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Title: Understanding Outcomes in Behavior Change Interventions to Prevent Pediatric Obesity: The Role of Dose and Behavior Change Techniques

Abstract: Background: Behavioral interventions to prevent pediatric obesity have shown inconsistent results across the field. Studying what happens within the 'black box' of these interventions and how differences in implementation lead to different outcomes will help researchers develop more effective interventions. Aims: To compare the implementation of three features of a phone-based intervention for parents (time spent discussing weight-related behaviors, behavior change techniques present in sessions, and intervention activities implemented by parents between sessions) with study outcomes. Methods: A random selection of 100 parent-child dyads in the intervention arm of a phone-based obesity prevention trial were included in this analysis. Sessions were coded for overall session length, length of time spent discussing specific weight-related behaviors, behavior change techniques used during sessions, and intervention-recommended activities implemented by parents between sessions (e.g., parent-reported implementation of behavioral practice/rehearsal between sessions). The primary study outcome, prevention of unhealthy increase in child BMI percentile, was measured at baseline and 12 months. Results: Overall session length was associated with decreases in child BMI percentile (b = -0.02, p = 0.01). There was no association between number of behavior change techniques used in sessions and decreases in child BMI percentile (b = -0.29, p = 0.27). The number of activities parents reported implementing between sessions was associated with decreases in child BMI percentile (b = -1.25, p = 0.02). Discussion: To improve future interventions, greater attention should be paid to the intended and delivered session length and efforts should be made to facilitate parents' implementation of intervention-recommended activities between sessions. (ClinicalTrials.gov number NCT01084590.)

Key Words: Pediatric obesity; process evaluation; dose; behavior change techniques; behavioral intervention.

Background

Childhood obesity prevention programs (Spiegel & Nabel, 2006) are a priority, but have had limited effectiveness (Summerbell et al., 2005). These interventions are often delivered as a package of behavior change techniques (i.e., the active ingredients in an intervention such as goal setting or problem solving) and activities for parents to complete between sessions. Little is known about the associations between intervention features (e.g., session length, in-session use of behavior change techniques, or participant implementation of between-sessions activities) and outcomes. Understanding these associations will allow researchers to design more effective and efficient interventions and begin to uncover the mechanisms by which intervention work or do not work. Tools to describe intervention implementation have been developed (JaKa, Seburg, Roeder, & Sherwood, 2015; Michie et al., 2013), but are not consistently used to understand intervention effectiveness.

Intervention dose (e.g., number of sessions, session length) is a key factor often associated with better study outcomes in behavioral research (Gearing et al., 2011), but is not often evaluated in pediatric obesity research (JaKa et al., 2016). The majority of obesity intervention studies that have examined the association between dose and study outcome have been treatment rather than prevention trials. A systematic review and meta-analysis of family-based lifestyle interventions for children who were already overweight or obese found that treatment duration and the number of treatment session were significantly associated with better weight outcomes (Janicke et al., 2014). In contrast, a second systematic review of obesity intervention trials did not find a clear association between dose and weight outcomes (Heerman et al., 2017). This second review and meta-regression analysis included children across the

weight spectrum, rather than only children with overweight or obesity, which may have contributed to the discrepant results. The specific methods for assessing dose may also contribute to the mixed findings in the literature. Measuring actual time spent in sessions or time spent discussing specific behaviors may lead to more consistent findings (Baranowski, Cerin, & Baranowski, 2009). It is possible that there is diminishing return as session length increases beyond a certain threshold. In fact, complex, non-linear associations between overall session length and outcomes have been observed in other counseling interventions (Baldwin, Berkeljon, Atkins, Olsen, & Nielsen, 2009; Leblanc & Ritchie, 2001), but are not consistently measured in obesity prevention or treatment research (JaKa et al., 2016).

