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Comparison of Dietary and Physical Activity Changes Across Family-Based Maintenance Treatments for Childhood Overweight and Obesity

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Abstract

Due to the pervasiveness of obesity-promoting environmental factors, interventions for childhood obesity must address a child's socioenvironmental context in order to facilitate healthful weight control in both the short- and long-term. Patterns of change in key energy balance behaviors (i.e., caloric intake, diet quality, physical activity, and screen time) were examined across family-based behavioral treatment (FBT) and three maintenance conditions (i.e., two doses (HIGH or LOW) of an enhanced social-facilitation maintenance intervention (SFM+) and CONTROL) to extend our understanding of mediators of the enhanced effect of SFM+ on child percentage overweight. Analyses were carried out in a multistage manner using mixed effect models. Results indicate significant curvilinear effects of time for all variables

(Caloric intake: β = 8.04 95% CI [6.53, 10.09], *t* = 9.11; Diet quality: β = -0.18, 95% CI [-0.24, -0.12], *t* = -6.08; Physical activity: β = 0.19, 95% CI [0.07, 0.30], *t* = 3.16; Screen time: β = 0.14, 95% CI [-1.63, 6.94], *t* = 6.48). Although significantly greater reductions in screen time within HIGH SFM+ as compared to CONTROL (β = -0.41, 95% CI [-0.73, -0.09], *t* = -2.49) were found, after adjustment for multiple comparisons, the interaction was no longer significant (*p* = 1.00). Future directions include the identification and exclusion of implausible reporters of dietary intake, investigation into measures of dietary quality more reflective of food classifications within FBT, and examination of changes in social support throughout treatment. Our findings may provide some support for the importance of screen time reduction in successful healthy behavior change and weight loss maintenance.

Introduction

Rates of childhood obesity have quadrupled over the last fifty years and the prevalence of severe obesity among children (BMI ≥ 120% of the 95th percentile according to the Center for Disease Control and Prevention's (CDC) 2000 age- and gender-specific growth charts) has increased nearly six-fold (CDC, 2000; Fryar, et al, 2018). Obesity is a multifactorial disease linked to both genetic and physiological (e.g., metabolism, hormones, etc.) determinants, however, these factors offer no rationale for the rapid development of the obesity epidemic (Albuquerque, et al., 2017; Ang, et al., 2012; Budd, et al., 2006). Dramatic shifts in key environmental contributors to both dietary intake and physical activity, concurrent with the surge in obesity rates, have been widely implicated instead (Binkley, et al., 2000). Portion sizes have increased steadily since the 1970s, with ready-to-eat food portions now drastically and universally exceeding standard USDA and FDA portion sizes, some by as much as 700% (e.g., an average chocolate chip cookie; Young & Nestle, 2002). The proportion of food consumed away from the home over this time period nearly doubled and the consumption of fast food specifically increased five-fold (Bowman, 2004; Guthrie, et al., 2002). These foods reliably contain more calories, total fat, and saturated fat than a typical meal prepared at home (Guthrie, et al., 2002). Dietary intake from sugar sweetened beverages has increased 135% since the 1970s, with children's consumption from such sources now estimated at approximately 270 calories per day (Han & Powell, 2012). Comparable trends have been documented for candy, desserts, pizza, and salty snacks, with 40% of children's total caloric consumption now attributed to empty calories (e.g., calories derived from foods containing little or no nutritional value; Dunford & Popkin, 2018; Piernas & Popkin, 2010; Reedy, et al., 2010). Moreover, rates of physical activity declined dramatically over the past fifty years (Brownson, et al, 2005; Ng & Popkin, 2012). Each of these factors can contribute to an adversely positive energy balance which, according to the well-established energy balance framework (e.g., weight change is the result of discrepancies between energy intake and energy expenditure), would result in sizable surges in weight over time (Hill at al, 2012; Tam & Ravussin, 2012).

Due to the pervasiveness of obesity-promoting environmental factors such as these, interventions for childhood overweight and obesity must address the obesogenic context in which children learn, live and play in order to facilitate healthful weight control in both the short- and long-term. Family-based behavioral treatment (FBT) is a comprehensive, evidence-based pediatric weight management intervention that targets both child and parent and promotes small, successive changes in participants' behaviors using established behavioral-change strategies (e.g., reinforcement, stimulus control, preplanning) to aid families in establishing healthier eating and activity habits (Altman & Wilfley, 2015; Wilfley, et al., 2007b). Wilfley, et al., (2007a) demonstrated that the addition of a socioenvironmental maintenance intervention following FBT significantly improved children's long-term weight outcomes compared to FBT alone. Enhanced social-facilitation maintenance (SFM+) is designed to optimize the durability and generalizability of the changes facilitated through FBT via practice of healthy behavior change across multiple social and environmental contexts (e.g., within the home, school, work, restaurants, with friends) creating an environment in which healthy choices related to dietary intake and physical activity become the default choices, a marked shift from the obesity promoting societal-changes of the last fifty years. A follow up study by Wilfley, et al. (2017), comparing two doses of SFM+ —HIGH which consisted of 32 weekly sessions and LOW which consisted of 16 every-other-week sessions—to a rigorous weight management education intervention (CONTROL), clarified questions about content, dose, and mediators of outcome. Children in HIGH demonstrated the greatest reductions in child percentage overweight with a 3.37 decrease compared to LOW ($p = 0.02$) and a decrease of 6.71 compared to CONTROL ($p < 0.001$; Wilfley, et al., 2017). Intermediate reductions were exhibited for children in LOW with a decrease of 3.34 as compared to CONTROL. Moreover, socioenvironmental components of SFM+ were identified as mediators of the effect of HIGH vs CONTROL on child percentage overweight over time. Monitoring and goal setting accounted for 42% of the superior effect of HIGH, the establishment of a healthy home environment and a family system that supports the child's healthy behaviors accounted for 27%, and a child's engagement in healthy behaviors with peers accounted for 25%. LOW vs CONTROL was mediated by monitoring and goal setting, which accounted for 50% of the superior effect of LOW. We utilized data from Wilfley, et al. (2017) within the current study.

