Effects of diet and exercise on weight-related outcomes for breast cancer survivors and their adult daughters: An analysis of the DAMES trial

Danielle B. Tometich, MS[1]

Catherine E. Mosher, PhD[1]

Joseph G. Winger, MS[1]

Hoda J. Badr, PhD[2]

Denise C. Snyder, MS, RD[3]

Richard J. Sloane, MS, MPH[4,5]

Wendy Demark-Wahnefried, PhD, RD[5,6]

[1]Department of Psychology, Indiana University-Purdue University Indianapolis, 402 North Blackford Street, LD 133, Indianapolis, IN 46202; [2]Department of Medicine, Baylor College of Medicine, One Baylor Plaza, Houston, TX 77030; [3]Duke University School of Medicine, DUMC 2713, Durham, NC 27710; [4]Duke Center for the Study of Aging and Human Development, Duke University Medical Center, Duke Box 3003, Durham, NC 27710; [5]Duke University School of Nursing, Durham, North Carolina; [6]Department of Nutrition Sciences, University of Alabama at Birmingham, 1824 6th Ave. S., WTI 102M, Birmingham, AL 35294.

Correspondence: Danielle Tometich, Department of Psychology, Indiana University-Purdue University Indianapolis, 402 North Blackford Street, LD 133, Indianapolis, IN 46202. Telephone: (317) 278-4005. Fax: (317) 274-6756. Email: dbtometi@iupui.edu

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Abstract

Purpose: Few trials have aimed to promote diet and exercise behaviors in both cancer survivors and their family members and examine their associations with weight-related outcomes. We conducted a secondary analysis to examine associations between change in diet and exercise behaviors and weight-related outcomes for overweight breast cancer survivors and their overweight adult daughters in the DAMES (Daughters And MothErS Against Breast Cancer) randomized trial.

Methods: The DAMES trial assessed the impact of two iteratively tailored, mailed print diet and exercise interventions against standard brochures over a 12-month period. This analysis examined change in diet and exercise behaviors and weight-related variables from baseline to post-intervention for the 50 breast cancer survivors and their adult daughters randomized to the intervention arms. To reduce the potential for Type II error in this pilot, p-values < 0.10 were considered statistically significant.

Results: For mothers, change in diet quality was uniquely related to change in BMI (β=-0.12, p=0.082), weight (β=-0.12, p=0.060), and waist circumference (β=-0.38, p=0.001), whereas change in caloric intake was related to waist circumference (β=0.21, p=0.002). For daughters, change in caloric intake was related to change in waist circumference (β=0.12, p=0.055). However, change in diet quality was not associated with weight-related outcomes in daughters. Additionally, change in exercise was not associated with weight-related outcomes in mothers or daughters.

Conclusions: Findings support mail-based and other tailored interventions for weight loss in this population, with an emphasis on diet quality for breast cancer survivors and caloric intake for their adult daughters.

Keywords: Diet, Exercise, Interventions, Breast neoplasms, First-degree relatives, Weight loss

Introduction

The number of breast cancer survivors is steadily increasing with over 3 million survivors in the U.S. alone [1]. Although this is promising, many survivors are obese and at increased risk for comorbidities such as cardiovascular disease, diabetes, and secondary cancers [2, 3]. Adult daughters of breast cancer survivors also face increased health risks, including an up to threefold increased risk of breast cancer compared to women without this family history [4, 5], and being overweight or obese further increases their risk of developing various cancers [2]. Therefore, weight loss interventions may help mitigate health risks for these women.

Results from randomized controlled trials (RCTs) with cancer and non-cancer samples suggest that improved diet is associated with weight loss [6-9], whereas improved exercise is associated with better mental health, physical function, body composition, and weight loss maintenance [10-16]. Other findings suggest that interventions may improve health behaviors among first-degree relatives of cancer survivors [17-19]; however, associations between change in specific health behaviors and weight-related outcomes were not assessed.