The number of behavior change techniques (e.g., goal setting) used may also be associated with outcomes (Kazdin, 1974; Romanczyk, Tracey, Wilson, & Thorpe, 1973; Spencer, 1978; Stunkard, 1972). The Behavior Change Technique Taxonomy (BCTTv1; Michie et al., 2013; Michie et al., 2015) allows researchers to use common vocabulary to identify behavior change techniques. Though session length and number of techniques used are associated (longer sessions allow for more techniques), it is proposed that use of more techniques by interventionists within a given session length may be a stronger predictor of outcomes. Findings have been inconsistent. One review of pediatric obesity treatment interventions found effective interventions reported that interventionists used a greater number of unique behavior change techniques (Hendrie et al., 2012), while another showed that effective and non-effective interventions did not differ with respect to the number of behavior change techniques used by interventionists (Martin, Chater, & Lorencatto, 2013). These reviews only evaluated *planned* techniques, and did not assess the number of unique behavior change techniques delivered or used by participants, nor did they control for session length (Lorencatto, West, Christopherson,

& Michie, 2013). This work has been successfully conducted in other domains (Lorencatto, West, Bruguera, Brose, & Michie, 2016), and is warranted in the field of pediatric obesity prevention.

Another factor likely associated with intervention effectiveness is the degree to which parents are able to implement intervention-assigned activities between sessions. Interventionists help parents set goals during sessions, but whether these goals are successfully implemented by parents between sessions is rarely measured (JaKa et al., 2016). Methods to characterize participants' role in the intervention process have been piloted in other fields like smoking cessation (Gainforth, Lorencatto, Erickson, West, & Michie, 2016) and adult physical activity (Michie et al., 2008). As with intervention dose and number of in-session techniques used, it is hypothesized that the number of between-session activities completed by parents will be associated with better outcomes in the context of an obesity prevention trial.

This study aimed to identify which intervention features are associated with outcomes by coding sessions from a completed behavioral obesity prevention intervention. The trial was designed to test the impact of a 14-session phone-based parent counseling intervention to improve weight-related behaviors and the home environment. It was hypothesized that (1) the amount of time parents spent in sessions with their phone coach would be inversely associated with child BMI percentile at 12 months, (2) the amount of time spent discussing specific behaviors (e.g., physical activity) would be associated with improvements in those behaviors, and (3) the number of behavior change techniques used within sessions would be inversely associated with child BMI percentile at 12 months. Exploratory analyses were also conducted to investigate whether the use of specific behavior change techniques and the number of between-

session activities completed by parents were inversely associated with child BMI percentile at 12 months.

Methods

Sample

One-hundred participants from the intervention arm of Healthy Homes/Healthy Kids (HHHK 5-10) were randomly selected. The HHHK 5-10 trial (ClinicalTrials.gov #NCT01084590) is described elsewhere (Sherwood et al., 2013). A random selection of participants was used due to the cost of transcribing and coding all intervention sessions. The trial recruited parents of children between 5 and 10 years at risk of becoming overweight or obese (70^{th}-95^{th} BMI percentile). Children were identified via electronic medical records at 20 primary care clinics in Minnesota. Exclusion criteria included children and parents who were not able to read and write in English, children taking medications affecting growth, and any children participating in other health-related research studies. The trial tested a parent-delivered phone intervention to reduce child BMI at 12 months (immediately post-intervention) and 24 months. Only data from baseline and 12 months were used in this analysis. Protocols in this study were approved by institutional review boards and informed consent was obtained from all participants.

Intervention

Intervention-arm parents agreed to participate in 14 phone sessions over one year. An intervention manual was used to standardize session length, format and content. Planned session length was 45 minutes for Session 1 and 15-30 minutes for Sessions 2-14. Interventionists and parents were allowed to determine the amount of time spent on each weight-related target behavior (Table 1). Session focused on behavioral and home environmental changes parents could make to prevent unhealthy weight gain in children, for example choosing to remove the

television from a child's bedroom (environmental change) or to walk to school instead of drive (behavioral change). Phone sessions were supplemented with workbooks which gave a description of each of the weight-related target behaviors, tips and example goals, a self-assessment worksheets. Sessions included a goal setting activity in which parents and interventionists identified specific activities parents would implement prior to the next session, (e.g., do something active as a family each weeknight after dinner.) At the beginning of subsequent sessions, interventionists would check-in to see if the activity was implemented. The intervention design was based on Social Cognitive Theory (Bandura, 2004) which attributes behavior to knowledge, environment, attitude and skills, and Motivational Interviewing (Miller & Rollnick, 2003) which uses a participant-centered approach focused on self-determination.

