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Effects of Open-Loop Feedback on Physical Activity and Television Viewing in Overweight and Obese Children: A Randomized, Controlled Trial

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ABSTRACT

OBJECTIVES. Television viewing and physical inactivity increase the risk of obesity in youth. Thus, identifying new interventions that increase physical activity and reduce television viewing would be helpful in the prevention and treatment of pediatric obesity. This study evaluated the effects of open-loop feedback plus reinforcement versus open-loop feedback alone on physical activity, targeted sedentary behavior, body composition, and energy intake in youth.

METHODS. Thirty overweight or obese 8- to 12-year-old children were randomly assigned to an intervention ($n = 14$) or control group ($n = 16$). Participants wore accelerometers every day for 8 weeks and attended biweekly meetings to download the activity monitors. For children in the open-loop feedback plus reinforcement (intervention) group, accumulating 400 counts of physical activity on pedometers earned 1 hour of television/VCR/DVD time, which was controlled by a Token TV electronic device. Open-loop feedback control subjects wore activity monitors but had free access to targeted sedentary behavior.

RESULTS. Compared with controls, the open-loop feedback plus reinforcement group demonstrated significantly greater increases in daily physical activity counts (+65% vs +16%) and minutes per day of moderate-to-vigorous physical activity (+9.4 vs +0.3) and greater reductions in minutes per day spent in television viewing (−116.1 vs +14.3). The intervention group also showed more favorable changes in body composition, dietary fat intake, and energy intake from snacks compared with controls. Reductions in sedentary behavior were directly related to reductions in BMI, fat intake, snack intake, and snack intake while watching television.

CONCLUSIONS. Providing feedback of physical activity in combination with reinforcing physical activity with sedentary behavior is a simple method of modifying the home environment that may play an important role in treating and preventing child obesity.

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Key Words

youth, physical activity, obesity, sedentary behavior, television viewing

Abbreviations

MVPA—moderate-to-vigorous physical activity
z-BMI—age/gender-standardized BMI
PD-PAR—Past Day Physical Activity Recall
ANOVA—analysis of variance
VPA—vigorous physical activity

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CHILD OBESITY IS increasingly being recognized as a global epidemic^{1,2} and represents a serious public health concern given its associated health complications.^{3,4} The etiology of obesity is a complex interaction between genetics and environment⁵ but, in its simplest terms, obesity results when energy intake exceeds energy expenditure; thus, intervention focuses on increasing physical activity and reducing food intake.

Physical activity in children is declining in North America,⁶ and the majority of youth do not get enough physical activity to obtain health benefits.⁷ Obese children are a group who may particularly benefit from increased energy expenditure from physical activity given that they are less physically active^{8,9} and less fit^{10,11} than nonobese children, and because obesity and sedentary lifestyles track from childhood to adulthood.¹² Television watching is a sedentary behavior that consumes a large part of children's leisure time,¹³ is cross-sectionally¹⁴ and prospectively¹³ related to the development of obesity in children, and is negatively correlated with physical activity^{14,15} and fitness.¹⁶ Increasing physical activity and reducing reinforcing sedentary behaviors, such as television viewing, are critical components of child obesity treatment¹⁷ and prevention.¹⁸ Behavioral interventions that reward increases in physical activity and/or decreases in sedentary behavior in obese children have shown some success at modifying activity and inactivity. However, there is need to further develop innovative methods of motivating overweight children to increase physical activity and reduce sedentary behavior to improve the treatment¹⁷ and prevention of childhood obesity.

Capitalizing on the reinforcing nature of television viewing, Saelens and Epstein¹⁹ demonstrated that one way of shifting choice from sedentary to physically active alternatives is to make access to popular sedentary behaviors contingent on physical activity, an empirically supported behavior modification technique known as the Premack Principle.²⁰ Saelens and Epstein¹⁹ used a self-contained, closed-loop feedback system whereby the stationary bicycle was interfaced with the television so that the television would turn on and remain on provided subjects pedaled at or above the programmed level of intensity (60 rpm). Applying the same behavioral contingencies and technology as used in the Saelens and Epstein study,¹⁹ Faith et al²¹ established that the closed-loop reinforcement system increased physical activity, decreased television watching, and reduced body fat in obese children under natural environmental conditions.