A dyadic intervention approach may leverage the close relationship between a cancer survivor and a family member to facilitate lifestyle changes and weight loss. This approach has been successfully used in non-cancer samples with mothers and their child or adolescent daughters [14, 20-23]. To our knowledge, the first lifestyle intervention trial to focus on mothers with a cancer history and their daughters was the Daughters And MothErS Against Breast Cancer (DAMES) study [24]. The DAMES trial assessed the feasibility of two tailored mailed print weight loss interventions against a standardized control in overweight or obese female breast cancer survivors and their overweight or obese daughters. Thus, DAMES aimed to capitalize on the "teachable moment" of cancer survivorship [25] and the mother-daughter bond to promote intergenerational lifestyle change and reduce cancer risk [26]. Social Cognitive Theory states that social support and self-efficacy are important factors involved in health behavior change [27]. It has been theorized that mothers may increase their daughters' self-efficacy for overcoming perceived barriers to health behavior change by offering various forms of support (e.g., advice, nurturance) [26]. Consistent with this theorizing, one study with a non-cancer sample found that greater social connectedness between mothers and daughters was associated with greater similarity between them on sedentary behavior and weight [28].

Identifying the degree to which changes in health behaviors are associated with weight-related outcomes in dyadic interventions could inform modifications to these interventions to enhance their efficacy. In this study, we aimed to examine these associations for mother-daughter dyads enrolled in DAMES, a group at elevated risk of cancer and other health problems [2-5]. Based on prior diet and exercise research with breast cancer survivors [6, 10-13, 29] and non-cancer samples [7, 9, 14, 15, 30], we hypothesized that improved diet quality and decreased daily caloric intake after the year-long intervention would be associated with better weight-related outcomes (i.e., body mass index [BMI], weight, and waist circumference) for both mothers and daughters, whereas change in exercise would have less of an association with weight-related outcomes for either dyad member. An exploratory aim was to compare mothers' and daughters' change in health behaviors and weight-related outcomes from baseline to post-intervention.

Methods

Participants

All trial procedures were approved by the Institutional Review Boards of Duke University and the University of Texas MD Anderson Cancer Center (UTMDACC). Participants were primarily identified through cancer registries at Duke University and UTMDACC and also were self-referred through recruitment flyers, community presentations, webpages, and listservs. Eligible survivors had been diagnosed with AJCC stage 0 to III breast cancer within the past 5 years and had completed primary treatment. In addition, eligible survivors did not have evidence of progressive disease or second primaries and had a biological daughter who was at least 21 years of age. Eligible daughters had no cancer history (exception: non-melanoma skin cancer). Inclusion criteria for mothers and daughters were: (1) a BMI of 25 kg/m^2 to 39.9 kg/m^2; (2) no contraindications to unsupervised exercise or a diet high in fruits and vegetables; (3) English language literacy and completion of at least the sixth grade; (4) community resident of the U.S., Puerto Rico, or Guam; (5) not currently exercising at least 150 minutes per week; and (6) not currently participating in a weight loss program.

Participant recruitment, consent, and randomization procedures were described in a previous report [24]. Ultimately, 68 mother-daughter dyads were randomized to one of three year-long study conditions: the individually tailored intervention (n=25), team tailored intervention (n=25), or attention control group (n=18). Sixty-three of the randomized dyads (93%) completed a post-intervention assessment (i.e., 12 months post-baseline).