Outcome Measures

Independent, trained staff blinded to condition collected outcome data at baseline (prior to randomization) and 12 months (immediately post-intervention). Separate staff were trained on coding protocols and coded data from audio-recorded and transcribed intervention sessions as a part of this analysis.

Anthropometry

Twelve-month change in child BMI percentile was calculated from staff-measured height and weight, Seca Corp., Hanover, MD (Kuczmarski et al., 2002). Both height and weight were measured twice. If the first 2 measurements differed by more than 0.2 kg for weight or more than 1.0 cm for height, the process was repeated a third time and the average measurement was used.

Accelerometry

Change in child physical activity from baseline to 12 months was assessed via accelerometers, a small device worn to measure vertical accelerations and estimate physical activity (GT1M ActiGraph LLC). Accelerometers were worn for 7 days, except while sleeping or doing water activities. Devices were set to collect data in 15-second epochs and aggregated to 1-minute for analysis. Accelerometry data were included if wear time criteria were met, (3 10-hour days of wear, with non-wear time defined as 60-minute strings of zero-counts with 2-minute interruption interval of 100 counts.) Average daily accelerometer counts per minute of valid wear time were calculated as a marker of total activity.

Dietary Intake

Dietary intake was measured via a 24-hour recall (Nutrition Data System for Research, Minneapolis, MN) at baseline and 12 months. Portion size estimates were supplemented by an adapted food amounts booklet (van Horn et al., 1993) and 3-dimensional cups, bowls, and measuring utensils. Change from baseline to 12 months was calculated for total energy intake (kcals) and servings of fruits/vegetables, unhealthy snacks, and sugary beverages by subtracting baseline values from 12-month values.

Additional Child Weight-Related Behaviors

Additional variables were measured via parent survey at baseline and 12 months. Child screen time was measured by averaging parent-reported amount of weekday and weekend time spent watching TV or using other media (Schmitz et al., 2004). Survey items also asked parents to estimate how many days in the past week the child had family meals (McGarvey et al., 2004), restaurant meals (Boutelle, Fulkerson, Neumark-Sztainer, Story, & French, 2007), and breakfast

meals. Response options for these items were: never, 1-2 times, 3-4 times, 5-6 times, and 7 or more times.

Intervention Measures

Session length, time spent discussing specific weight-related behaviors, in-session use of behavior change techniques, and parent implementation of intervention-recommended activities were coded from audio-recorded and transcribed intervention sessions. All coders (N = 5) were trained and certified in coding through practice intervention sessions. Weekly meetings were held to discuss coding decisions and prevent coder drift. A randomly selected portion of sessions from N = 20 participants were double coded by the lead coder to evaluate inter-rater reliability (IRR) throughout the study.

Session Length

Overall session length was calculated as total time parents and interventionists spent talking in phone sessions. This was calculated by summing the length of each completed intervention session for a given participant.

Time Spent Discussing Weight-Related Behaviors

The minutes parents and interventionists spent discussing specific weight-related behaviors lasting more than 1 minute were coded. Discussions covering more than one weight-related behavior were divided equally between behaviors. Time spent talking about each behavior was then summed across all sessions. The average inter-coder reliability of time spent discussing each behavior was measured by Pearson correlation coefficient (mean $r = 0.79$). Time spent discussing 'restaurant frequency' was excluded due to low reliability.

Behavior Change Techniques Used

The number of unique behavior change techniques used during sessions was coded in 5 randomly selected session transcripts per participant. All coders were trained and certified in coding using the 93-item BCTTv1 (Michie et al., 2013) through the online training (www.bct-taxonomy.com) and two additional days of study-specific training. Twenty-six techniques identified during training by any coder in the intervention manual, workbooks, or practice sessions constituted the set of techniques that were coded. Coders read transcript twice, the second time coding line-by-line any statement that qualified as a behavior change technique used during the session. As an example, the behavior change technique Review Behavior Goals (Review Progress) was coded in the following statement: "Last session, you set the goal of going to the farmers market to have your daughter pick out three new vegetables. Were you able to do that?" The number of unique behavior change techniques used was then counted across all coded sessions for a given participant. Average reliability as measured by Cohen's kappa (K) was 0.91.