An alternative to the closed-loop feedback system is a more flexible open-loop feedback system used by Goldfield et al.²² Open-loop systems operate under the same principle as closed-loop systems in that they require a person to do physical activity to gain access to high-rate sedentary activities. Unlike closed-loop feedback sys-

tems, however, open-loop feedback systems require an external method of accurately measuring physical activity and an individual (eg, parent) to evaluate the volume of physical activity performed and to deliver the reinforcement. Using this open-loop feedback system, Goldfield et al²² demonstrated in the laboratory that contingent access to certain sedentary behaviors, such as television and video games, resulted in marked increases in physical activity levels and time spent in moderate-to-vigorous physical activity (MVPA) in obese children. Furthermore, the open-loop feedback system has been shown to increase physical activity and reduce television viewing in nonobese children in the natural environment.²³ Both open- and closed-loop feedback studies demonstrate that highly valued sedentary activities can be used to increase physical activity in children when access to these behaviors is contingent on physical activity. However, the open-loop system may have greater potential in the natural home environment given that it is more flexible and allows the child to choose the type, duration, and intensity of physical activity that they want to do to earn access to whatever rewarding sedentary behaviors they choose.

To our knowledge, this study is the first to compare the effects of the open-loop feedback system that rewards physical activity by providing access to television to a control group that provides feedback of physical activity counts but offers free access to television independent of physical activity in overweight and obese children. We predicted that the open-loop feedback plus reinforcement condition would demonstrate larger increases in physical activity and greater reductions in targeted sedentary behavior compared with open-loop feedback-only control children. Because the link between television viewing and child obesity may be mediated, in part, through consumption of high-fat foods^{24,25} and/or intake of energy-dense snack foods while television viewing,^{26,27} and reducing television may reduce fat intake,²⁸ the effects of the intervention on body composition and energy intake were explored as secondary objectives.

METHODS

A total of 46 families were screened to determine eligibility (see Fig 1). Thirty families met the following inclusion criteria: 8- to 12-year-old children who were overweight or obese defined as a BMI above the 85th BMI percentile for age and gender²⁹; watching ≥ 15 hours of television per week, including VCR/DVD use and video-game playing; engaging in < 30 minutes of MVPA per day⁷; no conditions that would limit physical activity; agreement that the child or parent would not participate in any other exercise or weight control program during the course of the study; no regular participation in swimming or strength training, because these

