Interactive Multimedia for Promoting Physical Activity (IMPACT) in Children

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Abstract

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Objective: To develop and examine the efficacy of a computer-based interactive multimedia curriculum for promoting physical activity in fourth grade children.

Research Methods and Procedures: The participants were 209 fourth grade children (mean age of 9.5 ± 0.4 years) from four schools. Two schools received an 8-week multimedia intervention delivered by interactive CD-ROM, supplemented by four classroom and four homework assignments. Two control schools received educational CD-ROMS not related to health outcomes. Measures conducted before and after intervention included height, weight, percentage body fat (bioimpedance analysis), physical activity (5-day accelerometry), and psychosocial aspects of physical activity by questionnaire. All outcomes were examined using general linear models.

Results: There was a significant treatment effect for obesity reduction in girls but not in boys. There were no significant treatment effects on total physical activity by accelerometry (total counts per minute), but there was an overall treatment effect on reducing percent of time in moderate-intensity activity (16.5% to 15% of the time) and significant sex-by-treatment interactions for light-intensity activities (reduction in boys from 78% to 75% of the time and an increase in girls from 78% to 81% of the time). There were marginal/significant treatment effects for improvements in behavioral outcomes, including self-efficacy ($p = 0.06$), social norms ($p = 0.07$), and outcome expectancies ($p = 0.049$).

Discussion: The interactive multimedia curriculum favored an improvement in obesity indices in girls and was associated with subtle changes in physical activity in girls and general improvement in psychosocial outcomes related to physical activity.

Key words: multimedia, health behavior, physical activity

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Introduction

Current epidemiological data suggest recent and rapid increases in overweight, obesity, and type 2 diabetes in children in the United States, especially among certain ethnic groups, including African Americans, Hispanics, and Native Americans (1,2). Overweight during childhood is associated with increased risk for type 2 diabetes (3,4) and increased cardiovascular disease risk (4). Therefore, the development of novel obesity prevention programs for children and adolescents is a high priority. Interventions aimed at promoting physical activity in children are warranted based on several observations. First, fewer than 36% of elementary or secondary schools offer daily physical education (5), and even when physical education is offered, many students spend the majority of time being inactive (6). Second, a study of a nationally representative sample of 4063 children (8 to 16 years) during 1988 to 1991 showed that 20% of U.S. children do not get more than two bouts of vigorous exercise per week, and 67% of children watch >2 hours of television per day, with television viewing hours being linked to degree of obesity (7). Physical activity decreases in girls immediately before puberty (8), and decreased physical activity predicts increased fatness during growth (9). Thus, promoting increased physical activity and decreased sedentary activity is an obvious target for obesity prevention in children.

Several other previous studies have examined school-based interventions incorporating the promotion of physical activity for obesity prevention and have shown promising results. For example, Robinson (10) developed a school-based curriculum of 18 lessons for third and fourth grade children designed to reduce television, video, and video game use and examined its effects in 198 children from two schools. This 6-month intervention led to significant improvements in obesity outcomes, with a reduced increase in BMI in treatment versus control children. One other study by Gortmaker et al. (11) developed a school-based behavioral intervention (Planet Health) and tested its effects in a randomized trial over 2 years in five treatment and five control schools. The intervention led to successful decrease of obesity prevalence among girls.

Interactive multimedia provide tremendous potential to develop and deliver school-based, health promotion/education tools, which can also incorporate family involvement and can be designed around effective models of behavior change. One previous study developed a multimedia game called "Squire's Quest" and focused on improving fruit and vegetable intake in fourth grade children. The intervention was delivered in 10 sessions over 5 weeks and led to a significant increase in fruit and vegetable consumption by one serving per day (12). A family-based Internet intervention (13) was also used to promote weight loss in overweight African-American girls (11 to 15 years) and their parents. Also, in adults, an Internet weight loss intervention was shown to be more effective when supplemented by e-mail–based counseling (14). Thus, interactive multimedia show promise as an obesity prevention tool but have not been widely explored as a tool for delivery of effective health behavior interventions in children. It is likely that the increased use of creative and interactive multimedia tools will lead to a stronger impact and play a key role in long-term preventive efforts. Interactive multimedia have tremendous potential to deliver health interventions because of the combination of media formats and the likelihood that the incorporation of entertainment into health education messaging will make it more appealing and acceptable to target audiences. This should lead to greater use of the interactive media compared with more traditional forms of media (e.g., generic print), a higher intervention dose, and potentially greater change in behavior. Thus, the objective of this study was to develop and examine the effects of a novel interactive computer game, supplemented by classroom and homework assignments, for improving physical activity and reducing obesity in fourth grade children.