Activities Implemented by Parents between Sessions

Intervention activities parents reported implementing between sessions was coded from transcripts. When interventionists asked parents about their goal progress, parents reported whether or not they implement the activity identified in the previous session. When a statement was identified, it was categorized as one or more of 11 potential activity categories (Table 2). The definitions of these activity types correspond to behavior change techniques likely used when recommending the activity in the previous session. For example, during an intervention session interventionists could recommend the behavior change technique self-monitoring. During the next session, if a parent reports having done the self-monitoring strategy over the last week, that statement would be coded as parent implementation of self-monitoring. The number of

unique activities reported as implemented by parents was counted across transcribed sessions for each participant. For example, if a participant reported implementing 'behavioral practice/rehearsal' at least 1 times across sessions, this activity was identified as present. The number of "present" activities were then counted for a participant. The average inter-rater reliability of these items, as measured by Cohen's kappa (*K*) was 0.92.

Statistical Analysis

Descriptive statistics are provided as means, standard deviations and frequencies. Time spent discussing weight-related behaviors were log transformed due to largely right-skewed distributions. General linear regression was used to test overall time in sessions associated with change in child BMI (Hypothesis 1), time spent discussing specific behaviors associated with change in those behaviors (Hypothesis 2), number of behavior change techniques associated with change in child BMI (Hypothesis 3) and number of parent activities implemented between sessions associated with change in child BMI (Hypothesis 5). Models were adjusted for baseline levels of the outcome. Time spent in sessions was considered as a potential confounder. Due to possible clustering by interventionist, mixed regression models allowing for a random intercept by interventionist were also assessed. Finally, non-linear associations were tested using a quadratic term in Hypothesis 1.

Regression tree analysis (Lemon, Roy, Clark, Friedmann, & Rakowski, 2003) was used to test which combinations of behavior change techniques were most associated with change in child BMI percentile (Hypothesis 5). This analysis partitions the study sample into mutually exclusive subgroups defined by the presence or absence of unique behavior change techniques, based on variability in the outcome variable (change in child BMI percentile). Each subgroup continues to be partitioned until the between-subgroup variability in child BMI percentile change

is maximized, or until a pre-specified subgroup sample size is reached. The tree for this analysis was generated such that the minimum subgroup size was n = 12 participant, which would yield up to 8 possible subgroups (96 participants / 8 subgroups = 12 participants/ per subgroup) defined by up to 3 specific techniques (2^3 = 8 subgroups). Additional pruning and growing parameters were also evaluated. The final model adjusted for baseline child BMI percentile. Regression tree analysis is inherently data driven but helps identify variables to be tested in future research.

For all analyses, significance was assessed using 2-tailed tests with alpha set at 0.05. Regression coefficients, standard errors and p-values are presented and interpreted below. All analyses were conducted in SAS Version 9.4 (SAS Institute Inc., Cary, NC, 2017).

Power Analysis

Using a general linear model approach (Lenth, 2006), a sample size calculation was conducted assuming 80% power, 1 predictor, a two-tailed alpha of 0.05, and a clinically meaningful difference of 2.5 units change in child BMI percentile from baseline to 12 months. A standardized minimal detectable effect sizes was multiplied by the standard deviation of child BMI percentile change from baseline to 12 months in the 181 participant in the intervention arm (SD = 7.7). By coding 100 participants, a child BMI percentile change of 2.2 units (standardized minimal detectable effect size or beta of 0.28) for every 1 standard deviation difference in intervention delivery measure could be detected. This 2.2 unit change is smaller than the clinically meaningful difference of 2.5 units selected above, therefore allowing analyses to detect a meaningful difference with 100 participants.