Identification of mechanisms that mediated the superior effect of HIGH and LOW on children's weight outcomes as compared to CONTROL sheds light on the ways in which SFM+ aided children in achieving weight maintenance. As purported by the energy balance framework of overweight and obesity, behavior changes necessary for weight maintenance are those directly influencing one's energy intake and expenditure, such as dietary intake and physical activity (Hill at al, 2012; Tam & Ravussin, 2012). As such, extending our understanding of the mediational components of SFM+ through an investigation of specific weight-related behaviors (i.e., caloric intake, diet quality, physical activity, and screen time) engaged in by way of the previously identified mediators (i.e., monitoring and goal setting, the establishment of a healthy home environment and a family system that supports the child's healthy behaviors, and a child's engagement in healthy behaviors with peers) may offer insight into the key energy balance behaviors achieved during FBT and maintained through SFM+ as opposed to CONTROL. This understanding of weight-related behavior change may provide a more fine-grained understanding of the ways in which SFM+ achieves its robust effects.

Within the present study, we sought to better understand how these weight-related behaviors (i.e., caloric intake, diet quality, physical activity, and screen time) change across maintenance conditions (i.e., HIGH SFM+, LOW SFM+, and CONTROL) and examine whether these changes differ by condition. It is hypothesized that children in the HIGH SFM+ condition will have greater improvements in health-promoting behaviors (i.e., diet quality and physical activity) and greater reduction of unhealthy behaviors (i.e., screen time and caloric intake) as compared to LOW SFM+ participants and, additionally, that participants in the LOW SFM+ condition will demonstrate greater improvements than participants in the CONTROL group.

Methods

Procedure

Within the current study, we utilized data from a multisite (St. Louis, MO and Seattle, WA) randomized control trial comparing two doses of an enhanced social facilitation maintenance intervention, SFM+ (HIGH and LOW), to an educational, weight management program (CONTROL) following four months of a family-based behavioral weight loss treatment (FBT). Assessments were completed at baseline (month 0), end of FBT/randomization into maintenance intervention (month 4), and end of maintenance intervention (month 12). The data for the current study were collected at those timepoints. Parents and children provided written informed consent and assent, respectively. The study was approved by each site's institutional review board.

Participants

Children aged 7-11 years with overweight or obesity (BMI $\geq 85^{th}$ percentile for age and gender) and at least one parent with overweight or obesity (BMI $\geq$ 25) were recruited through fliers, newspapers, television, radio, referrals from schools and community programs, and word of mouth. Exclusion criteria included participation in another weight control program, use of weight affecting medications, and psychiatric and medical conditions that would hinder participation. Parent/child dyads (N=172) were randomized to a maintenance condition following the completion of FBT and all were included in analyses for the current study.

Family-Based Behavioral Weight Loss Treatment (FBT)

All families received FBT, delivered via 16 weekly, 30-minute family sessions immediately followed by separate 45-minute parent and child group sessions. In brief, FBT is an evidence-based, comprehensive, behavioral weight-control intervention that targets diet, physical activity, behavioral modification techniques, and parenting skills. Relevant to dietary intake is the Traffic

Light Diet used within FBT that classifies food into red, yellow, and green categories according to energy density (calories/volume; Epstein, et al., 2008). The Traffic Light Diet aims to aid families in decreasing their consumption of energy dense, nutrient-poor foods and increasing their consumption of low-calorie, nutrient-dense foods thereby facilitating a calorie deficit necessary for weight loss. Physical activity is classified into the same red, yellow, and green categories according to energy expenditure and level of exertion; no to low, light, and moderate to vigorous, respectively. The Traffic Light Activity Plan aims to aid families in decreasing their amount of sedentary behavior (e.g., screen time) and increasing higher intensity physical activity.

SFM+ Intervention

In brief, SFM+ is a multicomponent intervention designed to optimize the durability and generalizability of the dietary and physical activity changes emphasized within FBT through practice across multiple social and environmental contexts (e.g., within the home, school, work, restaurants, with friends). Supportive family and peer environments create a socioenvironmental context in which healthy choices related to dietary intake and physical activity become the default choices. SFM+ also bolstered skills introduced within FBT related to the management of negative peer interactions (e.g., teasing) known to hinder engagement of healthy behaviors (Barkley, et al., 2002; Faith, et al., 2002; Gray, et al., 2008; Hayden-Wade, et al., 2005; Storch et al., 2007). LOW matched HIGH in content and duration, but not frequency of contact allowing for investigation of the impact of treatment dosage and whether an increased frequency of sessions and repeated exposure to skills, feedback, and reinforcement would help facilitate the consolidation of learning and encourage behavioral mastery.

CONTROL Condition

CONTROL is a weight management educational intervention that provided families with nutrition and exercise information not presented within FBT and involved participation in hands-on activities such as cooking and grocery store tours. CONTROL matched LOW in number (16), frequency (every-other-week), and length (75 minutes) of sessions, but was delivered exclusively in a group format.

Measures

Demographics

Parents reported demographic information, including child race, ethnicity, age, and gender, that was collected via the Barratt (Hollingshead Modified) Demographics Questionnaire at baseline (Table 1; Hollingshead, 1975).

Dietary Intake

Three telephone-administered 24-hour dietary recalls were conducted by a registered dietitian or a trained bachelor's-level nutritionist, using the Nutrition Data System for Research (NDSR 2009, Nutrition Coordinating Center, University of Minnesota) at each of the three time points. Recalls were completed primarily by parents but assisted by the child if present, occurred on nonconsecutive days, and included at least one weekday and one weekend day. The NDSR is considered the gold standard method for assessment of dietary intake among children aged 4-11 years (Burrows, et al., 2010) Mean intakes for calories and each nutrient/food group were averaged across the three days for each time point.

The Healthy Eating Index-2015 (HEI-2015), a valid and reliable measure designed to assess adherence to dietary recommendations from the 2015-2020 Dietary Guidelines for Americans from the United States Department of Agriculture (USDA, 2015), was used as an indication of dietary quality. The scores range from 0 to 100, with higher scores indicating greater adherence to USDA's dietary recommendations (Reedy, 2018).

