Δ = −3.28; 95% CI = −5.57 to −0.99; *P* = 0.005; BMI between-group difference: Δ = −1.18; 95% CI = −2.12 to −0.24; *P* = 0.014; Table 3).

Exercise

For exercise, only the interaction between spatial closeness and treatment group for change in weekly walking MET-minutes within the very-close-relationship sample was found to be statistically significant (*P* = 0.027, Table 2). Among those who had a very close relationship

TABLE 2 Summary of interaction testing findings

Interaction term	Outcome of interest					
	Δ Weight (kg)	Δ BMI	Δ Weekly walking MET-min	Δ Weekly moderate-to-vigorous activity MET-min	Δ Weekly total MET-min	Δ REAP-S sum score
Among all SNMs (*n* ranged from 253 to 306)						
Relationship closeness*treatment group	**✓ (*P* = 0.030)**	✗ (*P* = 0.050)	✗ (*P* = 0.975)	✗ (*P* = 0.429)	✗ (*P* = 0.551)	**✓ (*P* = 0.007)**
Spatial closeness*treatment group	✗ (*P* = 0.132)	✗ (*P* = 0.208)	✗ (*P* = 0.401)	✗ (*P* = 0.771)	✗ (*P* = 0.507)	✗ (*P* = 0.291)
SNMs who had a very close relationship with trial participants (*n* ranged from 143 to 173)						
Spatial closeness*treatment group	**✓ (*P* = 0.046)**	✗ (*P* = 0.097)	**✓ (*P* = 0.027)**	n/a	n/a	✗ (*P* = 0.151)
SNMs who were spatially close to trial participants (*n* ranged from 155 to 185)						
Relationship closeness*treatment group	✗ (*P* = 0.473)	✗ (*P* = 0.292)	✗ (*P* = 0.132)	n/a	n/a	**✓ (*P* = 0.012)**

Significant *P* values indicated in bold. ✓ indicates statistically significant interaction terms. ✗ indicates statistically insignificant interaction terms. All models controlled for SNMs' age, sex, education, relationship status, employment status, self-rated health, trial participants' program attendance, and baseline value of outcome of interest as fixed effects. Trial program sites and trial participants' identification numbers treated as random effects in all models.

MET, metabolic equivalent; n/a, not applicable; REAP-S, Rapid Eating and Activity Assessment for Patients, shortened version; SNM, social network member.

with trial participants but were not spatially close, the intervention group's SNMs increased their weekly walking MET-minutes, whereas those associated with control group participants decreased their walking (between-group difference: Δ = +557.98; 95% CI = +76.22 to +1,039.75; $P = 0.023$; Table 4).

Diet

Although we observed a statistically significant interaction between relationship closeness and treatment group on diet changes within the entire SNM sample ($P = 0.007$) and among those who were spatially close ($P = 0.012$, Table 2), post hoc between-group comparisons did not observe any meaningful dietary change differences (Table 5).

Discussion

When comparing outcome changes between intervention and control group participants' SNMs, we did not find any statistically significant ripple effect on weight, BMI, exercise, or diet changes. These findings are in contrast with those of some prior studies (12-17). This could be due to different study designs and participant selection. In particular, whereas prior studies only focused on the ripple effect among spouses and partners, our SNM sample also included trial participants' parents, children, friends, coworkers, and others.

We also examined whether there was effect modification by relationship closeness and/or the spatial closeness between trial participants and their SNMs. We found that SNMs who had a very close relationship with intervention group participants lost weight and reduced their BMI in comparison with those who had a very close relationship with control-group trial participants. These findings also apply to a subsample of SNMs who had either overweight or obesity at baseline. Weight and BMI improvements among the intervention group's SNMs may have resulted from their increased weekly walking MET-minutes. We found that SNMs' weight and BMI changes were negatively associated with their weekly walking MET-minute changes ($P < 0.05$). These findings mirror intervention group participants' improvements in weight, BMI, and self-reported weekly walking MET-minutes (24,25). When intervention group participants experienced positive changes, they might have been more likely to share information with their close SNMs, be role models, and provide encouragement for behavior changes. Such an observation is similar to those of a few studies that have suggested relationship closeness might play a bigger role in influencing SNMs' weight and behaviors than SNMs' spatial proximity (19-21). In addition, a reciprocal relationship may have existed between trial participants and SNMs' walking behaviors: while the number of trial participants' SNM referrals was positively associated with trial participants' walking-minute improvements ($\beta = +13.01$, 95%CI = +2.62 to +23.41; $P = 0.015$), SNMs' improved walking minutes were also positively associated with trial participants' walking improvements, although the magnitude was small ($\beta = +0.07$, 95%CI = +0.01 to +0.14; $P = 0.022$).