Results

Descriptive Characteristics

Children included in this analysis were an average of 6.7 years old (*SD* = 1.7 years), 49% female, and 78% non-Hispanic and white. Parents included in the analysis were an average of 27.4 years old (SD = 6.2 years), 91% female and 58% were employed. Table 3 provides descriptive statistics for time spent in intervention sessions, in-session use of behavior change techniques, and parent implementation of intervention-recommended activities as well as change in study outcomes (child BMI percentile and weight-related behaviors) from baseline to 12 months. Participants completed 12.0 (*SD* = 3.9) sessions, lasting an average of 24.7 (*SD* = 5.1) minutes for a total intervention time of 297.6 (*SD* = 89.8) minutes over the 12-month intervention. Interventionists and parents spent the most amount of time discussing "physical activity" (48.8 ± 30.6 minutes) followed by "fruit and vegetable intake" (25.8 ± 24.1 minutes) and "screen time" (18.2 ± 21.5 minutes). A total of 13.9 (*SD* = 2.8) unique behavior change techniques were used by interventionists during sessions. Figure 1 shows the percent of parents whose interventionist used a given behavior change technique in at least one coded session. Goal setting and information gathering were the two most common behavior change techniques, followed by the identifying barrier portion of problem solving and providing social reward in sessions. Other behavior changes techniques such as those related to incentives or habit formation were used much less frequently. Parents reported implementing an average of 2.6 (*SD* = 1.3) unique activities throughout the intervention. Overall, child BMI percentile decreased by 4.0 (*SD* = 7.5) from baseline to 12 months.

Time Spent in Intervention Sessions

Overall time spent in intervention sessions (Hypothesis 1) was significantly associated with change in child BMI percentile. Every one hour of time that parents spent in intervention sessions corresponded to a 1.2 percentile reduction in child BMI from baseline to 12 months (b = -0.02, SE = 0.01, p = 0.01). Results are presented in Figure 2. This association remained after adjusting for baseline level of child BMI percentile and after allowing for a random effect for interventionist. There was no evidence of a quadratic association between time spent in intervention sessions and change in child BMI percentile. There were no significant associations between time spent discussing specific weight-related behaviors and subsequent changes in those behaviors (Hypothesis 2), except in the model with time spent discussing breakfast predicting change in breakfast frequency. This statistical association was driven by only one participant who spent a large amount of time discussing breakfast during the intervention and substantially increased their frequency of breakfast consumption at 12-month follow-up (Table 4).

Behavior Change Techniques Used in Sessions

The number of unique behavior change techniques utilized was not associated with change in child BMI percentile after adjusting for total time in intervention sessions (Hypothesis 3, b = -0.29, SE = 0.26, p = 0.2748). No statistically significant results were found when testing the exploratory hypothesis that certain behavior change techniques would be associated with greater decreases in child BMI percentile (Hypothesis 4). The regression tree model using a minimum subgroup size of 12 participants that best explained variance in child BMI did not include any splits (N = 1 leaf, average square error, ASE = 50.7). Reducing the minimum subgroup size, turning off pruning, and increasing the chi-square statistic parameters for splitting

also did not result in any splits. Thus, none of the specific behavior change techniques significantly explained variance in child BMI percentile change.

Intervention Activities Implemented by Parents between Sessions

The number of unique activities parents reported implementing between sessions was associated with change in child BMI percentile (Hypothesis 5). This remained after adjusting for time spent in intervention sessions. Each additional unique activity parents reported implementing between sessions, regardless of the amount of time spent in intervention sessions, was associated with a 1.25 unit decrease in child BMI percentile between baseline and 12 months (b = -1.25, SE = 0.52, p = 0.02). This remained statistically significant after controlling for baseline child BMI percentile and after allowing a random effect for interventionist.

Discussion

Efficacious behavior change interventions to prevent pediatric obesity are a major public health priority, yet these interventions have shown limited success thus far (Kamath et al., 2008). Measuring and reporting detailed intervention information may lead to a better understanding of the active, effective components of pediatric obesity prevention interventions. Promising intervention factors included in this analysis were time spent in intervention sessions, in-session use of behavior change techniques, and parent implementation of intervention-recommended activities. The results of the current study suggests that overall time spent in intervention sessions is an important consideration, as it was associated with decreases in child BMI percentile. These results are consistent with previous studies using crude measures of dose delivered, such as number of sessions delivered (Foster et al., 2012; Golan, Kaufman, & Shahar, 2006; Jelalian, Mehlenbeck, Lloyd-Richardson, Birmaher, & Wing, 2005; Kalarchian et al., 2009). The hypothesis that a more complex, non-linear association between intervention dose

and outcomes would exist was not supported by the current analysis. One explanation could be that this relatively low-intensity intervention (an average of five hours of intervention time over 12 months) was not sufficiently long and/or intense to demonstrate a quadratic effect. This requires further investigation.