Research Methods and Procedures

Subjects and Recruitment

Four elementary schools from the school district of West Covina in Los Angeles County were recruited for this study. These schools were selected on the basis of available computer laboratory resources and a close match among schools on ethnic and socioeconomic composition. Two schools received the interactive multimedia intervention, and the other two schools received a control intervention consisting of a variety of popular educational CD-ROMs not relating to health topics. From these four schools, consent forms were distributed to the parents of all fourth grade students (n = 307 children), and 209 of these families provided consent (68% recruitment yield). Data from one child were excluded because of a much higher age (12.3 years) compared with the remainder of the group, which ranged from 8.8 to 11.1 years of age. Complete pre- and post-testing data on height, weight, bioelectrical impedance, and questionnaires were collected in 202 of these children, and valid accelerometry data on at least 3 of the 5 days (using the criteria defined below) at both pre- and post-testing were obtained in 122 children. The study was approved by the Institutional Review Board at the University of Southern California.

Description of Intervention

The Interactive Multimedia for Promoting Physical Activity (IMPACT)[1] CD-ROM was developed as an interactive educational learning game based on social cognitive theory (SCT) (15,16). SCT proposes that behavior is influenced through the interaction of environmental, behavioral, and individual factors. The central educational goals were to increase levels of physical activity and decrease sedentary behavior, limit increases in BMI, and alter psychosocial variables related to physical activity. The intervention consisted of eight CD-ROM interactive animated lessons (45 minutes per lesson), four classroom lessons (45 minutes per lesson), and four family-based assignments (45 minutes per assignment), for a total of 12 hours of contact delivered over 8 weeks. The intervention was designed to be compelling, fun, innovative, and highly interactive. Each lesson was designed to incorporate elements of SCT including outcome expectancies (information on short- and long-term results of behavior change including more energy, faster healing, healthier body, and increased self-esteem); behavioral capability and modeling (information and skills needed to make a behavior change, such as identification of physical activities that can be done regularly); goal setting (tangible goals that are challenging but achievable, such as fewer bouts of inactivity, increased bouts of physical activity); self-monitoring (tracking progress relative to specific/individual needs); reinforcement (rewards for achieving goals, such as praise from teacher and parents and using engaging aspects of the game); self-efficacy (confidence to enact or change behavior, such as being more active); and environmental aspects (identification, understanding, and modification of external factors that have a powerful influence on

[1] Nonstandard abbreviations: IMPACT, Interactive Multimedia for Promoting Physical Activity; SCT, social cognitive theory; CSA, Computer Science and Applications; GLM, general linear model.

behavior, such as media influences, social influences, school policies and services, and availability of equipment and space for play).

Formative evaluation and feasibility testing were done in the development of the intervention in two major areas. First, the *content* of the program was refined based on the identification of key messages needed to alter components of the underlying SCT theory used to design the program (including messages for the CD-ROM, classroom, and homework components). Second, possible themes, plots, and characters of the program were examined in a series of focus groups on a total of 100 students, teachers, and parents. Phase 1 focus groups, which were conducted in July 1998, consisted of three teacher focus groups ($n = 17$ third to fifth grade teachers, physical education teachers, and media specialists), five student focus groups ($n = 29$ third to fifth grade children), and four parent focus groups ($n = 18$ parents), all of whom were recruited from schools outside of the district where the main intervention was conducted. The goal of these focus groups was to obtain information regarding computer use, nutrition and exercise education, children's role models, and children's attitudes about physical activity and nutrition. The data derived from the first phase of focus groups were used to refine our ideas about both the content and concept of the program. For example, we learned the importance of including various skill levels with concomitant reinforcement for completing each level, merging nutrition and exercise information with other major subjects, building adequate instructions and assistance into the program, including a wide range of children and animal characters with diverse personalities, and teaching children to overcome barriers to healthy eating and exercise (like chores, weather, negotiating with parents, etc.).