In contrast to our hypothesis, our sensitivity analyses did not find any ripple effects among SNMs who were both socially *and* spatially close to trial participants (mainly trial participants' spouses). This could be due to the different health goals and activity preferences between trial participants and their spouses. For example, rural women in some studies commented that their husband did not perceive walking as exercise and did not like to socialize (38). In addition, rural men in our formative

TABLE 3 Adjusted least square means for between-group comparisons: weight and BMI changes

	Within-group change (intervention)	Within-group change (control)	Between-group difference (intervention – control)	
	Mean change (95% CI)	Mean change (95% CI)	Mean change (95% CI)	*P* value
Among all SNMs				
Weight, kg				
Very close relationship (intervention *n* = 102; control *n* = 60)	−1.52 (−2.61 to −0.44)	+0.15 (−1.17 to +1.48)	−1.68 (−3.10 to −0.25)	**0.021**
Somewhat or not very close relationship (intervention *n* = 68; control *n* = 55)	+0.27 (−1.09 to +1.62)	−0.14 (−1.61 to +1.32)	+0.41 (−1.26 to +2.08)	0.630
Spatially close (intervention *n* = 94, control *n* = 77)	−0.70 (−1.86 to +0.46)	−0.38 (−1.64 to +0.89)	−0.32 (−1.74 to +1.10)	0.658
Not spatially close (intervention *n* = 76, control *n* = 38)	−1.39 (−2.63 to −0.14)	+0.48 (−1.09 to +2.06)	−1.87 (−3.59 to −0.14)	**0.034**
BMI				
Very close relationship (intervention *n* = 94; control *n* = 49)	−0.47 (−0.87 to −0.06)	+0.14 (−0.37 to +0.64)	−0.60 (−1.16 to −0.04)	**0.034**
Somewhat or not very close relationship (intervention *n* = 63; control *n* = 47)	+0.14 (−0.38 to +0.65)	−0.004 (−0.56 to +0.55)	+0.14 (−0.50 to +0.78)	0.670
Spatially close (intervention *n* = 90, control *n* = 67)	−0.18 (−0.64 to +0.27)	−0.02 (−0.53 to +0.49)	−0.17 (−0.76 to +0.42)	0.579
Not spatially close (intervention *n* = 67, control *n* = 29)	−0.50 (−1.00 to −0.01)	+0.20 (−0.46 to +0.85)	−0.70 (−1.44 to +0.04)	0.063
SNMs who had a very close relationship with trial participants				
Weight, kg				
Spatially close (intervention *n* = 56, control *n* = 37)	−1.43 (−2.96 to +0.11)	−0.91 (−2.71 to +0.90)	−0.52 (−2.57 to +1.52)	0.617
Not spatially close (intervention *n* = 46, control *n* = 23)	−2.07 (−3.69 to −0.45)	+1.21 (−0.94 to +3.35)	−3.28 (−5.57 to −0.99)	**0.005**
BMI				
Spatially close (intervention *n* = 52, control *n* = 32)	−0.33 (−0.91 to +0.24)	−0.11 (−0.80 to +0.59)	−0.23 (−1.03 to +0.57)	0.574
Not spatially close (intervention *n* = 42, control *n* = 17)	−0.66 (−1.27 to −0.04)	+0.52 (−0.35 to +1.40)	−1.18 (−2.12 to −0.24)	**0.014**
SNMs who were spatially close to trial participants				
Weight (kg)				
Very close relationship (intervention *n* = 53, control *n* = 37)	−0.89 (−2.09 to +0.31)	−0.50 (−1.90 to +0.89)	−0.39 (−1.93 to +1.15)	0.619
Somewhat or not very close relationship (intervention *n* = 40, control *n* = 42)	+0.37 (−1.13 to +1.87)	−0.02 (−1.50 to +1.47)	+0.39 (−1.21 to +1.99)	0.631
BMI				
Very close relationship (intervention *n* = 49, control *n* = 32)	−0.21 (−0.64 to +0.21)	−0.07 (−0.59 to +0.44)	−0.14 (−0.71 to +0.44)	0.635
Somewhat or not very close relationship (intervention *n* = 38, control *n* = 36)	+0.21 (−0.33 to +0.75)	−0.08 (−0.63 to +0.46)	+0.30 (−0.29 to +0.88)	0.321