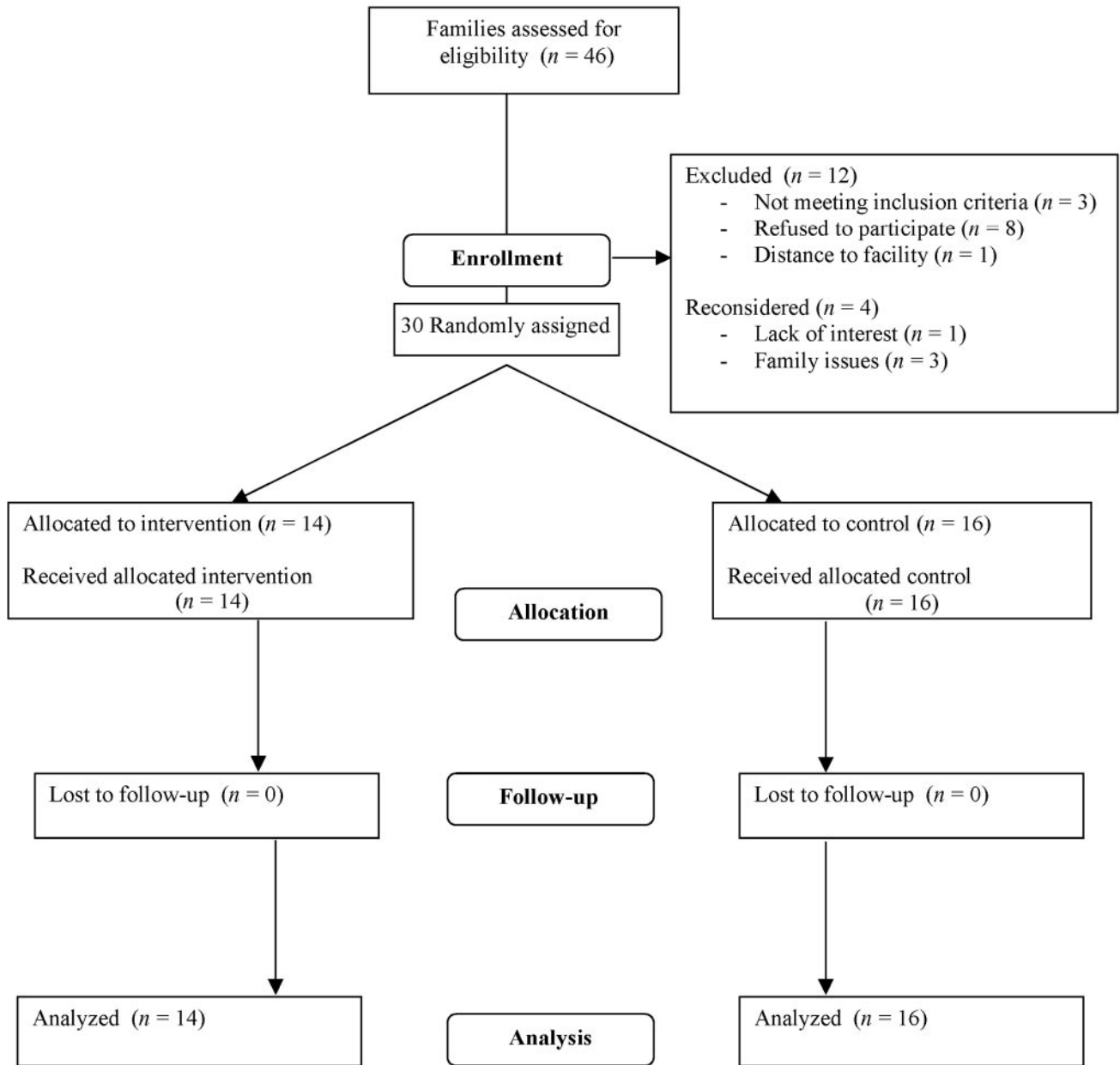


FIGURE 1
Participant flow per Consolidated Standards of Reporting Trials (CONSORT).

activities cannot be measured properly by accelerometry; willingness of the parents to enforce or maintain the contingencies or lack of as reflected by their assigned study group; parent providing signed informed consent; and child providing signed informed assent. Subjects were given \$10 for attending baseline assessment and each biweekly meeting during the 8-week intervention and \$20 for attending the posttreatment follow-up. Baseline characteristics of participants in each study group are shown in Table 1. This study was approved by the Research Ethics Board at the Children's Hospital of Eastern Ontario.

Design and Procedures

This randomized, controlled trial was conducted at the Children's Hospital of Eastern Ontario from September 2003 to June 2004. Thirty families were randomly assigned to open-loop feedback plus reinforcement ($n = 14$) or open-loop feedback alone ($n = 16$). None of the subjects dropped off the study. The computer-generated randomization sequence, stratified by weight status (between 85th and 94th BMI percentile vs ≥ 95 th BMI percentile) and gender, used random-permuted block sizes of 4 and 6. Although it is not possible for a behavioral intervention of this nature to be blinded, outcomes

TABLE 1 Characteristics of the Sample at Baseline

Variable	Intervention (n = 14)	Control (n = 16)	P
Gender, male/female ^a	6/8	7/9	.961
Age, mean (SD), y	10.0 (0.90)	10.7 (1.4)	.133
Height, mean (SD), cm	145.0 (8.7)	151.8 (11.6)	.090
Weight, mean (SD), kg	61.5 (16.9)	65.6 (13.9)	.473
BMI, mean (SD), kg/m ²	28.9 (6.2)	28.2 (3.0)	.691
Combined parental income, n (%) ^a			
<\$50 000	2 (14.3)	4 (25)	.272
\$50 000–\$75 000	5 (36)	6 (38)	.891
>\$75 000	7 (50)	6 (38)	.650
Physical activity, mean (SD), counts per d	247.0 (131.2)	206.8 (119.0)	.386
MVPA, mean (SD), min/d	14.4 (7.8)	12.0 (11.3)	.513
VPA, mean (SD), min/d	3.7 (4.9)	1.2 (1.6)	.091
Targeted sedentary behavior, mean (SD), min/d	160.5 (93.7)	152.1 (86.5)	.799
Nontargeted sedentary behavior, mean (SD), min/d	34.0 (17.5)	41.5 (41.7)	.530

Data are mean (SD) unless otherwise specified.

^a Group differences in gender and parental income were determined by χ^2 ; differences in other variables determined by independent *t* tests.

other than activity were evaluated at baseline and 8-week posttreatment by staff blinded to group membership.

Children in the open-loop feedback plus reinforcement group were provided objective feedback on their physical activity by wearing a physical activity monitor (BioTrainer, Individual Monitoring Systems, Baltimore, MD). The physical activity that they accumulated was rewarded with access to television. Based on pilot testing, 2 obese children walking on a treadmill with 0% grade at a standardized speed of 5.0 km/hour accrued counts at a rate of 6.5 per minute or 390 per hour, which is a level of intensity that ranges between moderate to vigorous^{30,31} and demonstrated to provide health benefits. For simplicity, we decided to round the number of counts required to gain 1 hour of television for children in the intervention group from 390 to 400 counts, thereby functionally establishing a 1:1 ratio of physical activity counts needed for television time. Thus, children in the intervention group accumulating 400 counts of physical activity on pedometers earned 1 hour of television/VCR/DVD time, which was controlled by a Token TV electronic device (Stokes Corporation, St Mazomanie, WI). A Token TV device was placed on each television in the house by 1 of our research assistants. Thus, television access could only be granted by inserting special tokens that were locked in a secured location determined by parents. Parents were given instruction in how to implement the contingencies and how much time each week children earned for television/VCR/DVD and television-based video-game playing. Family members in the intervention group could not access televisions without inserting tokens, but they were given unlimited tokens for television viewing, and children in the