The second phase of focus groups, conducted in February of 1999, refined our ideas about concepts, in that several stories and accompanying graphics that could potentially be used in the CD-ROM were presented and discussed. We conducted three co-ed student focus groups ($n = 25$ third to fifth grade children) and two teacher focus groups ($n = 12$ third to fifth grade teachers). As a result of these focus groups, we were able to obtain consistent information regarding children's preferences for program themes. For example, concepts involving a great deal of adventure were rated favorably, and group problem solving (rather than individual competition), adequate instructions and assistance, hierarchical skill levels, and "computerized" graphics (rather than cartoons or photographic images) were also emphasized. Three pilot concepts were developed and tested, including a game show type of approach, a space/time travel theme, a theme based on being stranded on a deserted island, and a story based around the creation of a fun fair. The final selected concept was based on a group of children traveling around the globe in search of magic ingredients to concoct an antidote to the elixir generated by the evil Snidwitt, who wants everybody to hate being physically active.

The development of the interactive game proceeded along several trajectories with the ultimate goal of producing a theory-driven behavioral change program within an entertainment media intervention strategy. The first trajectory involved the creation of a list of constructs from SCT, described earlier, that would be influenced by the intervention program. We considered which of these constructs could best be influenced through a focused single game session and which should be introduced and influenced through multiple sessions throughout the IMPACT game. For example, goal-setting and self-monitoring were constructs that readily served as the focal point for a game session. Perceived self-efficacy was more readily influenced by numerous communications throughout the game. Perceived outcome expectancies both provided the focal point for a single game session and was also targeted in various communications throughout the game. A second trajectory involved the development of a story line that was entertaining and that provided a beginning, middle, and end to a coherent plot. The story line was developed to correspond to the number of sessions required to address the theoretical constructs being influenced by the game (eight sessions). Once the story line was established, the script for the game was written to develop the plot and to allow for the delivery of activities and communications within the game that would influence the SCT constructs. The third trajectory involved the production of the game. This was accomplished through close collaboration among the project investigators, the script writers, a professional animation producer, and the media production team assembled by the producer. The production team included programmers, artists, music production staff, and professional voice talent. A very close collaborative relationship was developed among the investigators, the writing staff, and the production team to accomplish the finished game product.

While the game was being produced, a second team led by the study investigators was developing the classroom lessons and the family activities that complemented the interactive game. The design of the classroom and family activities was also driven by SCT providing an integrated approach to behavior change. The classroom and family intervention components also allowed students to enact behavior, skills, knowledge, and attitudes learned while using the interactive computer program. The classroom and parent activities were carefully designed to occur immediately after key content was covered in a computer session and to provide an opportunity to reinforce and enact the behavior, skills, and knowledge communicated in the computer session. For example, goal setting and self-monitoring exercises were provided as a part of the classroom and family activities after these concepts had been introduced as a part of the interactive computer game.

The main intervention was initiated in 2002 when schools were recruited. Recruitment and baseline testing occurred in the fall of 2002, and the schools were randomized. The main intervention commenced in January 2003, and post-testing occurred immediately after the intervention.

Outcome Measures

Height, Weight, and Body Fat. Body weight was measured with a Tanita TBF 300/A analyzer (Tanita Corporation of America, Inc., Arlington Heights, IL). Before use, the scale was leveled and zeroed out. Weight was recorded to the nearest 0.1 kg when children were lightly dressed and without shoes. Height was measured (to the nearest 0.1 cm) under the same conditions with a Seca Mobile Height Rod (Seca Corporation, Hanover, MD) while subjects were standing up straight with arms by their sides. BMI was calculated as weight (kilograms) divided by height (meters) squared, and age- and sex-specific percentiles were determined using Epi Info software (Centers for Disease Control) and the Centers for Disease Control growth curves for pediatric populations (17). Children ≥85th percentile of BMI for age and sex were classified as at risk for overweight or overweight. Bioelectrical impedance was measured, and total percentage body fat was estimated using a Tanita TBF 300/A analyzer.