Significant *P* values indicated in bold. All models controlled for SNMs' age, sex, education, relationship status, employment status, self-rated health, trial participants' program attendance, and baseline value of outcome of interest as fixed effects. Trial program sites and trial participants' identification numbers treated as random effects in all models. SNM, social network member.

work expressed that for physical activity, they preferred team sports and outdoor activities in the countryside, such as hunting and fishing (4). In other words, trial participants' increased engagement in walking, indoor aerobic exercise, and group strength training might not be of interest to their spouses in these rural communities.

Interestingly, SNMs who had a very close relationship with trial participants but were not spatially close mirrored trial participants' weight loss and improved walking patterns. These SNMs were mainly female and were trial participants' adult children or other relatives. In comparison with trial participants' spouses, these SNMs might have similar

TABLE 4 Adjusted least square means for between-group comparisons: physical activity changes

	Within-group change (intervention)	Within-group change (control)	Between-group difference (intervention – control)	
	Mean change (95% CI)	Mean change (95% CI)	Mean change (95% CI)	*P* value
Among all SNMs				
Weekly walking MET-min				
Very close relationship (intervention *n* = 103; control *n* = 61)	+87.58 (−149.18 to +324.34)	−10.39 (−303.47 to +282.68)	+97.98 (−210.95 to +406.90)	0.534
Somewhat or not very close relationship (intervention *n* = 70; control *n* = 63)	+161.30 (−140.88 to +463.48)	+70.51 (−238.93 to +379.96)	+90.79 (−255.55 to +437.13)	0.607
Spatially close (intervention *n* = 98, control *n* = 83)	+104.70 (−153.51 to +362.91)	+86.48 (−180.48 to +353.43)	+18.22 (−274.93 to +311.38)	0.903
Not spatially close (intervention *n* = 75, control *n* = 41)	+105.51 (−167.52 to +378.54)	−116.10 (−457.93 to +225.73)	+221.61 (−150.68 to +593.90)	0.243
Weekly moderate-to-vigorous MET-min				
Very close relationship (intervention *n* = 98, control *n* = 60)	+613.62 (+105.30 to +1,121.94)	+612.83 (−9.65 to +1,235.31)	+0.787 (−659.44 to +661.02)	0.998
Somewhat or not very close relationship (intervention *n* = 66, control *n* = 58)	+502.31 (−145.53 to +1,150.15)	+895.30 (+223.83 to +1,566.77)	−392.99 (−1,145.77 to +359.78)	0.306
Spatially close (intervention *n* = 93, control *n* = 79)	+693.39 (+149.44 to +1,237.33)	+890.44 (+311.81 to +1,469.08)	−197.06 (−830.53 to +436.42)	0.542
Not spatially close (intervention *n* = 71, control *n* = 39)	+408.30 (−176.88 to +993.49)	+456.95 (−281.02 to +1,194.93)	−48.65 (−851.73 to +754.43)	0.906
Weekly total MET-min				
Very close relationship (intervention *n* = 95, control *n* = 59)	+742.85 (+120.00 to +1,365.69)	+819.90 (+59.60 to +1,580.21)	−77.06 (−886.77 to +732.65)	0.852
Somewhat or not very close relationship (intervention *n* = 65, control *n* = 58)	+761.89 (−32.52 to +1,556.30)	+1,200.55 (+375.86 to +2025.24)	−438.66 (−1,365.53 to +488.21)	0.354
Spatially close (intervention *n* = 92, control *n* = 78)	+867.70 (+201.69 to +1,533.71)	+1,227.93 (+519.20 to +1936.65)	−360.23 (−1,133.44 to +412.99)	0.361
Not spatially close (intervention *n* = 68, control *n* = 39)	+572.59 (−145.03 to +1,290.21)	+518.89 (−371.78 to +1,409.57)	+53.69 (−927.03 to +1,034.42)	0.915
SNMs who had a very close relationship with trial participants				
Weekly walking MET-min				
Spatially close (intervention *n* = 52, control *n* = 36)	−89.19 (−418.04 to +239.67)	+87.23 (−298.02 to +472.49)	−176.42 (−607.91 to +255.07)	0.423
Not spatially close (intervention *n* = 51, control *n* = 25)	+14.99 (−334.83 to +364.80)	−543.00 (−1,005.85 to −80.15)	+557.98 (+76.22 to +1,039.75)	**0.023**
SNMs who were spatially close to trial participants				
Weekly walking MET-min				
Very close relationship (intervention *n* = 52, control *n* = 36)	−101.30 (−425.58 to +222.98)	+124.12 (−255.75 to +503.99)	−225.43 (−654.48 to +203.63)	0.303
Somewhat or not very close relationship (intervention *n* = 46, control *n* = 46)	+63.03 (−332.27 to +458.33)	−160.66 (−540.42 to +219.09)	+223.69 (−184.25 to +631.64)	0.283