The time spent discussing specific weight-related behaviors was not associated with changes in any of these behaviors from baseline to 12 months (e.g., spending more time discussing fruit and vegetable intake was not associated with greater increases in child fruit and vegetable intake). It is possible that the lack of association with these variables is due to measurement bias in these intermediate outcomes (i.e., dietary intake). It has been hypothesized that those participating in behavior change interventions become more accurate at reporting health behaviors post-intervention (Senso, Anderson, Crain, Sherwood, & Martinson, 2014). However, this would not influence objective measures, such as accelerometry, used in this study.

The hypothesis that use of a greater number of unique behavior change techniques used in sessions would be associated with better study outcomes was not observed after adjusting for overall intervention dose. Similarly, there were no specific behavior change techniques identified as important in explaining the variance in child BMI percentile change, as shown by the exploratory regression tree analysis. Though there was adequate sample size to detect a 9-point difference in child BMI percentile between possible subgroups, a larger sample size would have been able to identify smaller between-subgroup differences. It is also possible that current measures of intervention content relating to the behavior change techniques are not capturing the active ingredients of this type of intervention. Some have suggested that features such as interpersonal style of the interventionist (Hagger & Hardcastle, 2014) or the interventionist-participant relationship (i.e., therapeutic alliance; Martin, Garske, & Davis, 2000) may be

necessary to explain the variability in effectiveness of behavior change technique implementation. It is possible that interactions between behavior change techniques used and other features such as interventionist interpersonal and communication behaviors may be important in explaining outcomes.

The last hypothesis in this analysis examined whether the number of unique activities that parents reported implementing between intervention sessions would be positively associated with child BMI percentile change. Though there was relatively little reporting of implementation of activities between sessions (only 2.6 of the 11 possible activities reported on average), the number of unique activities parents reported implementing was positively associated with a reduction in child BMI percentile. This finding suggests that parental implementation of intervention-recommended activities is an important factor influencing the effectiveness of behavior change interventions. Similar findings have been reported in the adult weight-loss literature, with implementation of intervention activities such as self-monitoring of diet or physical activity and self-weighing between sessions being consistently associated with improved weight loss (Burke, Wang, & Sevick, 2011). The specific reasons parents did not implement activities were not explored in this study, but could include lack of support, time or competing priorities. An essential next step in this work is to identify key barriers to implementation and understand how various behavior change techniques can be delivered in sessions to address these barriers. Future research could also focus on the participant characteristics that may predict successful implementation of study goals and activities.

This study has a number of strengths including the use of objective measures to identify features of intervention delivery, measurement of these features on an individual participant level allowing for comparison with outcomes, and the reported high reliability of measuring these

features. Still, there are some important limitations. One limitation is that since data were from only one arm of a previously conducted trial, participants were not randomly allocated to differing levels of intervention implementation. To address this limitation, a thorough evaluation of potential confounders, including baseline child BMI percentile and the possible random effect of interventionist, was used. Another limitation of this work is the acknowledgement that many additional features discussed above likely contribute to a participant's success (e.g., interventionist-participant relationship, participant engagement or intention, interventionist attributes, and additional demographic characteristics.) The specific features were chosen for this study because of their measurability and their initial promise in existing literature; others may be important.

The current analysis suggests that amount of time spent in intervention sessions is an important factor in intervention success as is the number of intervention activities implemented by parents between sessions. There appears to be more complexity in the association between study outcomes and number or type of behavior change techniques delivered by interventionists. Though these two factors were not associated with intervention outcomes, this study has developed coding protocols that could be extended to cover other factors in future studies. Such studies would help identify the active ingredients in behavior change interventions to prevent unhealthy weight gain in children.