Physical Activity by Accelerometry. Computer Science and Applications (CSA) model 7164 activity monitors (MTI Health Systems, Fort Walton Beach, FL) were used to measure physical activity over 5 consecutive days. In laboratory studies, the CSA has shown significant positive correlations with energy expenditure (0.82), relative maximal oxygen uptake (0.89), heart rate (0.80), and treadmill speed (0.92) (18). The CSA accelerometer measures normal uniaxial vertical motion while filtering out high-frequency vibrations (such as riding in a car). The signal is digitized, summed in 1-minute intervals, and stored in memory for up to 22 days. In this study, monitors were worn on the right hip attached to an adjustable belt. Participants were instructed to wear the monitors at all times except when sleeping, bathing, or swimming. Monitors were collected, and the stored activity counts were downloaded to a computer for data reduction. Each child used the same unit at both pre- and post-testing.

Accelerometry data were reduced using a custom-developed software program (developed by Dr. John Sirard at Stanford University). Criteria were established to determine days and times with valid accelerometer data. Blocks of time incorporating at least 20 continuous minutes of “0” output were considered to be times when the subject was not wearing the monitor and, thus, not a valid representation of their activity level. These data points were eliminated and not used in any calculations. Also, days with <6 hours of data were eliminated from data reduction to account for unrepresentative days of activity data. Only subjects with ≥3 days of acceptable accelerometry data at both pre-testing and post-testing were included in the final analysis of the accelerometry outcome data. Data were averaged across all acceptable days and included the following: number of acceptable days; average number of minutes the unit was worn on those days; average percentage of time across days that the unit was worn; average counts per minute worn (instead of average counts per day, because each day had different numbers of contributing minutes of data); percent of time across all acceptable days (excluding times when the monitor was not worn) spent in light, moderate, vigorous, very vigorous, and moderate-to-vigorous physical activity, using the Freedson cut-off values (19).

Psychosocial Measures Related to Physical Activity. Social influences ($N = 8$ items), perceived self-efficacy ($N = 12$ items), and beliefs (i.e., outcome expectancies; $N = 16$ items) related to physical activity were measured using the scales of Saunders et al. (20). Reliability was determined for each scale and included internal consistency and test-retest reliability. Fair to good internal consistency reliability was shown for social influences ($r = 0.72$), perceived self-efficacy ($r = 0.71$, 0.71, and 0.54 for the support seeking, barriers, and alternatives subscales, respectively), and beliefs (physical outcomes subscale, $r = 0.75$; social outcomes subscale, $r = 0.58$). Fair to good test-retest reliability was also shown for social influences ($r = 0.78$), perceived self-efficacy ($r = 0.76$, 0.82, and 0.61 for the support seeking, barriers, and alternatives subscales, respectively), and beliefs (physical outcomes subscale, $r = 0.51$; social outcomes subscale, $r = 0.69$). The psychosocial questionnaires were completed at school during a class period identified in collaboration with school personnel.

Statistical Analysis

To verify that the randomization created similar groups, values for the main outcome variables were compared at baseline using ANOVA in those randomized to treatment or control. Major outcome analysis in regard to the significant effects of the intervention were examined using general linear models (GLMs). In this analysis, post-intervention values were examined as the dependent variable, with the baseline value as a covariate and treatment and sex as main effects; age and BMI z-scores were also included as covariates. Statistical analysis was conducted using SPSS version 11.0 (SPSS Inc., Chicago, IL).