Significant *P* values indicated in bold. All models controlled for SNMs' age, sex, education, relationship status, employment status, self-rated health, trial participants' program attendance, and baseline value of outcome of interest as fixed effects. Trial program sites and trial participants' identification numbers treated as random effects in all models.
MET, metabolic equivalent; SNM, social network member.

TABLE 5 Adjusted least square means for between-group comparisons: diet changes via REAP-S sum score

	Within-group change (intervention)	Within-group change (control)	Between-group difference (intervention - control)	
	Mean change (95% CI)	Mean change (95% CI)	Mean change (95% CI)	*P* value
Among all SNMs				
Very close relationship (intervention *n* = 111, control *n* = 62)	−0.23 (−1.33 to +0.86)	+0.62 (−0.70 to +1.93)	−0.85 (−2.34 to +0.64)	0.264
Somewhat or not very close relationship (intervention *n* = 72, control *n* = 61)	+0.66 (−0.72 to +2.03)	−0.97 (−2.42 to +0.48)	+1.63 (−0.08 to +3.34)	0.063
Spatially close (intervention *n* = 106, control *n* = 82)	−0.06 (−1.19 to +1.08)	+0.18 (−1.06 to +1.42)	−0.24 (−1.67 to +1.19)	0.746
Not spatially close (intervention *n* = 77, control *n* = 41)	+0.14 (−1.09 to +1.36)	−0.69 (−2.18 to +0.81)	+0.82 (−0.90 to +2.54)	0.348
SNMs who had a very close relationship with trial participants				
Spatially close (intervention *n* = 60, control In = 37)	−0.05 (−1.47 to +1.38)	+1.81 (+0.08 to +3.55)	−1.86 (−3.85 to +0.13)	0.066
Not spatially close (intervention *n* = 51, control *n* = 25)	+0.13 (−1.45 to +1.71)	+0.10 (−1.90 to +2.10)	+0.03 (−2.11 to +2.30)	0.932
SNMs who were spatially close to trial participants				
Very close relationship (intervention *n* = 57, control *n* = 37)	−0.36 (−1.76 to +1.03)	+1.37 (−0.28 to +3.02)	−1.73 (−3.64 to +0.17)	0.075
Somewhat or not very close relationship (intervention *n* = 46, control *n* = 45)	+0.51 (−1.26 to +2.28)	−0.78 (−2.50 to +0.95)	+1.29 (−0.72 to +3.29)	0.208

Significant *P* values indicated in bold. All models controlled for SNMs' age, sex, education, relationship status, employment status, self-rated health, trial participants' program attendance, and baseline value of outcome of interest as fixed effects. Trial program sites and trial participants' identification numbers treated as random effects in all models. REAP-S, Rapid Eating and Activity Assessment for Patients, shortened version; SNM, social network member.

health goals and exercise preferences; therefore, trial participants might be able to influence them to make positive behavioral changes.