Tables

Table 1. Target weight-related behaviors covered in the Healthy Homes, Healthy Kids intervention.

Increase fruit and vegetable intake	Decrease unhealthy snacks
Increase physical activity	Decrease sugary beverages
Increase breakfasts	Decrease TV and other screen time
Decrease eating at restaurants	Increase family meals

Table 2. Definitions of activities parents could implement between sessions.

Activity Category	Definition[1]
Goal implementation	Participant reports implementing a goal defined in terms of the behavior achieved
Self-monitoring of behavior	Participant reports implementing the monitoring and recording of their or their child's behavior(s) as part of a behavior change strategy
Social support, unspecified	Participant reports soliciting social support (e.g. from friends, relatives, colleagues, 'buddies' or staff) to perform the behavior
Social support, practical	Participant reports soliciting practical support (e.g. from friends, relatives, colleagues, 'buddies' or staff) to perform the behavior
Prompts/cues	Participant reports introducing or defining an environmental or social stimulus with the purpose of prompting or cueing their own or their child's behavior
Behavioral practice/rehearsal	Participant reports practicing or rehearsing performance of the behavior one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill
Behavior substitution	Participant reports substitution of an unwanted behavior with a wanted or neutral behavior
Habit formation	Participant reports rehearsing and repeating the behavior in the same context repeatedly so that the context elicits the behavior
Self-reward	Participant reports implementing self-praise or self-reward if and only if there has been effort and/or progress in performing the behavior
Restructuring the physical environment	Participant reports changing the physical environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments)
Adding objects to the environment	Participant reports adding objects to the environment in order to facilitate performance of the behavior

[1]Definitions based on the Behavior Change Technique Taxonomy (v1).

Table 3. Descriptive characteristics for selected participants, *N=96*.

	M	SD
Intervention Characteristics		
Overall time spent in intervention sessions, minutes	297.6	89.8
Time spent discussing weight-related behaviors, minutes		
Physical activity	48.8	30.6
Screen time	18.2	21.5
Energy intake	35.8	28.4
Sugary beverage intake	5.2	8.6
Fruit/vegetable intake	25.8	24.1
Breakfast frequency	4.6	7.8
Family meal frequency	4.4	5.6
Unique behavior change techniques used in sessions, 26 possible	13.9	2.8
Unique activities implemented by parents between sessions, 11 possible	2.6	1.3
Change in Child Variables from Baseline to 12 Months		
Child BMI percentile	-4.0	7.5
Child physical activity (counts/day)	-34.5	194.7
Child screen time (hours/day)	-0.1	1.0
Child energy intake (kcal/day)	-57.4	538.1
Child sugary beverage intake (servings/day)	+0.1	1.4
Child fruit/vegetable intake (servings/day)	+0.2	2.1
Child Breakfast frequency (0-4 scale)	+0.0	0.4
Family meal frequency (0-4 scale)	+0.0	0.9

Table 4. Separate univariate models of dose delivered by target behavior predicting change in related child weight-related behaviors, *N=96 participants*.[1]

Independent Variable	Dependent Variable	b[2]	p-value
Physical activity dose delivered	Change in child physical activity	-0.76	0.3032
Screen time dose delivered	Change in child screen time	0.01	0.2205
Energy intake dose delivered	Change in child energy intake	-1.76	0.2971
Sugary beverage dose delivered	Change in child sugary beverage intake	0.00	0.9654
Fruit/vegetable dose delivered	Change in child fruit/vegetable intake	0.01	0.1565
Breakfast dose delivered	Change in child breakfast frequency	-0.07	<.0001
Family meal dose delivered	Change in family meal frequency	0.01	0.3309

[1]Adjusted for baseline values of specific child weight-related behaviors.
[2]Unstandardized betas for separate regression models.