The dietary variables assessed in the current study were average daily kilocalories and overall HEI score.

Physical Activity

ActiGraph® accelerometers, worn on a waist belt, were used at each of the three timepoints to provide an objective measure of child physical activity. Families were instructed to have their child wear the belt on seven consecutive days for a minimum of ten hours each day, removing them for sleep and water-based activities. Data were included in the analysis if at least ten hours was available on four or more days. A metabolic equivalent of task (MET) measurement, the ratio of the rate of energy expenditure during an activity to the rate of energy expenditure at rest, of ≥ 4 (e.g., exercise requiring four times the energy than the average person consumes at rest) was used as a cut off for moderate-to-vigorous physical activity (MVPA), meeting the Traffic Light Activity Plan's classification for green activity. Average daily minutes of green activity are reported.

Screen Time

Parents reported the number of hours their children spent a day engaging in screen time on a typical weekday and weekend day (e.g., watching television, playing computer or video games, using the computer for leisure, etc.) via a modified version of the Sedentary Behavior Questionnaire (Rosenberg, et al., 2010). Hours were summed to reflect total number of hours per week.

Statistical Analyses

All analyses were intention-to-treat, using all available data from randomized participants (N = 172 dyads). Differences in baseline characteristics of participants were assessed using chi-square tests for categorical variables and analysis of variance tests (ANOVA) for continuous variables. Primary outcome analyses were carried out in a multistage manner using mixed effects models, assuming random intercepts for each participant. Models were run separately for each of the four behaviors (i.e., average daily kilocalories, overall HEI score, daily moderate-to-vigorous physical activity, and weekly screen time). Main effects of both time (month 0, 4, 12; linear) and condition (HIGH, LOW, CONTROL) were analyzed first to investigate the linear effect of time across all groups for the given variable and/or a significant effect of condition across all time points for the given variable. Two-way interactions, month^2 (i.e., a quadratic effect of time to examine whether the model demonstrates a curvilinear trend), and the interaction between condition and time, were then added to the model. Finally, the three-way interaction between condition and time squared (month^2) was added to the model. All predictors were modeled using fixed effects, while intercepts and error components were allowed to vary randomly. Model comparisons were carried out via likelihood ratio tests (ANOVA) and, when applicable, planned contrasts were performed to further understand between group differences in variables. All analyses were completed in R version 3.6.2.

Results

There were no significant differences in baseline demographic characteristics between groups.

Table 1. Demographic characteristics at baseline

Variable	All (n = 172)*	High (n = 59)*	Low (n = 56)*	Control (n = 57)*
Child age, M (SD)	9.44 (1.28)	9.46 (1.32)	9.38 (1.18)	9.49 (1.34)
Child gender (female, %)	61.63	62.71	64.29	57.89
Child race/ethnicity, %				
White Non-Hispanic	63.37	61.02	64.29	64.91
White Hispanic	7.56	5.08	7.14	10.53
African American	22.09	23.73	23.21	19.30
Other	6.98	10.17	5.36	5.26

*Sample sizes reflect those at end of FBT/randomization

Weight and weight-related behaviors were also analyzed at both 0 and 4 months, and no significant differences between groups were found. Values at 12 months have also been included for reference.

<u>Table 2.</u> Mean relative weight and weight-related behaviors at baseline and randomization

Variable, M (SD)	All (n = 172)*	High (n = 59)*	Low (n = 56)*	Control (n = 57)*
Child percentage overweight				
Baseline (month 0)	64.15 (25.21)	66.99 (25.78)	64.03 (26.19)	61.34 (23.72)
Randomization (month 4)	50.76 (26.08)	54.08 (26.80)	50.79 (25.68)	47.30 (25.71)
End of treatment (month 12)	48.66 (28.41)	49.15 (29.27)	48.23 (27.35)	48.58 (29.11)
Calories				
Baseline (month 0)	1705.31 (436.71)	1703.80 (380.39)	1643.79 (359.77)	1767.28 (544.84)
Randomization (month 4)	1357.08 (299.91)	1369.03 (327.49)	1363.46 (306.72)	1337.51 (263.84)
End of treatment (month 12)	1457.88 (335.46)	1420.19 (355.22)	1440.46 (327.83)	1516.09 (320.44)
Total HEI score				
Baseline (month 0)	53.01 (12.24)	50.68 (13.31)	53.84 (11.23)	54.55 (11.91)
Randomization (month 4)	61.35 (11.52)	60.83 (10.79)	60.35 (13.00)	62.93 (10.69)
End of treatment (month 12)	60.52 (11.63)	61.10 (10.79)	57.54 (13.00)	63.00 (10.69)
Physical activity (minutes)				
Baseline (month 0)	110.12 (40.90)	108.20 (38.87)	107.92 (37.31)	114.26 (46.38)
Randomization (month 4)	97.68 (37.31)	95.90 (32.16)	97.58 (40.50)	99.63 (39.56)
End of treatment (month 12)	91.59 (35.98)	90.10 (32.31)	94.49 (38.30)	90.08 (37.68)
Screen time (hours)				
Baseline (month 0)	24.45 (14.12)	25.90 (15.60)	24.25 (13.74)	23.14 (12.93)
Randomization (month 4)	18.05 (12.25)	19.03 (11.93)	16.89 (11.54)	18.18 (13.32)
End of treatment (month 12)	18.64 (10.63)	17.45 (10.31)	18.69 (10.21)	19.91 (11.44)

*Sample sizes reflect those at end of FBT/randomization

Graphical illustrations of behavior change over time by condition are included below (Figures 1-4).