The present study did not find any meaningful dietary improvements among trial participants' SNMs. This is similar to the dietary outcomes in the trial participants as well, in whom only a slight increase of the intervention group's combined intake of fruit and vegetables was observed in comparison with the control group (between-group difference [cups daily]: Δ = +0.6; 95% CI = +0.1 to +1.1; *P* = 0.026) (25). In fact, within-group analyses of the original trial found that the intervention group's combined intake of fruit and vegetables did not change significantly after the intervention (within-group difference [cups daily]: Δ = +0.1; 95% CI = −0.2 to +0.5; *P* = 0.529) (25). When intervention group participants did not make significant dietary improvements, it was very unlikely to generate a ripple effect on SNMs. Our process evaluation found that intervention group trial participants found it challenging to eat healthfully while needing to accommodate family members' food preferences (39).

This study has limitations to be noted. First, SNMs self-reported their height, weight, exercise, and diet and may have been subject to measurement error. Second, the SNM sample was referred by trial participants; therefore, our SNM sample might have been biased toward certain types of relationships, such as relationships with spouses, children, friends, or coworkers. Although the SNM sample was collected prior to randomization, future studies should include purposeful variation in relationship types to help further understand the association between SNM characteristics and intervention outcomes. Third, because our SNM sample might have known about the study, social desirability bias might exist in self-reporting data. Fourth, the majority of the SNMs were female and white, with excess weight and obesity. Findings might not be generalizable to other populations. Fifth, although this study provides important insights into factors that influence an intervention's ripple effects, mechanisms that contributed to SNMs' weight loss and behavior changes are still unclear. Future studies should examine how social dynamics contribute to weight loss and behavior change, particularly among individuals who are spatially distant but have a very close relationship. Findings will inform how to best use social networks to generate bigger intervention impacts. Finally, because this was an exploratory secondary analysis of the original SHHC study, we did not adjust *P* values for multiple testing; this might have increased the type 1 error rate (40). Further hypothesis testing is needed in future studies.

Conclusion

Our study contributes a new understanding related to ripple effects, demonstrating that relationship closeness, rather than spatial closeness, plays an important role in influencing SNMs' weight and health behaviors. Exploring ways to engage SNMs who are in close relationships with intervention participants, independent of spatial proximity, could improve the reach, impact, and cost-effectiveness of programs.O

Acknowledgments

We are grateful to the rural women and their SNMs who participated in our study and the extension agents from Montana and New York who recruited them, as well as Judy Ward, Kristin Pullyblank, Urshila Sriram, Isabel Lu, Shuling Liu, and Gail Rogers for their work and contributions to this research. Researchers who want to access trial data and other accompanying documents (e.g., informed consent form, statistical analysis plan) should contact the principal investigator (RAS-F; r.seguin-fowler@ag.tamu.edu) with a methodologically sound proposal for further analyses. The original trial protocol was previously published in *BMC Public Health* (23).

Funding agencies: This research was funded by grant R01 HL120702 from the NIH and the National Heart, Lung and Blood Institute and by the US Department of Agriculture, National Institute of Food and Agriculture, Hatch/Multi State (1013938). The funders/sponsors had no role in the design or conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Disclosure: The authors declared no conflict of interest.

Author contributions: Study concept and design: RAS-F. Acquisition, analysis, or interpretation of data: BKL, MLG, GE, MRD, SCF, DS, MEN, LCP, SAP, and RAS-F. Drafting of the manuscript: BKL. Critical revision of the manuscript for important intellectual content: BKL, MLG, GE, MRD, SCF, DS, MEN, LCP, SAP, and RAS-F. Statistical analysis: BKL and SAP. Obtained funding: RAS-F. Administrative, technical, or material support: MLG, GE, MRD, SAP, and RAS-F. Study supervision: MLG and RAS-F.