Procedure

The DAMES trial tested year-long diet and exercise interventions, and all study procedures have been published elsewhere [24]. Briefly, participants in all study groups received print informational mailings every two months along with brief surveys, for a total of six mailings over the course of the year. All participants also received a workbook that was personalized with their name and weight loss goals. Participants assigned to the individually-tailored newsletters received reinforcement regarding their progress on diet, exercise and weight loss goals and guidance on overcoming barriers. Those assigned to the team-tailored intervention received similar feedback on themselves and their dyad partner as well as tips for eliciting and providing support. Participants in both intervention groups also received various materials (e.g., logbooks) to promote self-monitoring. Bimonthly mailings in the attention control group were standard brochures on weight management in the public domain.. In addition, control participants received bimonthly surveys assessing the perceived helpfulness of the brochures. Compared to the control group, the intervention groups showed statistically and clinically significant reductions in BMI, body weight, and waist circumference and increased exercise post-intervention; however, there were no differences observed between the team vs. individually-tailored interventions in these or other outcomes, including diet quality and caloric intake;[24]thus, the data on these two groups were pooled for analysis

Measurements

Exercise. The Leisure Time Exercise Questionnaire of Godin et al. [31, 32] was used to assess exercise at baseline and post-intervention. Participants were asked to report the number of times over the past week that they engaged in mild, moderate, and strenuous exercise and the average duration of the exercise each time. Minutes of mild exercise were excluded from analyses because activities that typically qualify as mild exercise are not typically associated with the health benefits of moderate to strenuous exercise [31]. This questionnaire has adequate test-retest reliability and concurrent validity [32].

Calories and diet quality. Two random 24-hour diet recall assessments were conducted with the interactive Nutrition Data System Revised software (NCC Food and Nutrient Database System Version 2006, Minneapolis, MN) to assess total daily energy intake (i.e., calories) and diet quality at baseline and post-intervention. A Healthy Eating Index (HEI) 2005 score [33] was calculated with higher scores indicating better diet quality [34]. The HEI-2005 has shown good predictive validity [33].

Weight-related outcomes. Participants' body weight, height, and waist circumference were objectively measured at baseline and post-intervention. These measurements were completed in the clinic or at participants' homes by a visiting nurse using calibrated scales and identical protocols. Body mass index (BMI) (kg/m^2) was calculated based on height and weight.

Statistical analysis

The purpose of this study was to examine associations between change in diet and exercise behaviors and weight-related outcomes for dyads receiving the team or individual interventions; thus, data from the attention control group were not examined. Additionally, no significant differences were found between the team and individual intervention groups on diet and exercise behaviors or weight-related outcomes [24]. Therefore, data from participants in the two intervention groups were collapsed for all analyses.

Preliminary analyses were conducted using Statistical Package for the Social Sciences (SPSS) 23.0. Pearson correlations were computed to examine relationships between residualized change scores for diet and exercise behaviors and residualized change scores for weight-related outcomes. Residualized change scores were used to account for the variance in post-intervention values that could be predicted by baseline values [35].

We then ran cross-lagged measured variable panel models in LISREL 8.8 to examine associations between residualized changes in diet and exercise and change in weight-related outcomes from baseline to post-intervention (i.e., 12 months post-baseline) in mothers and daughters. Two predictors (i.e., change in exercise and diet quality, change in calories and diet quality, or change in calories and exercise) and one weight-related outcome (i.e., BMI, weight, or waist circumference) were included in each model for a total of nine examined models. This approach allowed us to examine the independent effect of each predictor while controlling for baseline levels of the respective outcomes and correlated errors of the dyadic data structure. Age was considered as a possible covariate, but was not correlated with any variables of interest. Model fit was examined with the χ^2 statistic and the root mean square error of approximation (RMSEA) statistic. A non-significant χ^2 statistic suggests that the hypothesized model is adequate because the estimated and observed relationships do not differ [36]. The RMSEA statistic also estimates the absolute fit of the model while adjusting for model parsimony. RMSEA values below 0.06 indicate good fit [37]. Given the potential for Type II error due to sample size, the significance criterion for effects of change in exercise and diet on weight-related outcomes was set at $\alpha < 0.10$.

Finally, we compared mothers' and daughters' residualized change in health behaviors and weight-related outcomes from baseline to post-intervention by conducting dependent samples t-tests.