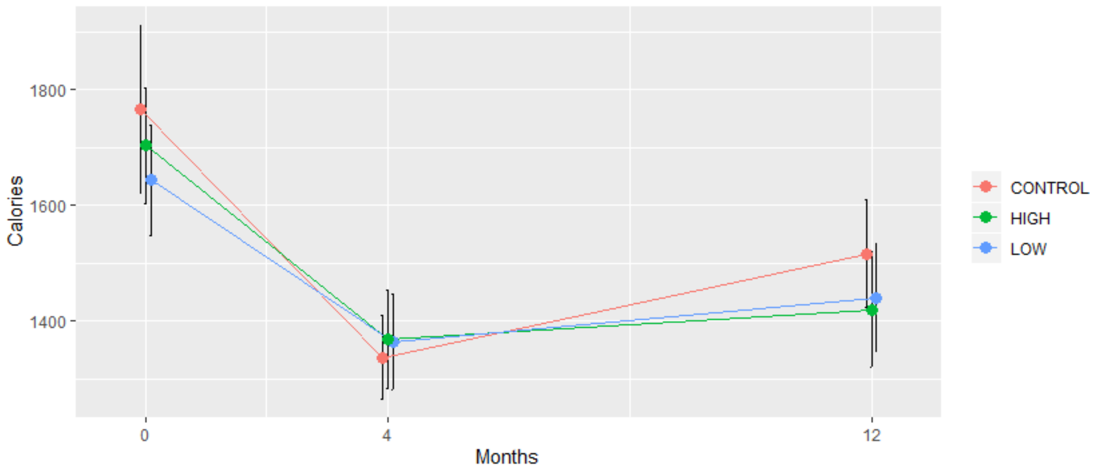


Figure 1. **Change in Calories Over Time by Group**

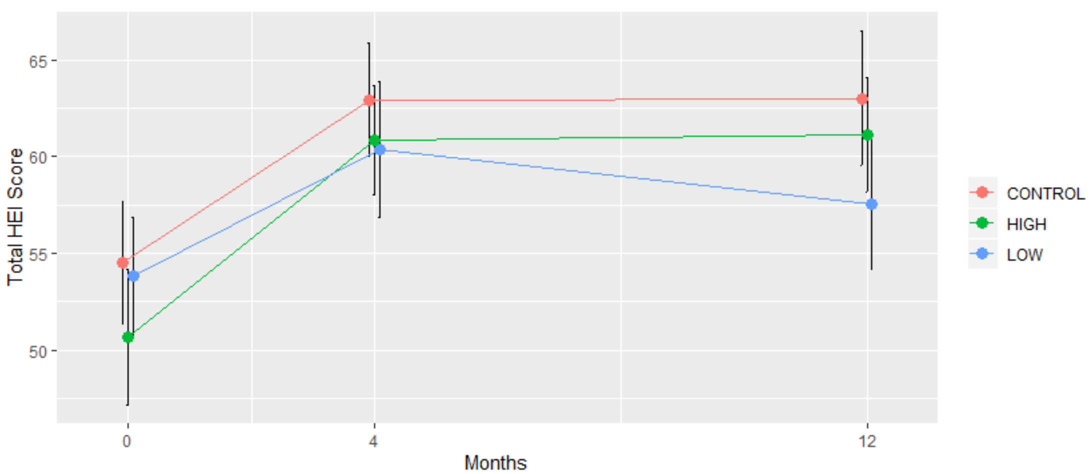
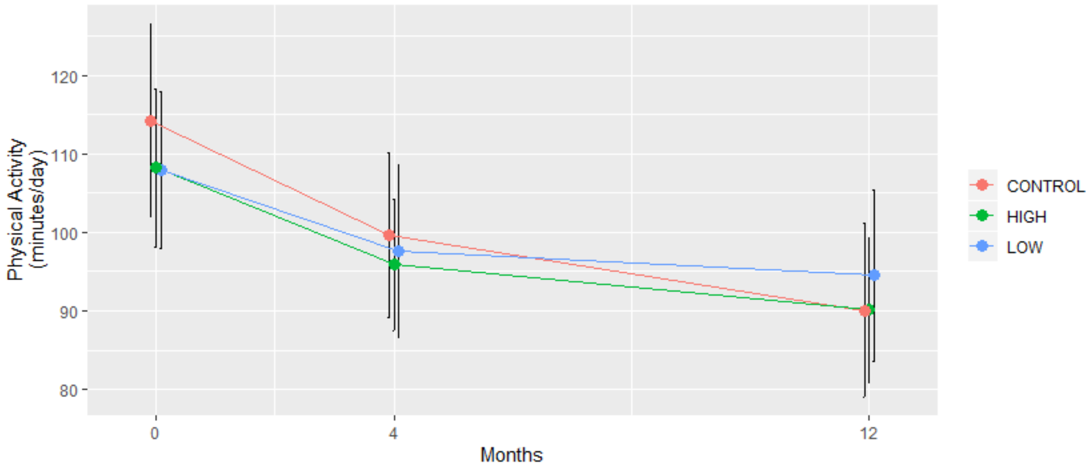
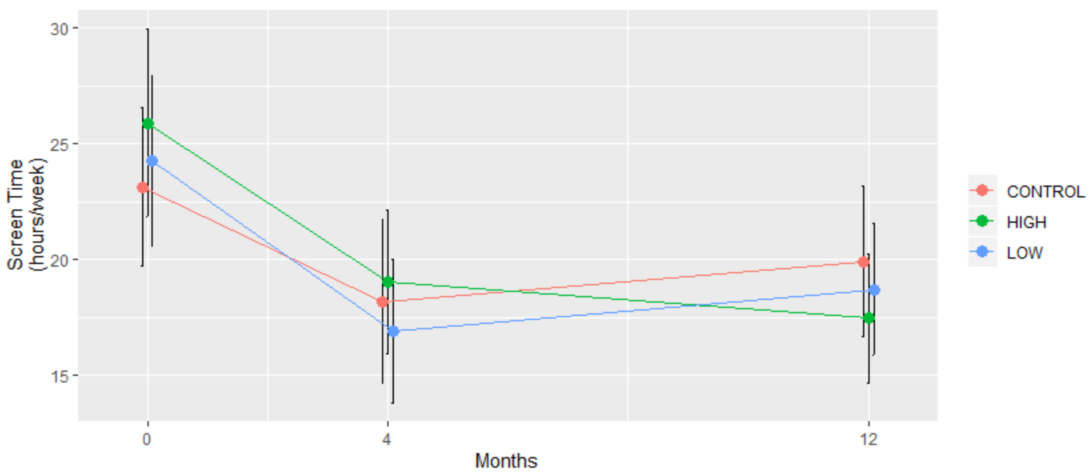


Figure 2. **Change in Total HEI Score Over Time by Group**



<u>Figure 3.</u> Change in Physical Activity Over Time by Group



<u>Figure 4.</u> Change in Screen Time Over Time

Model assumptions of linearity and homoscedasticity were not violated. Residuals were not normally distributed; however, follow-up analyses using bootstrapping produced inferences that matched the original analyses, suggesting that the violation of this assumption did not impact our findings in a considerable way.