intervention group were prevented from watching television with family members unless it was from tokens they earned. Each token provided 30-minute access to the television, and the television would automatically shut off if no additional tokens were inserted. Children would not have access the television for the remainder of the week once they spent their allotted tokens. At each biweekly meeting with research staff, parents were provided the total amount of television hours earned each week for their child and the corresponding number of tokens (rounded to the nearest 30 minutes of the hour); the television hours could be used by the child at anytime during the 2 weeks, and any unused hours of television could be banked by children and added to the hours earned for the subsequent weeks. We requested that parents did not restrict television viewing as a form of punishment for the duration of the study to prevent confounding the results. There were no limitations in access to television viewing during the first week of treatment, but pedometer counts accrued in this week determined the amount of television time earned for the following week. After the week 2 visit, which determined the amount of television time earned each week for the subsequent weeks (3 and 4), 3 more biweekly visits were scheduled.

Children in the open-loop feedback control group were required to wear activity monitors and, therefore, were provided feedback on physical activity but had free access to television independent of physical activity. They were not given token television devices, but were required to visit the laboratory for downloading according to the same schedule as the intervention group. Families in this group were not given any activity goals to avoid confounding goals with the effects of the feedback from activity monitors.

Before baseline assessment, all of the subjects wore activity monitors for 4 days as an adaptation procedure designed to offset any spontaneous increases in activity (ie, novelty effects) that may occur in children who initially wear these devices. After the adaptation period, which subjects were not told about, all of the subjects wore the monitor with the display feedback turned off for 7 days as baseline measurement. Children in both groups were asked to wear the monitors before and after school until bedtime during weekdays and on waking until bedtime on weekends. The number of hours per day, as well as days per week in which monitors were worn was determined by the presence of physical activity counts downloaded from the monitors. We encouraged participants to wear the monitors ≥ 4 hours per day during weekdays and ≥ 12 hours on weekend days. Children were also asked to self-report their physical activity and sedentary behavior. Children and parents met biweekly with a research assistant to download activity monitors and address compliance to protocol and self-report measurement of physical and sedentary activity.

Measurement

Demographics were evaluated by self-report, and socioeconomic status was assessed by the sum of parental income. Medical history and current medical problems that contraindicate physical activity were evaluated by clinical interview supervised by a study physician.

Body Composition

Child weight was assessed to the nearest 0.1 kg with subjects wearing light clothing without shoes using a calibrated balance beam scale. Height was measured to the nearest 5 mm using a standardized wall-mounted height board. Height and body weight were measured at baseline and 8-week follow-up assessment and used to determine BMI according to the following formula: weight in kilograms divided by height in meters squared. Changes in adiposity over time can be based on 1 of 3 proxy measures: change in BMI, the proportional (%) change in BMI, or the change in BMI z score or centile. We chose to use BMI rather than age/gender-standardized BMI (z-BMI) in light of new research indicating that traditional BMI is more sensitive to change over time than z-BMI,³² making it more suitable to evaluate intervention effects.

Measurement of Daily Physical Activity

Physical activity was objectively measured by the BioTrainer, a small, unobtrusive unidimensional pedometer validated under laboratory and field conditions,³³ and has detected significant increases in physical activity in clinical outcome research.³⁴ The BioTrainer provides minute-by-minute measures of physical activity and, thus, can provide information on when children are active and not active and the intensity of activity performed. Total activity counts, average daily activity counts, time spent in MVPA (3–5.9 metabolic equivalents [metabolic rate consuming 4.2 kJ/kg of body weight per hour]), and vigorous activity (≥ 6 metabolic equivalents)⁷ were determined from the downloading of the BioTrainer at 7-day baseline, biweekly during the intervention, and 8 weeks posttreatment.

Self-Reported Behaviors

The Past Day Physical Activity Recall (PD-PAR), a valid self-report measure of physical activity in children³⁵ (including obese children) was used in combination with the BioTrainer to indicate what children were doing when they were active and sedentary. Participants were asked to use the PD-PAR daily to record all targeted and nontargeted forms of sedentary behaviors, as well as physical activities throughout each day of the week during baseline and posttreatment assessment periods, as well as daily during the intervention. The PD-PAR was also used with interviews at screening to assess eligibility. Children self-reported the amount of time they wore the activity monitor by writing the time of day they put

the monitor on and when they took it off using a self-report form prepared by the investigative team. The self-reported activity was compared with the objective activity monitors to verify accuracy of reporting when activity monitors were worn and discrepancies between self-report and activity monitors were addressed with families in the biweekly meetings.