Clinical trial registration: ClinicalTrials.gov identifier NCT02499731.

References

1. Lundeen E, Park S, Pan L, O'Toole T, Matthews K, Blanck H. Obesity revalence among adults living inmetropolitan and nonmetropolitan counties — United States, 2016. *MMWR Morb Mortal Wkly Rep*;2018;67:653-658.
2. Bove CF, Olson CM. Obesity in low-income rural women: qualitative insights about physical activity and eating patterns. *Women Health* 2006;44:57-78.
3. Dye CJ, Cason KL. Perceptions of older, low-income women about increasing intake of fruits and vegetables. *J Nutr Elder* 2006;25:21-41.
4. Morgan EH, Graham ML, Folta SC, Seguin RA. A qualitative study of factors related to cardiometabolic risk in rural men. *BMC Public Health* 2016;16:305. doi:10.1186/s12889-016-2977-1
5. Wilcox S, Castro C, King AC, Housemann R, Brownson RC. Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *J Epidemiol Community Health* 2000;54:667-672.
6. Vilaro MJ, Barnett TE, Mathews A, Pomeranz J, Curbow B. Income differences in social control of eating behaviors and food choice priorities among southern rural women in the US: a qualitative study. *Appetite* 2016;107:604-612.
7. Gustafson A, McGladrey M, Liu E, et al. Examining key stakeholder and community residents' understanding of environmental influences to inform place-based interventions to reduce obesity in rural communities, Kentucky 2015. *J Rural Health* 2018;34:388-395.
8. McGannon KR, Busanich R, Witcher CSG, Schinke RJ. A social ecological exploration of physical activity influences among rural men and women across life stages. *Qual Res Sport Exerc Health* 2014;6:517-536.
9. Peterson J, Schmer C, Ward-Smith P. Perceptions of Midwest rural women related to their physical activity and eating behaviors. *J Community Health Nurs* 2013;30:72-82.
10. Meyler D, Stimpson JP, Peek MK. Health concordance within couples: a systematic review. *Soc Sci Med* 2007;64:2297-2310.
11. Cunningham SA, Vaquera E, Maturo CC, Venkat Narayan KM. Is there evidence that friends influence body weight? A systematic review of empirical research. *Soc Sci Med* 2012;75:1175-1183.
12. Aarts F, Radhakishun NN, van Vliet M, et al. Gastric bypass may promote weight loss in overweight partners. *J Am Board Fam Med* 2015;28:90-96.
13. Woodard GA, Encarnacion B, Peraza J, Hernandez-Boussard T, Morton J. Halo effect for bariatric surgery collateral weight loss in patients' family members. *Arch Surg* 2011;146:1185-1190.
14. Willmer M, Berglind D, Thorell A, et al. Changes in BMI and psychosocial functioning in partners of women who undergo gastric bypass surgery for obesity. *Obes Surg* 2015;25:319-324.
15. Golan R, Schwarzfuchs D, Stampfer MJ, Shai I; DIRECT group. Halo effect of a weight-loss trial on spouses: the DIRECT-Spouse study. *Public Health Nutr* 2010;13:544-549.
16. Gorin AA, Lenz EM, Cornelius T, Huedo-Medina T, Wojtanowski AC, Foster GD. Randomized controlled trial examining the ripple effect of a nationally available weight management program on untreated spouses. *Obesity (Silver Spring)* 2018;26:499-504.
17. Schierberl Scherr AE, McClure Brenchley KJ, Gorin AA. Examining a ripple effect: do spouses' behavior changes predict each other's weight loss? *J Obes* 2013:297268. doi:10.1155/2013/297268
18. Pachucki MA, Jacques PF, Christakis NA. Social network concordance in food choice among spouses, friends, and siblings. *Am J Public Health* 2011;101:2170-2177.
19. Leahey TM, Larose JG, Fava JL, Wing RR. Social influences are associated with BMI and weight loss intentions in young adults. *Obesity (Silver Spring)* 2011;19:1157-1162.
20. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med* 2007;357:370-379.