There was a significant linear effect of time (collapsing across treatment conditions) but no significant effect of treatment condition for each variable (Table 3). Both calories (β = -17.02, 95% CI [-23.15, -10.85], t = -5.43) and screen time (β = -0.41, 95% CI [-0.55, -0.27], t = -5.34) decreased linearly over time and total HEI score (β = 0.55, 95% CI [0.36, 0.74], t = 5.62) increased linearly over time, in the expected directions for each. Physical activity (β = -1.52, 95% CI [-1.89, -1.15], t = -8.12) unexpectedly decreased over time. Two-way interaction models were run for each variable to investigate quadratic effects of time (collapsing across treatment condition) for each variable and the interaction between time (linear) and treatment condition. A significant quadratic effect of time was demonstrated across all groups (Table 4). Calories (β = 8.04, 95% CI [6.53, 10.0], t = 9.111), physical activity (β = 0.19, 95% CI [0.07, 0.30], t = 3.16), and screen time (β = 0.14, 95% CI [-1.63, 6.94], t = 6.48) all demonstrated a curvilinear pattern, decreasing sharply across FBT (month 0 to month 4) then leveling off or increasing slightly during maintenance (month 4 to month 12). Total HEI score demonstrated the opposite curvilinear patter, increasing sharply across FBT, then leveling off during maintenance (β = -0.18, 95% CI [-0.24, -0.12], t = -6.08). The time (linear) by condition (HIGH vs CONTROL) interaction was significant for screen time (β = -0.41, 95% CI [-0.73, -0.09], t = -2.49). A three-way interaction model was then run for each variable, investigating the interaction between condition and time squared (month^2), but no significant differences were found (Table 5).

<u>Table 3.</u> Mixed Effects Models

	Estimate	**Std. Error**	***t* value**	**2.5%**	**97.5%**
Calories					
(Intercept)	**1628.19**	39.45	41.27	1551.15	1705.23
Month	**-17.02**	3.13	-5.43	-23.15	-10.85
HIGH vs CONTROL	-43.56	50.77	0.86	-142.74	55.63
LOW vs CONTROL	-59.49	51.33	-1.16	-159.79	40.79
Physical activity					
(Intercept)	**109.81**	4.76	23.05	100.51	119.12
Month	**-1.52**	0.19	-8.12	-1.89	-1.15
HIGH vs CONTROL	-4.17	6.56	-0.64	-16.98	8.65
LOW vs CONTROL	-2.37	6.64	-0.36	-15.35	10.61
Screen time					
(Intercept)	**22.40**	1.50	14.97	19.48	25.33
Month	**-0.41**	0.07	-5.34	-0.55	-0.27
HIGH vs CONTROL	0.62	2.04	0.31	-3.36	4.61
LOW vs CONTROL	-0.23	2.07	-0.11	-4.26	3.80
Total HEI score					
(Intercept)	**57.20**	1.25	45.83	54.76	59.63
Month	**0.55**	0.10	5.62	0.36	0.74
HIGH vs CONTROL	-2.47	1.61	-1.53	-5.61	0.68
LOW vs CONTROL	-2.75	1.63	-1.69	-5.93	0.43

(Intercept): Expected value for CONTROL at baseline (month 0)
Month: Overall linear effect
HIGH vs CONTROL: Difference in expected values between groups
LOW vs CONTROL: Difference in expected values between groups

Bolded estimates are significantly different from 0 based on 95% confidence interval

Table 4. **Two-Way Interaction Models**

	Estimate	**Std. Error**	***t* value**	**2.5%**	**97.5%**
Calories					
(Intercept)	**1732.97**	45.04	38.47	1645.15	1820.78
Month	**-119.69**	12.34	-9.70	-143.79	-95.59
Month^2	**8.31**	0.91	9.11	6.53	10.09
HIGH vs CONTROL	-19.17	60.94	-0.32	-137.99	99.65
LOW vs CONTROL	-66.28	61.64	-1.08	-186.44	53.92
Month*Group (HIGH vs CONTROL)	-4.01	6.88	-0.58	-17.45	9.43
Month*Group (LOW vs CONTROL)	1.51	6.92	0.22	-12.00	15.04
Physical activity					
(Intercept)	**113.86**	4.99	37.54	104.12	123.59
Month	**-4.15**	0.80	7.12	-5.71	-2.59
Month^2	**0.19**	0.06	3.16	0.07	0.30
HIGH vs CONTROL	-5.60	6.91	-0.81	-19.08	7.88
LOW vs CONTROL	-5.58	7.00	-0.80	-19.24	8.08
Month*Group (HIGH vs CONTROL)	0.30	0.45	0.65	-0.59	1.19
Month*Group (LOW vs CONTROL)	0.64	0.46	1.41	-0.25	1.53
Screen time					
(Intercept)	**23.42**	1.59	14.70	20.31	26.53
Month	**-1.98**	0.30	-6.72	-2.56	-1.41
Month^2	**0.14**	2.19	6.48	-1.63	6.94
HIGH vs CONTROL	2.65	2.23	1.21	-3.99	4.70
LOW vs CONTROL	0.36	0.02	0.16	0.10	0.18
Month*Group (HIGH vs CONTROL)	**-0.41**	0.16	-2.49	-0.73	-0.09
Month*Group (LOW vs CONTROL)	-0.12	0.17	-0.75	-0.45	0.20
Total HEI score					
(Intercept)	**54.47**	1.45	37.54	51.64	57.30
Month	**2.89**	0.41	7.12	2.10	3.68
Month^2	**-0.18**	0.03	-6.08	-0.24	-0.12
HIGH vs CONTROL	-3.45	1.96	-1.76	-7.27	0.38
LOW vs CONTROL	-0.87	1.98	-0.44	-4.73	3.00
Month*Group (HIGH vs CONTROL)	0.18	0.23	0.79	-0.26	0.62
Month*Group (LOW vs CONTROL)	-0.38	0.23	-1.67	-0.82	0.07