Legend of Figures

Figure 1. Behavior change techniques used in session transcripts*, N=96 participants.*

Figure 2. Time spent in intervention sessions compared to change in child BMI percentile*, N=96 participants.*

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Understanding Outcomes in Behavior Change Interventions to Prevent Pediatric Obesity: The Role of Dose and Behavior Change Techniques

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Figure 1. Behavior change techniques used in session transcripts*, N=96 participants.*

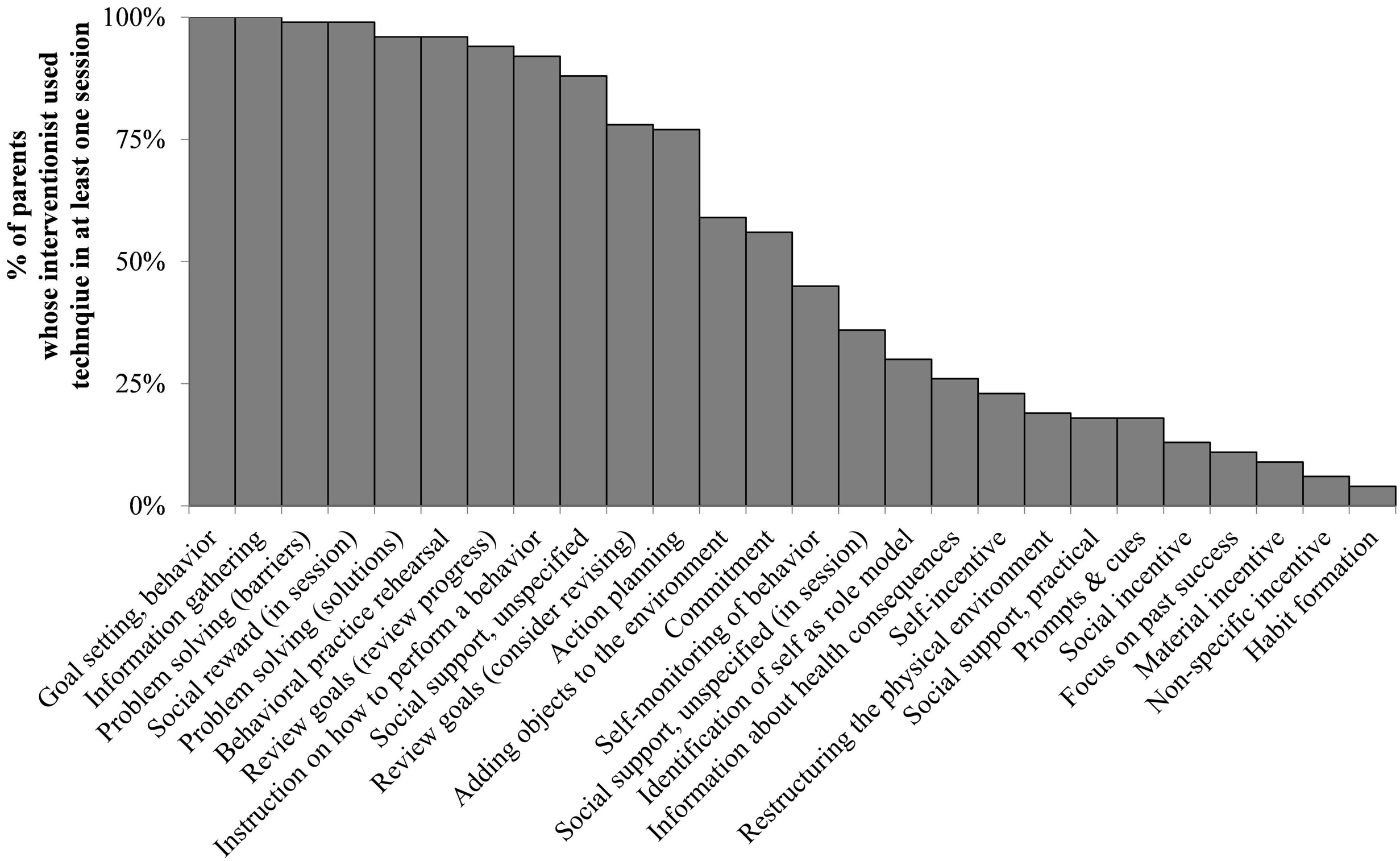

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Figure 2. Time spent in intervention sessions compared to change in child BMI percentile, *N=96 participants.*