Energy and Macronutrient Intake

Child dietary intake, including total calories consumed, calories from snacks, snack intake while watching television, and macronutrient composition (percentage of calories from fats, carbohydrates, and protein) were assessed using 3-day food records at baseline and posttesting by a registered dietician. The dietician provided 30 minutes of instruction on food recording to all of the families before prepost evaluation of energy intake, and families were provided with food models, measuring cups, measuring spoons, and a ruler for estimating portion sizes. Food records were done on 2 weekdays and 1 weekend day at pretesting and posttesting, and mean intakes reported herein were averaged across 3 days using Food Smart nutrition software.³⁶ Children wore accelerometers on days in which energy intake was evaluated. At each assessment period, the dietician met individually with each child and parent shortly after the completion of 3-day food records to clarify recording and gain more accurate measurement of energy intake. Participants were instructed to record snack intake separate from meal intake on the food records.

Analytic Plan

Between-group changes in total physical activity counts, minutes spent in MVPA and vigorous activity, time spent in targeted sedentary behavior, and amount of time that activity monitors were worn were evaluated using an intention-to-treat approach with separate mixed analysis of variance (ANOVA) models. Each ANOVA consisted of a between-subjects factor of group (open-loop feedback plus reinforcements versus open-loop feedback only), as well as a repeated-measures factor of time (baseline, weeks 1–2, weeks 3–5, and weeks 6–8), to reflect changes across the beginning, middle, and end of the intervention period, respectively. Significant interactions (group \times time) indicating group differences in rate of change over time were explored by linear contrasts using Fisher's exact tests, with Huynh-Feldt significance level used to correct for violations of sphericity common in repeated-measures analysis. Additional prepost changes between groups in secondary outcomes, including height, weight, BMI, energy intake, average daily counts of physical activity, minutes per day in MVPA, and vigorous physical activity (VPA), targeted sedentary behavior were also evaluated by using mixed ANOVA models. The magnitude of correlation among the changes in physical activity, targeted sedentary be-

behavior, body composition, and energy intake was evaluated by Pearson product moment correlations. In all of the analyses, we used 2-tailed α values set at .05. Statistical analyses were conducted using SPSS 13.0 (SPSS Inc, Chicago, IL).

RESULTS

Demographic and anthropometric characteristics of the sample are reported in Table 1. No group differences emerged on these variables.

No group differences emerged in the amount of time that pedometers were worn during baseline and the intervention. During baseline, the intervention group wore monitors an average of 7.7 ± 2.1 hours per day compared with 7.0 ± 1.9 hours per day for controls. During the 8-week study period, subjects in the intervention and control groups wore monitors an average of 7.7 ± 2.8 and 7.3 ± 3.0 hours per day, respectively.

ANOVAs yielded significant group \times time interactions indicating that, compared with control subjects, the intervention group demonstrated significantly greater changes in total physical activity counts ($P < .05$) and time spent in MVPA ($P < .05$). The pattern of change between groups over time is shown in Fig 2. As shown in Table 2, ANOVA also revealed that, from baseline through the 8-week intervention period, the interven-

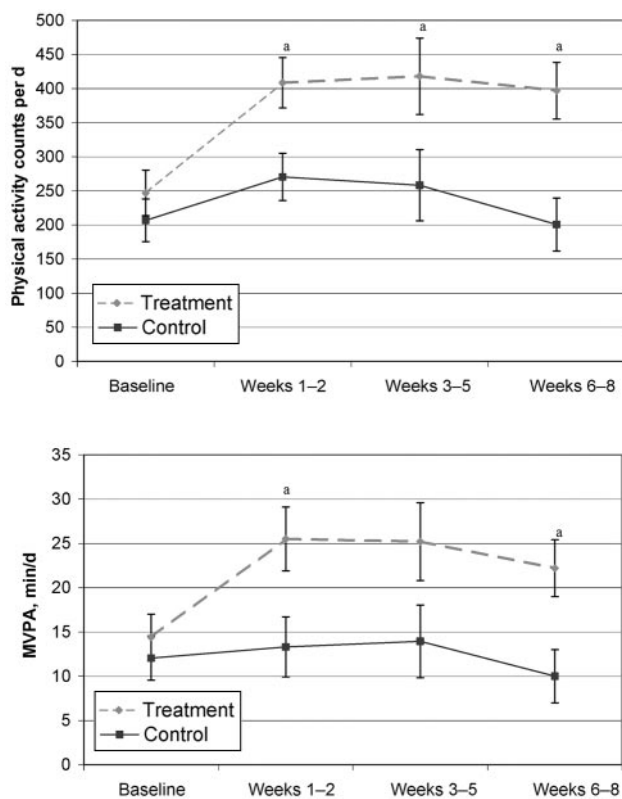


FIGURE 2

Changes over time in daily physical activity counts (top) and MVPA. Data are presented as mean \pm SEM. ^a $P < .05$ changes between study groups.