(Intercept): Expected value for CONTROL at baseline (month 0)
Month: Linear slope for CONTROL
Month^2: Quadratic effect for CONTROL
HIGH vs CONTROL: Difference in expected values between groups at baseline (month 0)
LOW vs CONTROL: Difference in expected values between groups at baseline (month 0)
Month*Group (HIGH vs CONTROL): Difference in linear slope between groups
Month*Group (LOW vs CONTROL): Difference in linear slope between groups

Bolded estimates are significantly different from 0 based on 95% confidence interval

Table 5. **Three-Way Interaction Model**

	Estimate	**Std. Error**	***t* value**	**2.5%**	**97.5%**
Screen time					
(Intercept)	**23.14**	1.65	14.04	19.92	26.35
Month	**-1.72**	0.49	-3.54	-2.67	-0.70
Month^2	**0.12**	0.04	3.16	0.05	0.19
HIGH vs CONTROL	2.77	2.31	1.20	-1.74	7.27
LOW vs CONTROL	1.12	2.34	0.48	-3.45	5.68
Month*Group (HIGH vs CONTROL)	-0.51	0.68	-0.75	-1.84	0.82
Month*Group (LOW vs CONTROL)	-0.83	0.69	-1.20	-2.17	0.52
Month^2*Group (HIGH vs CONTROL)	0.01	0.05	0.16	-0.10	0.11
Month^2*Group (LOW vs CONTROL)	0.06	0.05	1.05	0.05	0.16

(Intercept): Expected value for CONTROL at baseline (month 0)
Month: Linear slope for CONTROL
Month^2: Quadratic effect for CONTROL
HIGH vs CONTROL: Difference in expected values between groups at baseline (month 0)
LOW vs CONTROL: Difference in expected values between groups at baseline (month 0)
Month*Group (HIGH vs CONTROL): Difference in slope between groups
Month*Group (LOW vs CONTROL): Difference in slope between groups
Month^2*Group (HIGH vs CONTROL): Difference in quadratic effect between groups
Month^2*Group (LOW vs CONTROL): Difference in quadratic effect between groups

Bolded estimates are significantly different from 0 based on 95% confidence interval

Planned contrasts were performed to further understand between group differences within the screen time, time (linear) by condition (HIGH vs CONROL) interaction. Mean differences at month 12 were not significant. Moreover, after adjustment for multiple comparisons, the time (linear) by condition (HIGH vs CONTROL) interaction for screen time was no longer significant (p = 1.00). The slopes for HIGH (β = -5.36, 95% CI -8.00, -2.73], p < 0.001 and LOW (β = -2.90, 95% CI -5.60, -0.19], p = 0.04) differed significantly from 0, whereas CONTROL did not. Differences in linear slope between CONTROL vs LOW and LOW vs HIGH were not significant (Table 6).

<u>Table 6.</u> Planned Contrasts

	Estimate	Std. Error	*z* value	*p* value*	2.5%	97.5%
Weekly screen time						
Mean comparisons (month 12)						
LOW vs CONTROL	0.70	2.40	0.292	1.00	-5.78	7.18
HIGH vs CONTROL	2.15	2.37	0.908	1.00	-4.24	8.54
LOW vs HIGH	1.45	2.36	0.613	1.00	-4.93	7.82
Linear comparisons						
CONTROL vs 0	-1.86	1.02	-1.83	0.47	-4.61	0.89
LOW vs 0	**-2.90**	1.00	-2.89	0.04	-5.60	-0.19
HIGH vs 0	**-5.36**	0.98	-5.49	0.00	-8.00	-2.73
CONTROL vs LOW	1.03	1.43	0.72	1.00	-2.83	4.89
CONTROL vs HIGH	**3.50**	1.41	2.48	0.11	-0.31	7.31
LOW vs HIGH	2.47	1.40	1.76	0.47	-1.31	6.24

Mean comparisons: Comparisons between average value at month 12 for each group (e.g. LOW vs HIGH)
Linear comparisons: Comparisons between slope for each group across all time points (e.g., CONTROL slope different from 0 or CONTROL vs LOW)

**p* values are not adjusted for multiple comparisons

Statistically significant likelihood ratio tests and lower AIC and BIC values demonstrated that the two-way interaction model was a better fit than the main effect model for all variables (Table 7). This confirms that the curvilinear patterns described above better reflect the trajectory of these variables across FBT and maintenance than a linear pattern, which suggests that the rate and/or direction of change for each of these variables differed between FBT and maintenance.

Table 7. **Likelihood Ratio Tests**

	Df	AIC	BIC	LogLik	Deviance	X^2	X Df	*p* value
Calories								
Main effect	6	7178.6	7203.7	-3583.3	7166.6			
2-way interaction	9	7109.3	7147.0	-3545.6	7091.3	75.34	3	<0.001
3-way interaction	11	7109.0	7155.1	-3543.5	7087.0	4.30	2	0.12
Physical activity								
Main effect	6	4703.9	4729.1	-2345.9	4691.9			
2-way interaction	9	4697.9	4735.6	-2339.9	4679.9	12.00	3	<0.001
3-way interaction	11	4701.7	4747.9	-2339.9	4679.7	0.15	2	0.93
Screen time								
Main effect	6	3784.8	3810.1	-1886.4	3772.8			
2-way interaction	9	3745.1	3783.1	-1863.6	3727.1	45.68	3	<0.001
3-way interaction	11	3747.8	3794.2	-1862.9	3725.8	1.30	2	0.52
Total HEI score								
Main effect	6	3800.5	3825.6	-1894.2	3788.5			
2-way interaction	9	3765.2	3802.9	-1873.6	3747.2	41.29	3	<0.001
3-way interaction	11	3768.8	3814.9	-1873.4	3746.8	0.33	2	0.85