Results

The descriptive characteristics of the children entering the study are shown in Table 1. The children were 8.8 to 11.1 years of age and covered a broad spectrum of body weight status. The ethnic composition of this group was 58% His-

Table 1. Mean values at baseline in subjects selected vs. not selected for inclusion in the main outcome analysis based on accelerometry data

	Total group ($n = 207$)	Not selected ($n = 85$)	Selected ($n = 122$)
Sex	51% girls	40% girls	60% girls
Age (years)	9.5 ± 0.4	9.5 ± 0.5	9.4 ± 0.4
Weight (kg)	36.2 ± 9.2	35.7 ± 9.3	36.5 ± 9.2
BMI (kg/m^2)	19.3 ± 3.8	19.0 ± 4.0	19.5 ± 3.7
BMI z-score	0.72 ± 1.04	0.58 ± 1.1	0.81 ± 1.0
Percent fat	23.1 ± 9.5	22.4 ± 9.7	23.5 ± 9.3

Values are means ± SD.

panic, 35% non-Hispanic, and 7% other or undetermined. An intent-to-treat analysis for all children completing the intervention was conducted and showed a significant treatment-by-sex interaction for BMI z-score ($p = 0.04$), such that the intervention led to lower values in treatment in girls and higher values in boys and a trend toward a similar effect for effects on percent body fat ($p = 0.09$).

Because the main outcome analysis was conducted in a smaller group of 122 children providing valid accelerometry data at pre- and post-intervention, Table 1 also compares those children not selected and selected for this analysis. There were no significant differences between these two groups, although the group used for the final analysis tended to be heavier and tended to include more girls than boys. Table 2 presents the baseline data for the 122 children used in the main outcome analysis and shows that, at the beginning of the study, there were no significant differences in baseline characteristics between treatment and control children, with the exception of age (control children were older by 0.1 month) and a nonsignificant tendency for the control children to be heavier. Baseline age and BMI z-scores were used as covariates in the major outcome analysis.

Table 2. Baseline descriptive data in subjects with valid accelerometry

	Mean baseline value in control ($n = 59$)	Mean baseline value in treatment ($n = 63$)
Ethnicity	66% Hispanic 27% non-Hispanic 7% other	51% Hispanic 40% non-Hispanic 10% other
Sex	61% girls	57% girls
Age (years)	9.5 ± 0.4	9.3 ± 0.4
Weight (kg)	37.2 ± 8.6	35.9 ± 9.8
BMI (kg/m^2)	19.9 ± 3.4	19.3 ± 4.0
BMI z-score	0.94 ± 0.91	0.71 ± 1.08
Percent fat	24.7 ± 8.9	22.5 ± 9.6
Counts per minute	578 ± 148	598 ± 178
Percent time in light	79 ± 10	78 ± 8
Percent time in moderate	16 ± 4	16 ± 4
Percent time in vigorous	1.7 ± 1	1.9 ± 4
Percent time in MVPA	18 ± 5	18 ± 6
Percent time in very vigorous	2 ± 1.4	2.4 ± 1.6

Values are means ± SD. MVPA, moderate to vigorous physical activity.

Table 3. Main outcome analysis: adjusted mean values after treatment in subjects with valid accelerometry data