TABLE 2 Time in Physical Activity and Sedentary Behavior

Variable and Assessment Period	Intervention (n = 14)	Control (n = 16)	P, Group \times Time
Physical activity, counts per d			
Baseline	247.0 (131.2)	206.8 (119.0)	.019
During intervention	407.8 (192.4)	239.8 (130.2)	
MVPA, min/d			
Baseline	14.4 (7.8)	12.0 (11.3)	.050
During intervention	23.8 (17.0)	12.3 (8.9)	
VPA, min/d			
Baseline	3.7 (4.9)	1.2 (1.6)	.572
During intervention	9.5 (14.6)	4.3 (4.7)	
Targeted sedentary behavior, min/d			
Baseline	160.5 (93.7)	152.1 (86.5)	.001
During intervention	44.4 (26.5)	166.3 (102.7)	
Nontargeted sedentary behavior, min/d			
Baseline	34.0 (17.5)	41.5 (41.7)	.321
During intervention	38.4 (24.7)	38.9 (37.5)	

Data are mean (SD).

tion group showed a larger increase in total physical activity counts per day ($P < .05$) and minutes per day spent in MVPA ($P < .05$). The group \times time interaction for VPA was not significant.

The intervention group exhibited significantly greater reductions in targeted sedentary behavior over time ($P < .001$), as shown in Fig 3. Similarly, the intervention group demonstrated larger reductions than controls in minutes per day of television/VCR/DVD/video-game playing from baseline through intervention ($P < .001$), as shown in Table 2.

A significant group \times time interaction emerged for weight ($P < .05$) and BMI ($P < .05$), indicating greater improvements for the intervention group compared with the control group (Table 3). No group differences emerged in prepost changes in height, as shown in Table 3.

The intervention group demonstrated larger reduc-

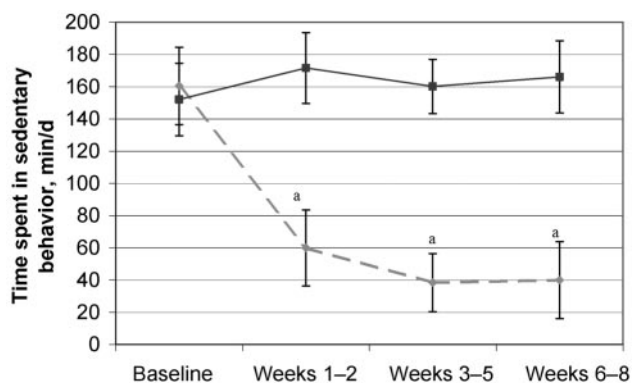


FIGURE 3

Changes in time spent in targeted sedentary behavior (television/VCR/DVD viewing and television-based video games). Data are presented as mean \pm SEM bars; ^a $P < .05$ between study groups.

TABLE 3 Change in Body Composition Between Groups

Variable and Assessment Period	Intervention (n = 14)	Control (n = 16)	P, Group × Time
Height, cm			
Baseline	145.0 (8.7)	151.8 (11.6)	.400
Posttreatment	146.4 (8.4)	152.7 (12.4)	
Weight, kg			
Baseline	61.5 (16.9)	65.6 (13.9)	.044
Posttreatment	61.6 (17.1)	67.2 (15.0)	
BMI, kg/m ²			
Baseline	28.9 (6.2)	28.2 (3.0)	.037
Posttreatment	28.3 (6.6)	28.5 (3.1)	

Data are mean (SD). Group differences in pretreatment/posttreatment changes were determined by ANOVA.

tions in fat intake ($P < .05$), calories from snacks ($P < .05$), and snack intake consumed in front of television ($P < .05$; Table 4). The intervention group showed larger reductions in caloric intake, but the magnitude of change did not reach statistical significance, nor did groups differ on energy intake from protein or carbohydrates.