Discussion

Three of the four key energy balance behaviors considered (i.e., caloric intake, screen time, diet quality) demonstrate curvilinear patterns across weight loss and maintenance with no differences among conditions, indicating improvements in these behaviors throughout treatment. More specifically, caloric intake and screen time decreased sharply during FBT and those reductions were largely retained throughout maintenance. Diet quality demonstrated the opposite curvilinear pattern whereby quality increased sharply across FBT with these gains persisting across maintenance. Physical activity, the fourth key energy balance behavior examined, demonstrated a curvilinear pattern across weight loss and maintenance inconsistent with the weight loss demonstrated within this sample according to the energy balance framework. Physical activity declined sharply across FBT and more moderately throughout maintenance. Additionally, examination of screen time within each of three maintenance conditions (HIGH SFM+, LOW SFM+, and CONTROL) demonstrated a trend towards a difference between HIGH SFM+ and CONTROL; however, this difference was not definitive. Specifically, although significantly greater reductions in screen time within HIGH SFM+ as compared to CONTROL were found, the interaction was no longer significant after adjustment for multiple comparisons. Thus, screen time, an unhealthy behavior targeted for reduction throughout treatment, may have decreased slightly more within HIGH SFM+ than CONTROL. As such, our hypothesis that participants in the HIGH SFM+ condition established the greatest reductions in unhealthy screen time behavior remains plausible but was not conclusively supported. Our findings did not support the hypothesized difference in screen time between HIGH and LOW SFM+. Moreover, support for our hypothesis was not demonstrated for the other weight-related behaviors examined, as no additional differences between conditions were identified. Our findings present several possibilities that may afford a more fine-grained understanding of the mediational mechanisms by which SFM+ yielded enhanced weight outcomes.

The trend towards a larger reduction in screen time for individuals in the HIGH SFM+ condition than those in CONTROL may provide some support for our hypothesis of a greater reduction in unhealthy behavior (i.e., screen time) within the HIGH SFM+ condition. This finding, though inconclusive, offers a plausible explanation for a specific weight-related behavior facilitated by the mediators of the superior effect of HIGH SFM+ vs CONTROL on child percentage overweight. SFM+ facilitates screen time reductions in part through the establishment of clear screen time expectations (e.g., time limits, an "electronic curfew," etc.) as well as individualized, weekly goals shaping families toward a target of less than fourteen hours of screen time per week. When sedentary behavior such as screen time is reduced, children may reallocate some of that time to more active pursuits even if such pursuits do not reach the threshold of MVPA used as the measure of physical activity within this study. Such a reallocation could increase energy expenditure and shift energy balance toward weight loss (Epstein, et al., 2000, 2005, 2006). SFM+ assists families in altering the layout of their home environment (e.g., removing televisions from bedrooms, having physical activity equipment in sight and easily accessible, etc.) in ways that would foster such a reallocation. If a portion of that time was reallocated to MVPA, as has been demonstrated in several FBT studies, these energy deficits would contribute greatly to enhanced weight outcomes (Epstein, et al., 2000, 2005, 2006). As such, SFM+ emphasizes the importance of engaging in physically active, community-based activities (e.g., sport teams, exercise classes, playground-based after school programs, etc.) to reduce the amount of unstructured time available for screens and promoting physically-active play dates (e.g., jumping on the trampoline instead of watching television or playing video games). Additionally, eating while watching television is associated with poorer diet quality for children, including increased consumption of energy dense, nutrient-poor food (Avery, et al., 2017). SFM+ addresses this association through limiting access to such energy dense, nutrient poor food options and encouraging families not to eat while watching television. Food marketing to children also influences dietary preference and purchase requests, and exposure to food advertisements targeting children is associated with increased intake of advertised foods, most of which are of low nutritional quality (Dalton, et al., 2017; Institute of Medicine, 2006; Powell, et al., 2013; Sadeghirad, et al., 2016; Utter, et al., 2006). Relatedly, SFM+ facilitates discussion of such messaging to help families develop awareness of how the media attempts to influence their choices in unhealthy ways. Given these findings and the ways in which SFM+ worked to decrease screen time and the related consumption of energy-dense, nutrient poor food, the trend toward differential reductions by maintenance condition may be a mechanism through which the identified mediators enhanced weight outcomes of participants in the HIGH SFM+ condition. However, in this sample, this trend towards a difference in screen time did not translate to group differences in caloric intake or overall diet quality, a finding which will be addressed below.

Patterns across maintenance for caloric intake did not demonstrate statistically significant differences by condition as hypothesized. Several possible explanations for this result are worth consideration. Accuracy in the assessment of dietary intake is one of the most challenging aspects of nutrition-related research (Burrows, et al., 2010; Collins, et al., 2010; Foster & Bradley, 2018). Although the specific 24-hour recall method utilized within this study is widely considered the gold standard by which to gauge energy intake in children, implausible reporting remains a substantial concern and the presence of error within such measures often obscures associations between dietary intake and weight status (Beaton, et al., 1997; Burrows, et al., 2010; Goldberg, et al., 1991; Huang, et al., 2005). Underreporting of caloric intake is a particularly pervasive problem (Livingstone, et al., 2004, Magary, et al., 2011). According to the energy balance framework and the attenuated weight reductions within LOW SFM+ and CONTROL, children in these conditions would have consumed more calories than children in HIGH SFM+, however their reported caloric intake was statistically equivalent, potentially indicating underreporting for LOW SFM+ and CONTROL participants. HIGH SFM+ participants, who received twice as many opportunities to engage with and practice FBT and SFM+ concepts, and for whom monitoring (including monitoring of food intake) and goal setting accounted for 42% of their superior weight reductions, may have more accurately reported their children's true reductions in caloric intake by the end of treatment. These factors may account for a lack of statistically significant differentiation in caloric intake by condition.