Results

Preliminary analyses

Participant demographics, medical characteristics, and mean levels of the pre-intervention health behaviors and weight-related outcomes appear in Table 1. Paired samples t-tests were used to compare health behaviors and weight-related outcomes between mothers and daughters at baseline. Only HEI scores differed between these two groups; mothers reported significantly better diet quality than daughters, $t(49)=4.07$, $p<0.001$.

Twelve outliers were found, and a Winsorization transformation was employed to reduce the influence of these extreme values [38]. All of the variables were within recommendations for normality [36].

Means, standard deviations, and Pearson correlations for residualized change in main study variables appear in Table 2. For mothers, improved diet quality was associated with decreased waist circumference, but was unrelated to change in BMI or weight. Additionally, changes in mothers' daily caloric intake and exercise were not significantly associated with change in any weight-related outcomes. For daughters, decreased daily caloric intake was only associated with reduced waist circumference. Finally, change in daughters' diet quality and exercise were not associated with change in any weight-related outcomes.

Primary analyses

BMI. Our first model examined the effects of change in exercise and diet quality on change in mothers' and daughters' BMI from baseline to post-intervention. The hypothesized model showed good fit to the combined team and individual intervention group data, $\chi^2(22, N=50)=6.86$, $p=0.99$, RMSEA=0.00, 90% confidence interval (CI): 0.00, 0.00, and results supported some of the hypothesized pathways (see Fig. 1). There was a significant independent effect for change in mothers' diet quality after controlling for change in mothers' exercise, such that improved diet quality was associated with lower BMI; however, this effect was not found for daughters.

We then examined the independent effects of change in exercise and daily caloric intake on change in mothers' and daughters' BMI. Although the hypothesized model showed good fit to the data, $\chi^2(22, N=50)=11.22$, $p=0.97$, RMSEA=0.00, 90% CI: 0.00, 0.00, change in exercise and daily caloric intake were unrelated to change in mothers' or daughters' BMI.

We also examined the independent effects of change in daily caloric intake and diet quality on change in mothers' and daughters' BMI. Although the hypothesized model showed good fit to the data, $\chi^2(22, N=50)=12.97$, $p=0.93$, RMSEA=0.00, 90% CI: 0.00, 0.03, change in daily caloric intake and diet quality were unrelated to change in mothers' or daughters' BMI. Across models, results also showed that mothers' and daughters' BMI were positively associated at baseline; therefore, the dyadic nature of the data was supported.

Weight. Our next model examined the independent effects of change in exercise and diet quality on change in mothers' and daughters' weight. The hypothesized model showed good fit to the data, $\chi^2(22, N=50)=7.54$, *p*=0.99, RMSEA=0.00, 90% CI: 0.00, 0.00, and results supported some of the hypothesized pathways (see Fig. 2a). There was a significant independent effect for change in mothers' diet quality, such that improved diet quality was associated with lower weight; however, this effect was not found for daughters.

We then examined the independent effects of change in daily caloric intake and diet quality on mothers' and daughters' weight. The hypothesized model showed good fit to the data, $\chi^2(22, N=50)=6.46$, $p=0.99$, RMSEA=0.00, 90% CI: 0.00, 0.00, and results supported some of the hypothesized pathways (see Fig 2b). There was a significant independent effect for change in mothers' diet quality, such that improved diet quality was associated with lower weight; however, this effect was not found for daughters.

We also examined the independent effects of change in daily caloric intake and exercise on mothers' and daughters' weight. Although the hypothesized model showed good fit to the data, $\chi^2(22, N=50)=6.54$, $p=0.99$, RMSEA=0.00, 90% CI: 0.00, 0.00, daily caloric intake and exercise were unrelated to change in mothers' or daughters' weight. Across models, mothers' and daughters' weight were significantly associated post-intervention, but were not significantly associated at baseline.