21. Auld MC. Effect of large-scale social interactions on body weight. *J Health Econ* 2011;30:303-316.
22. Henning-Smith C, Moscovice I, Kozhimannil K. Differences in social isolation and its relationship to health by rurality. *J Rural Health* 2019;35:540-549.
23. Seguin RA, Eldridge G, Graham ML, Folta SC, Nelson ME, Strogatz D. Strong Hearts, Healthy Communities: a rural community-based cardiovascular disease prevention program. *BMC Public Health* 2016;16:86. doi:10.1186/s12889-016-2751-4
24. Seguin RA, Paul L, Folta SC, et al. Strong Hearts, Healthy Communities: a community-based randomized trial for rural women. *Obesity (Silver Spring)* 2018;26:845-853.
25. Folta SC, Paul L, Nelson ME, et al. Changes in diet and physical activity resulting from the Strong Hearts, Healthy Communities randomized cardiovascular disease risk reduction multilevel intervention trial. *Int J Behav Nutr Phys Act* 2019;16:91. doi:10.1186/s12966-019-0852-z
26. Antonucci T, Akiyama H. Social networks in adult life and a preliminary examination of the convoy model. *J Gerontol* 1987;42:519-527.
27. Burke TJ, Dailey SL, Zhu Y. Let's work out: communication in workplace wellness programs. *Int J Workplace Health Manag* 2017;10:101-115.
28. Tabak RG, Hipp JA, Marx CM, Brownson RC. Workplace social and organizational environments and healthy-weight behaviors. *PLoS One* 2015;10:e0125424. doi:10.1371/journal.pone.0125424
29. The Food Trust. The grocery gap. http://thefoodtrust.org/what-we-do/administrative/hffi-impacts/the-grocery-gap. Accessed July 15, 2019.
30. Lam O, Broderick B, Toor S. How far Americans live from the closest hospital differs by community type. Pew Research Center website. https://www.pewresearch.org/fact-tank/2018/12/12/how-far-americans-live-from-the-closest-hospital-differs-by-community-type/. Published December 12, 2018. Accessed July 15, 2019.
31. Heinrich M; Joint Economic Committee Democrats. Investing in Rural America: Bringing Progress and Economic Opportunity to Rural Communities. https://www.jec.senate.gov/public/_cache/files/ed5bf0b5-dd14-473f-acdc-fd86ba98a6e1/investing-in-rural-america.pdf. Published June 2018. Accessed July 15, 2019.
32. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35:1381-1395.
33. IPAQ scoring protocol. International Physical Activity Questionnaire website. https://sites.google.com/site/theipaq/scoring-protocol. Accessed July 19, 2019.
34. Gans KM, Risica PM, Wylie-Rosett J, et al. Development and evaluation of the nutrition component of the Rapid Eating and Activity Assessment for Patients (REAP): a new tool for primary care providers. *J Nutr Educ Behav* 2006;38:286-292.
35. Segal-Isaacson CJ, Wylie-Rosett J, Gans KM. Validation of a short dietary assessment questionnaire: the Rapid Eating and Activity Assessment for Participants Short Version (REAP-S). *Diabetes Educ* 2004;30:774-781.
36. Jakobsen JC, Gluud C, Wetterslev J, Winkel P. When and how should multiple imputation be used for handling missing data in randomised clinical trials - a practical guide with flowcharts. *BMC Med Res Methodol* 2017;17:162. doi:10.1186/s12874-017-0442-1
37. Garson G. *Missing Values Analysis and Data Imputation*. Statistical Associates Publishers; 2015.
38. Hess JM, Davis SM. Increasing community-level social support for physical activity in the rural Southwestern United States [published May 21, 2019]. *Z Gesundh Wiss*. doi:10.1007/s10389-019-01085-1
39. Sriram U, Sandreuter K, Graham M, et al. Process evaluation of Strong Hearts, Healthy Communities: a rural community-based cardiovascular disease prevention program. *J Nutr Educ Behav* 2019;51:138-249.
40. Bender R, Lange S. Adjusting for multiple testing—when and how? *J Clin Epidemiol* 2001;54:343-349.