	Control boys (*n* = 24)	Intervention boys (*n* = 27)	Control girls (*n* = 36)	Intervention girls (*n* = 35)	Significant main effects of sex and treatment in GLM
Height (cm)	138.3 ± 0.2	138.0 ± 0.2	138.7 ± 0.2	138.5 ± 0.2	S ($p = 0.013$)
Weight (kg)	37.3 ± 0.3	37.6 ± 0.3	38.0 ± 0.2	37.8 ± 0.3	S ($p = 0.09$)
BMI (kg/m^2)	19.3 ± 0.2	19.5 ± 0.1	19.6 ± 0.1	19.5 ± 0.1	None
BMI z-score	0.54 ± 0.05	0.69 ± 0.05	0.69 ± 0.04	0.62 ± 0.04	S×T ($p = 0.016$)
Percent fat	21.4 ± 0.5	22.5 ± 0.5	23.4 ± 0.4	22.0 ± 0.4	S×T ($p = 0.009$)
Counts per minute	671 ± 32	614 ± 29	569 ± 25	548 ± 26	S ($p = 0.004$)
Percent time in light	0.78 ± 0.02	0.75 ± 0.02	0.78 ± 0.01	0.81 ± 0.01	S×T ($p = 0.052$)
Percent time in moderate	0.18 ± 0.008	0.15 ± 0.007	0.16 ± 0.006	0.15 ± 0.007	T ($p = 0.03$)
Percent time in vigorous	0.025 ± 0.002	0.026 ± 0.002	0.017 ± 0.002	0.017 ± 0.002	S ($p < 0.001$)
Percent time in MVPA	0.21 ± 0.01	0.18 ± 0.01	0.18 ± 0.01	0.17 ± 0.01	S ($p = 0.02$) T ($p = 0.06$)
Percent time in very vigorous	0.03 ± 0.003	0.03 ± 0.003	0.02 ± 0.002	0.02 ± 0.002	S ($p = 0.002$)
Beliefs	33.5 ± 1.2	30.5 ± 1.0	30.7 ± 1.0	30.9 ± 1.1	None
Self-efficacy	8.7 ± 0.5	9.7 ± 0.5	8.7 ± 0.4	9.3 ± 0.4	S ($p = 0.06$)
Self-efficacy asking	2.7 ± 0.2	3.4 ± 0.2	3.4 ± 0.2	3.1 ± 0.2	S ($p = 0.07$)
Self-efficacy barriers	3.9 ± 0.2	3.8 ± 0.2	3.3 ± 0.2	3.5 ± 0.2	S ($p = 0.05$)
Social norms	4.1 ± 0.7	6.2 ± 0.6	4.1 ± 0.6	4.3 ± 0.6	T ($p = 0.07$)
Family norms	2.0 ± 0.5	3.5 ± 0.4	2.5 ± 0.4	2.6 ± 0.4	T ($p = 0.045$) T×S ($p = 0.09$)
Friends norms	2.1 ± 0.3	2.7 ± 0.3	1.7 ± 0.3	1.6 ± 0.3	S ($p = 0.009$)
Outcome expectancies	11.4 ± 0.5	13.3 ± 0.4	11.9 ± 0.4	11.8 ± 0.4	T ($p = 0.049$) T×S ($p = 0.027$)
Outcome expectancies positive	7.9 ± 0.5	9.5 ± 0.4	8.1 ± 0.4	8.3 ± 0.4	T ($p = 0.04$) T×S ($p = 0.08$)
Outcome expectancies negative	1.6 ± 0.2	1.1 ± 0.2	1.5 ± 0.2	1.3 ± 0.2	None

Values are means ± SE. MVPA, moderate to vigorous physical activity.

Table 3 provides a summary of the main outcome analysis by GLM and presents adjusted mean values at post-test in control versus treatment boys and girls. These values are adjusted for baseline age, BMI z-score, and baseline value of the dependent variable being examined. There were no significant treatment effects on total physical activity by accelerometry, but there was a treatment effect on reducing percentage of time in moderate-intensity activity (16.5% to 15% of the time), and significant sex-by-treatment interactions for the percentage of time in light-intensity activities (reduction in boys from 78% to 75% of the time and an increase in girls from 78% to 81% of the time). There were marginal or significant treatment effects for improvements in psychosocial outcomes related to physical activity, including self-efficacy ($p = 0.06$), social norms ($p = 0.07$), and outcome expectancies ($p = 0.05$). These marginal treatment effects became significant when ethnicity was included as a covariate. The improvement in outcome expectancies was more significant in boys than in girls ($p = 0.027$ for treatment by sex interaction).

With regard to obesity outcomes, there were significant sex-by-treatment interactions for BMI z-score ($p = 0.016$) and percent body fat ($p = 0.009$), such that there was a significant treatment effect for obesity reduction in girls but not in boys. For BMI z-score, adjusted mean value after intervention was 0.54 ± 0.05 in control boys, 0.69 ± 0.05 in treatment boys, 0.69 ± 0.04 in control girls, and 0.62 ± 0.04 in treatment girls. For percent body fat, adjusted mean value after intervention was 21.4 ± 0.5% in control boys, 22.5 ± 0.5% in treatment boys, 23.4 ± 0.4% in control girls, and 22.0 ± 0.4% in treatment girls.

Discussion

This is the first study that we are aware of that has examined the efficacy of interactive multimedia for promoting physical activity and preventing obesity in children. Our major findings are that this novel 8-week interactive multimedia curriculum, supplemented by classroom and homework assignments, led to significant treatment effects for light- (increase in girls, reduction in boys) and moderate- (overall decrease) intensity physical activity and improvement in psychosocial outcomes related to physical activity. The intervention also produced improvements in obesity indices in girls but not in boys. These obesity improvements were likely caused by increases in light activity resulting from the intervention translating to ~20 minutes more time spent in light activities per day.