Waist circumference. Next, we examined the independent effects of change in exercise and diet quality on change in mothers' and daughters' waist circumference. The hypothesized model showed good fit to the data, $\chi^2(22, N=50)=16.78$, $p=0.76$, RMSEA=0.00, 90% CI: 0.00, 0.08, and results supported some of the hypothesized pathways (see Fig. 3a). There was a significant independent effect for mothers' diet quality, such that improved diet quality was associated with reduced waist circumference; however, this effect was not found for daughters. Additionally, exercise showed no significant relationship with mothers' or daughters' waist circumference.

We then examined the independent effects of change in daily caloric intake and diet quality on change in mothers' and daughters' waist circumference. The hypothesized model showed adequate fit to the data, $\chi^2(22, N=50)=30.46$, $p=0.11$, RMSEA=0.09, 90% CI: 0.00, 0.16, and results supported some of the hypothesized pathways (see Fig. 3b). Specifically, there were significant independent effects for change in mothers' caloric intake and diet quality, such that decreased caloric intake and improved diet quality were independently associated with smaller waist circumferences. There was also a significant independent effect for change in daughters' calories, such that decreased caloric intake was associated with smaller waist circumferences. However, change in daughters' diet quality was unrelated to their waist circumference.

Lastly, we examined the independent effects of daily caloric intake and exercise on change in mothers' and daughters' waist circumference. The hypothesized model showed good fit to the data, $\chi^2(22, N=50)=20.13$, $p=0.57$, RMSEA=0.00, 90% CI: 0.00, 0.11, and results supported some of the hypothesized pathways (see Fig. 3c). Specifically, there was a significant independent effect for change in daughters' calories, such that decreased caloric intake was associated with smaller waist circumferences. However, this effect was not found for mothers. Exercise was unrelated to change in mothers' or daughters' waist circumference. Across models, mothers' and daughters' waist circumferences were not significantly associated at baseline or post-intervention.

Exploratory analyses

Finally, we compared mothers' and daughters' residualized change in exercise, diet quality, caloric intake, BMI, weight, and waist circumference (see Table 3). Change in all of these variables did not differ between mothers and daughters.

Discussion

This study examined relationships between change in diet and exercise behaviors and weight-related outcomes in the first dyadic lifestyle intervention trial for overweight breast cancer survivors and their overweight adult daughters. Identifying the effects of specific health behaviors on weight management informs future interventions to promote intergenerational lifestyle change following a cancer diagnosis. As predicted, among mothers, improved diet quality and decreased daily caloric intake were associated with better weight-related outcomes. However, among daughters, dietary factors and exercise were not associated with weight-related outcomes, with the exception of a relationship between decreased daily caloric intake and reduced waist circumference. These differential effects were present for mothers and daughters even though their changes in health behaviors and weight-related outcomes did not significantly differ. Also consistent with hypotheses, increased exercise was not associated with any weight-related outcome for mothers or daughters.

Associations between improved diet quality and reduced BMI, weight, and waist circumference among mothers are consistent with prior RCT evidence of dietary influences on weight-related outcomes in overweight cancer survivors [6, 29]. The current results extend prior research by examining relationships between diet and weight-related outcomes in a dyadic intervention trial. Whereas previous RCTs with overweight adults suggest a link between dietary factors and weight-related outcomes [8, 15], only waist circumference was associated with both improved diet quality and decreased caloric intake among breast cancer survivors and decreased caloric intake among daughters in the current trial. Waist circumference was the most sensitive measure of adiposity in the DAMES trial [24] and other research with similarly-aged women [40] and, therefore, might have been more affected by diet quality and reduced caloric intake than other weight-related outcomes.

Findings regarding diet quality differed between mothers and daughters. Whereas mothers' improved diet quality was associated with reduced BMI, weight, and waist circumference, diet quality was not significantly associated with any weight-related outcomes for daughters. Diet quality may become more important with increased age as caloric needs diminish, which typically occurs for healthy women between age 51-55 [41]. Caloric needs may be further reduced by an accelerated aging effect of cancer treatments [42]. Therefore, diet quality may have impacted weight-related outcomes for mothers (mean age: 63) more so than daughters (mean age: 36) in the current study due to the effects of aging and cancer treatment. Alternatively, daughters in the current study may have over-reported improvement in their diet quality due to social desirability bias.