Correlational analyses indicated that reductions in targeted sedentary behavior were significantly related to reductions in weight ($r = 0.70$; $P < .001$), BMI ($r = 0.54$; $P < .05$), calories from dietary fat ($r = 0.68$; $P < .001$), snacks ($r = 0.54$; $P < .01$), and snacks consumed while watching television ($r = 0.41$; $P < .05$). Although not significant, there was a trend for an association between changes in sedentary behavior and changes in total caloric intake ($r = 0.33$; $P = .08$), but changes in sedentary

TABLE 4 Change in Energy Intake Between Groups

Variable and Assessment Period	Intervention (n = 14)	Control (n = 14)	P, Group × Time
Total energy intake, kJ/d			
Baseline	10 462.2 (3158.4)	10 054.8 (4200)	.253
Posttreatment	9067.8 (5136.6)	11 264.4 (4326)	
Fat, kJ/d			
Baseline	3628.8 (1344)	3309.6 (1415.4)	.037
Posttreatment	2667 (1646.4)	3733.8 (1327.2)	
Carbohydrate, kJ/d			
Baseline	5401.2 (1974)	5357.94 (2872.8)	.545
Posttreatment	5149.2 (3725.4)	6090 (2763.6)	
Protein, kJ/d			
Baseline	1432.2 (369.6)	1390.2 (701.4)	.282
Posttreatment	1251.6 (428.4)	1440.6 (462)	
Total snack intake, kJ/d			
Baseline	1822.8 (928.2)	1293.6 (936.6)	.015
Posttreatment	882 (877.8)	1533 (6438.6)	
Snack intake while viewing television, kJ/d			
Baseline	907.2 (613.2)	735 (596.4)	.026
Posttreatment	273 (361.2)	831.6 (8072.4)	

Data are mean (SD). Group-by-time interaction was determined by ANOVA.

behavior were not related to changes in protein or carbohydrate intake. The relationship between changes in physical activity and body composition and physical activity and energy intake were not significant.

DISCUSSION

To our knowledge, this is the first study to examine the effects of open-loop feedback of physical activity counts in combination with using sedentary behavior to reward children for increased physical activity in obese children. We found that this intervention produced marked increases in physical activity and reductions in sedentary behavior, consistent with our previous laboratory study in obese children,²² thus extending the short-term use of this intervention to the natural environment. Similar results were obtained by the same intervention and contingencies in normal-weight youth.²⁸ Although the open-loop feedback intervention did not change VPA significantly, the intervention had powerful effects on overall activity levels (65% increase), as well as time spent in MVPA (+9.4 minutes per day [64% increase]), without instruction to do so. The intervention increased physical activity performed at or above moderate intensity to >30 minutes per day and exceeded 150 minutes per week, a duration and intensity reported to provide health benefits.⁷ These findings are of clinical relevance given that increasing physical activity is an important component in pediatric obesity treatment,¹⁷ as well as management of comorbidities.^{37–39}

In addition to marked increases in MVPA, the intervention reduced television viewing by ~2 hours per day to only 45 minutes per day, representing a 72% decrease. Similar findings were obtained by application of closed-loop feedback in obese youth.²¹ However, the same contingencies used in the application of open-loop feedback produced a significant but smaller reduction of 20 minutes of television/VCR/DVD viewing and television-based video-game playing in normal-weight children.²³ Given that overall physical activity levels and sedentary behavior time earned in our study is comparable to data obtained by Roemmich et al,²³ the larger percentage of changes in activity and inactivity observed in our study may be because of differences in baseline values between studies. It is interesting to note that our data show no group differences in changes in nontargeted sedentary behaviors, such as reading or listening to music, suggesting that obese children were so highly motivated to be physically active to earn television time that they did not substitute nontargeted for targeted sedentary behaviors. Conversely, no between group differences were found by Roemmich et al²³ in time spent in overall sedentary behavior that included targeted and nontargeted behavior, and given large group differences in targeted sedentary behavior, this suggests that normal-weight children in this study likely substituted nontargeted sedentary behaviors for targeted sedentary

behaviors. These differences in substitutability are consistent with research indicating that obese children find television/VCR/DVD and television-based video-game playing more reinforcing compared with nonobese youth,⁴⁰ and, therefore, may be more motivated to engage in physical activity to earn additional time in sedentary behavior compared with normal-weight youth.²⁰ The declining trend of physical activity observed in weeks 6 to 8 (see Fig 2), although not statistically significant, may reflect a reduction in the reinforcing efficacy of television to reward physical activity. Such satiation often occurs eventually with most rewards, highlighting the importance of alternating several rewards for short periods of time. Future research needs to examine whether using sedentary behavior as a reward for increased physical activity alters the relative reinforcing value of these behaviors, and, if so, how these changes influence choices to be sedentary or active when the contingencies are removed.