The reasons the program produced increases in light activity and decreases in moderate activity are not readily apparent. One possible explanation may stem from the nature of moderate and light activity and the role of environmental barriers. Substantial increases in moderate-to-vigorous activity may require changes in the environment or, at least, an individual's control over the environment. For example, increases in moderate-to-vigorous activities may require the presence of equipment and friends who can participate. For children, this may also require being taken to a public facility (e.g., swimming pool) or to a team sports activity by parents or the close proximity of a park or other open space. In contrast, increases in light activity can be achieved through activities that may not require special environments or equipment (e.g., walking, playing). In addition, parents may be reluctant to participate with children in moderate-to-vigorous physical activities. However, light activities produce less discomfort for the parents and may result in more direct participation and support by the parents. The IMPACT intervention attempted to modify these environmental factors through the use of family intervention components and by building awareness of the need for environmental change into the program as one of the eight interactive media sessions. However, these components of the program may not have been sufficiently strong to overcome real world constraints on moderate-to-vigorous physical activity.

In contrast, we showed an increase in light-intensity activity in girls that translated to ~24 min/d (~36 kcal/d, assuming that light activities average 1.7 METS) and that this subtle change was sufficient to reduce obesity indices, even though it was counteracted by a reduction in moderate-intensity activities of ~8 min/d (~20 kcal/d, assuming that moderate activities are 2.5 METS). We believe that these subtle changes in physical activity could potentially explain the small reduction in obesity in girls caused by the net increase in energy expenditure of ~16 kcal/d (almost 1000 kcal over the 8-week intervention). In addition, it is possible that other subtle changes in sedentary activity (e.g., reduced television watching) occurred that would not have been detected by accelerometry and would be impossible to detect by imprecise questionnaire methods. It is extremely difficult to translate this projected difference in energy expenditure to changes in body composition because of the changes occurring as a result of growth and the unknown deposition as fat and lean tissue. However, if this net difference in energy expenditure were deposited as fat and lean tissue in the ratio of 2:1, it would result in an approximate weight change of 0.15 kg, which is close to the 0.2-kg difference in post-intervention body weights between treatment and control girls.

The use of novel multimedia teaching approaches has been recognized as one of the most important ways to improve the status of nutrition education in children (21), and computer-assisted behavioral counseling has been shown to be effective in various studies in high school students (22), undergraduate students (23), and fourth grade children (12). Together with these previous studies, evidence is beginning to mount that shows the power and potential effectiveness of multimedia approaches for affecting health behavior. This approach may be particularly suitable to children, who are generally attracted to the use of technology, and may be more widely disseminated than traditional intervention approaches because of their acceptability by the target audience (24). Multimedia teaching approaches can also target other family members, and this has shown to be critical in effective obesity interventions for children (25). The intervention approach used in this study combines the highly novel interactive computer technology with more extensively tested approaches to reach and impact family behavior. Our experience shows that this approach is feasible and potentially effective. Future studies might examine the ability of interactive technology to produce family intervention activities tailored to characteristics of individual children and families and to the game experience of the children.

Controlled intervention studies suggest that exercise intervention in children may or may not have beneficial effects on obesity, depending on the nature of the intervention. Project SPARK was a large-scale study that randomly assigned seven elementary schools to receive physical education through either usual mechanisms, trained teachers, or specialized instructors (26). There was a nonsignificant trend for children exposed to specialized physical education to have lower total body fat after 2 years. Results from other school-based studies that included physical education are controversial, with some showing no changes in adiposity (27) and others showing a decrease (28). Several intervention studies that targeted obese children and were designed to prevent obesity have been conducted in a school-based setting. These programs included an exercise component (although not clearly defined), and the results suggested that intervention can significantly reduce the prevalence of obesity (29,30). The IMPACT intervention produced positive changes in physical activity and obesity without the inclusion of active exercise components implemented in the school setting. The effectiveness of the IMPACT intervention might be enhanced by the addition of such an active exercise component at school. The IMPACT intervention could be used as a means to increase the amount of time students spend being active when the physical education environment in the school is altered to increase opportunities to be physically active.