As hypothesized, exercise was not significantly associated with weight-related outcomes for mothers or daughters. Exercise has shown inconsistent associations with weight loss in both cancer and non-cancer samples [43-45]. However, the importance of exercise in weight management interventions for individuals with and without a cancer history should not be discounted. Treatment-related weight gain, particularly with respect to chemotherapeutic and hormonal agents has been reported for decades, along with the rapid onset of "sarcopenic obesity" (i.e., gains in adipose tissue at the expense of lean body mass) [42, 46]. While energy intake is indisputably a key factor in weight control in healthy populations, for the management of sarcopenic obesity, exercise, particularly strength training exercise, plays a larger role in preserving lean body mass [11, 15].

Limitations of our study should be mentioned. The DAMES trial was a feasibility study with a sample size of 50 dyads across the intervention groups, which may have limited statistical power and precluded testing a model with all study variables. However, the analytic approach controlled for the dyadic nature of the data, and an exploratory approach was appropriate given the paucity of research on dyadic weight management interventions with this population. Similar effect sizes have also been obtained in other studies examining associations between self-reported diet and exercise and weight outcomes in non-cancer samples [43-45]. Additionally, although the sample was diverse with regard to race, age, and stage of non-metastatic disease, the sample represents a minority of those approached for participation. Lastly, the diet and exercise variables relied on self-report, which is subject to biases such as inaccurate recall. However, attempts to minimize bias were made throughout the study. For example, participants were provided with materials such as logbooks to increase the accuracy of their self-reported diet. Furthermore, weight-related outcomes were measured objectively.

Our findings inform and support future research and clinical practice using targeted and tailored weight loss interventions for breast cancer survivors and their adult daughters. Specifically, results suggest that dyadic weight loss interventions for breast cancer survivors and their adult daughters should have a dual emphasis on diet quality and caloric restriction in order to improve weight-related outcomes for both groups. However, exercise should also be included in order to preserve lean body mass and reduce disease risk. Future research with larger samples may also examine whether a greater emphasis on diet quality in materials for mothers and caloric restriction in materials for daughters would optimize weight-related outcomes. Finally, the small to negligible associations between mothers' and daughters' exercise and dietary behaviors and suboptimal response rate suggest a need to optimize the design of dyadic weight loss interventions for cancer survivors and their adult children. Increasing the reach of weight loss interventions and enhancing their efficacy for overweight cancer survivors and their family members is an important goal for future research.

Compliance with Ethical Standards

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Table 1 Sample characteristics

Variable	Mothers (*n* = 50)	Daughters (*n* = 50)
Age, mean (SD[a])	62.7 (7.7)	36.4 (8.5)
Race, no. (%)		
Non-Hispanic White	36 (72.0)	
African-American	10 (20.0)	
Hispanic White	3 (6.0)	
Asian	1 (2.0)	
Some college education, no. (%)	36 (72.0)	44 (88.0)
Income greater than $40k per year, no. (%)	33 (66.0)	38 (76.0)
AJCC[b] Disease stage, no. (%)		
0	8 (16.0)	
I	20 (40.0)	
II	18 (36.0)	
III	3 (6.0)	
Missing	1 (2.0)	
Months since cancer diagnosis, mean (SD)	24.6 (16.0)	
Cancer treatment history, no. (%)		
Chemotherapy	30 (60.0)	
Hormonal therapy	32 (64.0)	
Radiotherapy	31 (62.0)	
Lumpectomy	26 (52.0)	
Mastectomy	23 (46.0)	
Baseline levels of the outcomes, mean (SD)		
BMI[c], kg/m^2	31.2 (3.3)	32.5 (5.9)
Weight, kg	82.2 (9.7)	87.3 (17.8)
Waist circumference, inches	38.2 (3.6)	38.0 (5.0)
Exercise[d]	31.7 (58.3)	27.8 (46.1)
Calories[e]	1629.6 (533.1)	1733.6 (561.5)
Diet quality[f]	60.1 (10.1)	53.7 (9.4)