However, although patterns of caloric intake between maintenance conditions did not meet the threshold of statistical significance, differential mean changes suggest the potential for differences that are clinically meaningful. Mean caloric consumption for CONTROL participants increased by 178.58 calories from month 4 (M = 1337.51, SD = 263.84) to month 12 (M = 1516.01, SD = 320.43), substantially exceeding increased intake for LOW (77 calories) and HIGH (51.16 calories), respectively (Table 2). Over time, this trend toward a greater caloric intake for CONTROL, although not statistically significant, could result in the consumption of 700 more calories each week than individuals in both LOW and HIGH SFM+, equating to approximately additional 2800 calories per month, and a total of over 22,000 across the eight-month maintenance intervention. Using Wishnofsky's crude 3500 calories per pound conversion, this could add up to a hypothetical weight gain of over 6 and 8 pounds more than what would be expected across the same eight-month time period for individuals in LOW and HIGH SFM+ (Wishnofsky, 1958).

Differences in dietary quality between conditions were also not observed. Notably, a study evaluating dietary change following FBT determined that decreased consumption of red (e.g., energy dense, nutrient-poor) foods uniquely predicted weight maintenance while green food (e.g., fruit and vegetable) intake did not (Best, et al., 2016). Therefore, differences in dietary quality by maintenance treatment conditions may not have been reflected as accurately by the total HEI score as they would have been by measures that more specifically capture change in foods categorized as red within the Traffic Light Diet. This hypothesis is considered further in the context of future directions.

The objective measurement of children's physical activity was a considerable strength of the study. However, contrary to expectation, minutes per day of MVPA decreased for all groups during FBT and maintenance. Accelerometry data from the National Health and Nutrition Examination Survey (NHANES 2005-2006) suggests that only 42.5% of children 6 to 11 years of age participate in 60 minutes of MVPA on at least 5 of 7 days of the week. As such, the slight decrease in MVPA over the year of treatment could represent an overestimation of typical MVPA for our participants at month 0 despite the instructions given to participants of "to the best of your ability, to go about a normal week." A novelty effect has been hypothesized to explain similar patterns in children's accelerometry data, whereby initial excitement about the device prompted acute engagement with the technology and high rates of physical activity that then diminished over time (Goodyear, et al., 2019; Ho, et al., 2013; Marttinen, et al., 2019). Despite the decrease in MVPA across the study period, it is notable that mean MVPA levels collapsed across group at each time point (month 0: M = 110.12, SD = 40.91; month 4: M = 97.68, SD = 37.31; month 12 M = 91.59, SD = 35.98) far exceeded the U.S. Department of Health and Human Services (2018) minimum daily recommendation for children and adolescents of 60 minutes of daily MVPA as well as FBT's more stringent recommendation of 90 minutes of daily MVPA. Therefore, participants were still engaging in high levels of MVPA (>90 minutes per day) at month 12, and our findings may represent a ceiling effect such that average levels across groups are indistinguishable.

Strengths of the current study include the large multisite sample of treatment-seeking children, the objective measurement of MVPA through accelerometry, and the use of a rigorous dietary intake assessment considered to be the gold standard method by which to measure dietary intake in children (Burrows, et al., 2010). Additionally, this method of dietary assessment allowed eating behavior to be analyzed according to overall caloric intake as well as through a valid and reliable measure of dietary quality. The inclusion of a credible, educational weight management intervention, matched for dose with LOW as a control condition, is also a considerable strength, and one which may shed further light upon the lack of observable differences in these behaviors across conditions. To our knowledge, this is also the first study to have examined dietary intake, physical activity, and screen time across a weight maintenance intervention targeting children and their families. One limitation of the current study may be the use of a retrospective, parentreport to measure screen time. Additionally, this trial was conducted in an academic research setting which may limit generalizability and warrants replication within other settings.

Important questions remain about the ways in which SFM+, and the mediational mechanisms accounting for the superior weight outcomes facilitated by HIGH SFM+ as compared to both LOW SFM+ and CONTROL, relate to the key energy balance behaviors (e.g., caloric intake, diet quality, screen time, and physical activity) tied to weight change. Although the method of calculating dietary recall utilized by this study is widely considered the gold standard by which to gauge energy intake in children, the difficulty in accurately capturing consumption as well as the well documented obfuscation of associations between dietary intake and weight status as a result of these inaccuracies, has led to the development of a number of widely used methods by which to identify potential implausible reporters (Goldberg, et al., 1991; Huang, et al., 2005). Future directions include the identification and exclusion of possibly implausible reporters of dietary intake to determine whether potential underreporting may have impacted the trends, or lack thereof, in our measures of dietary intake. Methods for the identification of such implausible reporters remain imperative because while innovative and promising developments in dietary assessment methods (e.g., electronic food records, wearable cameras) are emerging, it is unlikely that a measure will ever be able to completely overcome the challenges inherent in the assessment of such a complex and often socially stigmatized behavior (Collins, et al., 2010; Walker, et al., 2018). We also plan to investigate the HEI subscales most closely associated with foods categorized as red according to FBT's Traffic Light Diet (e.g., acids, added sugar, and saturated fat) to shed light on more precise dietary quality modifications across treatment. Outside of key energy balance behaviors, examination of change in some of the more nuanced measures of social support collected may contribute to a more refined understanding of the changes facilitated by SFM+ and the ways in which the largely socially focused mediators of the superior effect of HIGH SFM+ facilitated change.

Conclusion

Our findings demonstrate change over time in the expected directions for key energy behaviors including dietary intake (e.g., reductions in caloric intake and increases in dietary quality) and screen time (e.g. reductions) across weight maintenance interventions targeting children and their families. The change over time for physical activity was opposite of what was expected (e.g., decreasing MVPA or green activity). Moreover, despite differential weight outcomes among maintenance conditions and the identification of robust mediational mechanisms of SFM+ groups accounting for the superior effects of HIGH compared to LOW, and LOW compared to CONTROL, screen time was the only key energy balance behavior that trended toward a difference by condition. The lack of support for our hypotheses for caloric intake, dietary quality, and physical activity may be a result of a ceiling effect in the observed levels of physical activity, the difficulties inherent in accurately capturing dietary intake, and a lack of nuance in our measure of dietary quality. Although additional analyses may more clearly elucidate differential patterns by maintenance condition, our current findings emphasize the critical role of screen time in healthy behavior change and weight loss for children and the importance of addressing this behavior within weight management interventions.

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