The major challenge of this study was to successfully integrate our learning objectives and learning theory into the context of animated stories through collaboration between behavioral scientists and the production team. Another challenge was to design a learning game that met individual differences across the sociocultural diversity of the population. Sex and cultural differences were carefully considered in the design of the IMPACT intervention and in initial focus group assessments. Cultural and sex adaptations may need to occur in the language used for specific messages and for the models and communication sources used. Additional attention to these issues was addressed during message pretesting at various stages of the development process. Despite this level of activity, there were obvious sex differences in the effects of the intervention, and possibly also ethnic differences that we did not have sufficient power to examine. The IMPACT intervention produced changes in the predicted direction on a number of outcomes for girls but not for boys. This is consistent with two school-based obesity prevention interventions that showed intervention effects among children (10,11). The reasons for these observed sex differences are difficult to discern. The moderating effect of sex may be a result of subtle differences in the characters or messages used in the intervention that led to greater acceptance and credibility for the game by girls relative to boys. In the IMPACT intervention, boys also tended to play the game faster and to use more "gaming" techniques that might speed their progress through the game but hinder their understanding and processing of each of the activities within the game. This could lead to reduced strength of the interactive media for boys, whereas girls process and get the full impact from the interactive game environment. Future versions of the IMPACT intervention might benefit from the explicit inclusion of tailoring strategies based on sex, ethnicity, and selected psychosocial variables (31,32).

We realize the irony of our findings and the implications, given that the intervention is based on the use of an inactive behavior (computer-based education) to promote a more physically active lifestyle. Our response to this is that we cannot ignore the power of computers and computer technology. Obviously children are drawn to computers, and computer technology is here to stay. Our philosophy was to use the power of computer technology to our advantage to invoke beneficial changes in behavior. In addition, it is important to recognize that only one-half of the intervention material in this study was delivered through the computer; the remainder was delivered in classroom activity sessions or in homework assignments involving other family members. Thus, the interactive elements were not limited to computer activities. Further studies are needed to determine which specific component of the intervention had significant effects, although we would hypothesize that it was the combination.

A number of future directions can be proposed for this research. First, the intervention should be replicated with a broader range of schools representing diverse ethnic and socioeconomic backgrounds. This will help establish the efficacy of the program with a range of target population groups of interest for future dissemination. Second, conducting mediational analyses in future studies will help determine the underlying factors that account for the effectiveness of the intervention (33,34). The lack of mediational analyses, because of limited sample size, is a limitation of this study. Third, the addition of a dietary intervention component is warranted to enhance the strength of the program to modify obesity outcomes. This trial has established the feasibility of the approach and suggests that the intervention can be readily extended to include dietary components. Fourth, careful consideration should be given to linking the IMPACT intervention to direct modification of physical activity at the school site. As noted previously, behavioral intervention programs have been most effective at modifying physical activity at school and less effective outside of school. The simultaneous delivery of the interactive media program along with enhanced physical activity programs in physical education and at other available times at school might lead to a substantially strengthened intervention approach. Fifth, the interactive game might be enhanced through the addition of several design features that link to our underlying theory of behavior change. For example, in the present IMPACT interactive media intervention, self-monitoring of behavior occurs entirely apart from the interactive game but is included in the classroom and family activities. Future versions of the intervention may provide for the input of self-monitoring data, allowing the children to more carefully track and modify their improvements in physical activity as the intervention progresses.

In conclusion, we developed a novel interactive multimedia curriculum using an interactive CD-ROM, supplemented by classroom and homework assignments, focused on promoting physical activity. An 8-week intervention led to significant treatment effects for light- (reduction in boys, increase in girls) and moderate- (overall decrease) intensity physical activities and improvement in psychosocial outcomes related to physical activity. The increase in light activity and the decrease in moderate activity resulted in a projected net increase in energy expenditure in girls. Overall, these effects favored an improvement in obesity indices in girls but not in boys. This study further showed the use of interactive multimedia for delivering effective interventions for behavior change.

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