[a]SD = standard deviation. [b]AJCC = American Joint Committee on Cancer staging system. [c]BMI = Body Mass Index. [d]Exercise included minutes of moderate and strenuous physical activity over the past week. [e]Calories were total daily energy intake. [f]Diet quality was measured with the Healthy Eating Index (HEI-2005).

Table 2 Pearson correlations, means, and standard deviations for change[a] in diet and exercise behaviors and weight-related outcomes

	1	2	3	4	5	6	7	8	9	10	11	12
1. Exercise[b] change for mothers												
2. Exercise change for daughters	0.05											
3. Diet quality[c] change for mothers	-0.07	0.02										
4. Diet quality change for daughters	0.32*	0.18	-0.03									
5. Calorie[d] change for mothers	0.03	0.13	-0.18	-0.01								
6. Calorie change for daughters	-0.44*	-0.05	-0.06	-0.07	0.15							
7. BMI[e] change for mothers	-0.15	-0.28†	-0.23	-0.31*	0.07	0.12						
8. BMI change for daughters	-0.09	-0.18	-0.05	-0.22	0.11	0.19	0.34*					
9. Weight change for mothers	-0.16	-0.26†	-0.23	-0.29†	0.10	0.14	0.99*	0.33*				
10. Weight change for daughters	-0.11	-0.18	0.06	-0.23	-0.10	0.20	0.31*	0.99*	0.31*			
11. Waist circumference change for mothers	-0.15	-0.04	-0.40*	-0.21	0.23	0.33*	0.59*	0.23	0.64*	0.23		
12. Waist circumference change for daughters	-0.25	-0.15	0.17	0.03	-0.24	0.36*	0.21	0.60*	0.22	0.59*	0.20	

*n*s=42-50 due to missingness. [a]Residualized change from baseline to immediately after the 12-month intervention. [b]Exercise included minutes of moderate and strenuous physical activity over the past week. [c]Diet quality was measured with the Healthy Eating Index (HEI-2005). [d]Calories were total daily energy intake. [e]BMI = body mass index.
†$p < 0.10$. *$p < 0.05$.

Table 3 Comparisons of mothers' and daughters' residualized change in health behaviors and weight-related outcomes

Mothers' change – Daughters' change	Mean	*SD*[b]	95% Confidence Interval for the Difference		*t*	*df*	*p*
			Lower	Upper			
Exercise	1.12	100.67	-29.49	31.73	0.07	43	0.94
Diet quality	0.22	14.85	-4.30	4.73	0.10	43	0.92
Caloric intake	-39.62	557.44	-209.10	129.86	-0.47	43	0.64
BMI[a]	-0.14	2.61	-0.93	0.66	-0.35	43	0.73
Weight	-0.49	7.09	-2.65	1.66	-0.46	43	0.65
Waist circumference	-0.17	2.84	-1.07	0.73	-0.39	40	0.70

[a]BMI = body mass index. [b]SD = standard deviation.

Fig. 1 – 3c Standardized regression coefficients are presented. Paths represented with solid lines and * are significant at $p < 0.05$, solid lines and † are significant at $p < 0.10$, and dashed lines are non-significant

Fig. 1 Model of the effects of change in exercise and diet quality on change in body mass index (BMI)

Fig. 2a Model of the effects of change in exercise and diet quality on change in weight

Fig. 2b Model of the effects of change in caloric intake and diet quality on change in weight

Fig. 3a Model of the effects of change in exercise and diet quality on change in waist circumference

Fig. 3b Model of the effects of change in caloric intake and diet quality on change in waist circumference

Fig. 3c Model of the effects of change in exercise and caloric intake on change in waist circumference