The intervention produced significant improvements in weight and BMI compared with controls, despite no dietary intervention and a short intervention period, indicating powerful effects on energy balance behaviors. Data indicate that the intervention group maintained their weight over time while capitalizing on growth in height to reduce BMI, whereas the control group gained weight at an accelerated trajectory for height, resulting in increased weight and BMI. These findings are similar to those of Faith et al,²¹ who implemented a closed-loop feedback system to reduce adiposity in obese children. However, the open-loop system used in the current study may be a better alternative in that it is more flexible and allows children to accumulate physical activity by doing activities they enjoy in the natural environment. It is important to note that reductions in adiposity observed in our study and the study by Faith et al²¹ although statistically significant in relation to controls, are modest and should be interpreted with caution. Given that a stronger degree of negative energy balance is needed for treatment than prevention of pediatric obesity, providing feedback and contingent access to reinforcing sedentary behaviors used in open- and closed-loop applications alone may be more effective for child obesity prevention,¹⁸ but more comprehensive intervention is likely needed for treatment.^{41,42}

Several mechanisms may link the relationship between reduced television viewing and reduced BMI. First, television viewing competes with physical activity, and there is evidence that a portion of the time saved from reduced television viewing may be reallocated for physical activity,⁴³ although this is not a universal finding^{18,44} and may be influenced to some degree by age, weight status, and baseline values.^{42,45} Second, television acts as a prompt for food intake,²⁷ sometimes in the absence of hunger, leading to overconsumption, and this may happen in several ways: by repeated pairing of

eating while television viewing, a behavioral principle known as classical conditioning; television may impair satiation by interfering with oral habituation to gustatory and olfactory cues;^{46,47} and/or by television commercials that encourage children to consume energy-dense snack products.^{24,25} Our data seem more consistent with the second mechanism, reduced food intake. Although reductions in sedentary behavior were associated with increased physical activity, change in physical activity was only weakly correlated with reductions in weight or BMI. In addition, the intervention reduced the calories consumed in dietary fat (−1087.8 kJ), a reduction of 26.5% from baseline and 80% of the caloric deficit. Moreover, snack intake was reduced by 940.8 kJ (−50% from baseline, 68% of caloric deficit), as well as 630 kJ from snacks while viewing television (−70% from baseline, 45% of caloric deficit). Importantly, all of these reductions in energy intake were significantly related to reductions in weight and BMI, supporting the hypothesis that reducing television reduces snacking and high-fat intake. Nutritional data indicated no statistically significant group differences in overall caloric consumption, but the reduction of 1386 kJ found in our study may be clinically significant if sustained over time. The strong association between reduced television viewing and reduced fat intake in the natural environment is remarkably similar in magnitude and symmetry to data by Epstein et al²⁸ and suggests that reduced television viewing provided less opportunity and reduced exposure to cues that prompt eating. Both our study and data from Epstein et al²⁸ showed that reductions in television viewing only affected fat intake but did not modify intake of other macronutrients, further supporting the notion that reducing television viewing may be helpful in the treatment and prevention of child obesity, and the likely mechanisms may be reduced snacking and/or reduced intake of high-fat foods.

There are several limitations of this study. Despite the limited number of children, the full sample completed the study, and the intervention produced significant group differences in the primary outcome variables (ie, physical activity and television viewing), indicating powerful intervention effects. Moreover, the intervention positively impacted secondary outcomes, such as body composition, despite not being powered to do so, but additional indicators and more precise measurement of body composition is needed for future research. Additional limitations of this study include a short intervention period and lack of posttreatment follow-up evaluation, which precludes evaluation of the maintenance of treatment effects that are important in obesity outcome research. Including diet would likely enhance body composition changes,¹⁷ but, as an initial study, we wanted to evaluate the effects of the intervention without diet. We did not measure aerobic fitness, and this should be included in future research to better evaluate

health benefits of the intervention. Finally, our sample size precluded meaningful analyses of how treatment effects are moderated by weight status (overweight versus obese) or gender. Thus, the degree to which these variables influence energy balance behaviors in response to open-loop feedback contingencies needs further examination.

CONCLUSIONS

This study shows that, compared with pedometer feedback alone, pedometer count feedback combined with rewarding increases in physical activity with television viewing produces marked increases in overall physical activity levels, time spent in MVPA, as well as reductions in television viewing, BMI, dietary fat intake, and calories from snacks. These data support the hypothesis that the relationship between reduced television viewing and BMI may be mediated by reductions in dietary fat in meals and/or reduced intake from snacks. These findings indicate that a manipulation of the home environment involving activity feedback with contingent access to television viewing may be helpful in promoting healthier eating and activity behavior changes and, therefore, may be effective components in the prevention and short-term treatment of obese children. The intervention highlights the power of behavior modification principles to modify physical activity and sedentary behavior in the home environment. Family physicians and pediatricians are in a unique position to help committed and motivated families to modify the home environment to promote healthier active living for children with the help of simple and inexpensive technology.

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Effects of Open-Loop Feedback on Physical Activity and Television Viewing in Overweight and Obese Children: A Randomized, Controlled Trial

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