“Creature-101”: A Serious Game to Promote Energy Balance-Related Behaviors Among Middle School Adolescents

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Abstract

Background: Considering adolescents’ heavy use of media, serious videogames may provide an engaging and innovative way to achieve positive impact on adolescents’ diet and physical activity. The objective of this study was to evaluate the efficacy of playing a serious game, “Creature-101” (developed by Teachers College, Columbia University [New York, NY] and Stottler Henke Inc. [San Mateo, CA]), at promoting energy balance-related behaviors (EBRBs) such as increasing fruits and vegetables intake, water intake, and physical activity and decreasing processed snacks intake, sweetened beverages intake, and recreational screen time.

Subjects and Methods: This pre–post intervention–control study ($n = 590$) was conducted in New York City low-income public middle schools. The students (11–13 years of age, 51.6 percent male) played “Creature-101” online in science/health education classes (seven sessions, 30 minutes each session for 1 month). “Creature-101” used behavioral theories as the framework for “creature care” in a world “Tween.” Students were provided with scientific evidence that promoted energy balance through minigames, educational videos, and slideshows and were motivated with interactive dialogues with game characters. Students also assessed their own behaviors, created their own “real life” food and activity goals, and reported their progress. A self-reported, validated, online instrument that measured frequency and amount of targeted behaviors was administered at baseline and post-intervention.

Results: Analysis of covariance compared post-test means between groups with pretest scores as covariates. Intervention students reported significant decreases in frequency and amount of consumption of sweetened beverages and processed snacks compared with the controls. No changes were observed for the other behaviors.

Conclusions: “Creature-101” was effective at reducing consumption of sweetened beverages and processed snacks, which are related to obesity risks, indicating that the game shows promise at promoting EBRBs.

Introduction

OBESITY AMONG ADOLESCENTS has led to serious concerns because of the strong associations between obesity and cardiovascular disease risks, hypertension, dyslipidemias, and childhood-onset type 2 diabetes mellitus.^{1–8} The main cause of obesity is considered to be energy imbalance, that is, the discrepancy between calories consumed as food and beverages and calories expended to support normal growth and development, metabolism, and physical activity (PA).⁹ Research shows that the top sources of energy for adolescents today are sugar-sweetened beverages (sugar-SB), energy-

dense snacks, and candies.^{10,11} The consumption of fruit, vegetables, and water is low.¹² The direct relationships between some of these specific behaviors and childhood obesity have been difficult to establish.^{13–15} However, there are many methodological concerns with the studies.¹⁶ Based on the total evidence, the 2010 Dietary Guideline Advisory Committee suggested that strategies to prevent childhood obesity should include efforts to reduce surplus energy intake, especially energy from foods and beverages that provide empty calories from added sugars and solid fats.¹⁷ Increasing consumption of fruits and vegetables (FV) in childhood is an important public health goal because diets high in a variety of FV tend to

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be lower in energy density and higher in essential nutrients and phytochemicals and therefore likely to improve energy balance and prevent obesity.¹⁷

Adolescents' PA levels are below recommendations. Adolescents spend less time in PA and more time in sedentary activities.^{18–21} Among sedentary activities, media use has increased tremendously. In the United States, approximately 93 percent of adolescents 12–17 years of age go online and devote an average of 7 hours 38 minutes with entertainment media across a typical day (more than 53 hours a week).²² Adolescents are also extensive users of digital devices, and videogames are a big part of their digital experiences.²³ Capitalizing on children's preexisting attention and enjoyment of videogames, research is investigating educational videogames for obesity prevention and health promotion.²³ Two reviews have indicated that serious videogames have resulted to some improvements in diet and PA in children.^{23,24} Serious videogames are specially designed to entertain players as they educate, train, or change behavior.²⁵

Children in the United States spend roughly a third of every weekday, equivalent to about 32.5 hours a week, in schools, making schools an ideal place for implementing behavior change interventions.²⁶ Middle school represents a strategic time and place to study interventions as this is a time of both physical and emotional development. Diet and PA behaviors are in flux during this period, and this transition represents an optimal opportunity to encourage healthier behaviors.²⁷ Although schools serve as an ideal place to implement interventions, a few barriers should be noted. Limited resources for staff training and frequent staff turnover are coupled with the lack of time to implement the interventions given the strict academic schedules in schools. Serious games can offer an innovative solution to mitigate these barriers. They can provide seamless implementation within the school day with minimal teacher oversight.²⁸ However, there are few evidence-based educational nutrition games that are currently available for middle school adolescents. These games have focused on increasing students' FV intake only or accompanied by water intake and/or PA.^{29–31} The results are mixed. One game found an increase in FV intake but not water intake or PA, and the research study was conducted in the student's homes as opposed to classrooms.³¹

"Creature-101" was developed by Teachers College of Columbia University (New York, NY) and Stottler Henke Inc. (San Mateo, CA) for middle school adolescents. The game content was based on a previously tested nutrition science curriculum called Choice, Control & Change (C3) that was successfully evaluated with positive behavioral outcomes.^{32,33} However, the curriculum consisted of 24 lessons, making it challenging to fit into tight classrooms schedules.³³ Thus, the goal was to deliver the educational content in an appealing game format that would take up less classroom time. In addition, "Creature-101" targeted a range of eating and PA behaviors in a single intervention that others did not target before.

The purpose of this study was to evaluate the efficacy of "Creature-101." It was hypothesized that adolescents who played "Creature-101" would significantly increase their FV and water intake, increase PA, decrease intake of processed snacks (e.g., chips, candy) and SB, and reduce recreational screen time (watching TV and playing videogames for en-

tertainment) activities; taken together, these are energy balance-related behaviors (EBRBs).

Subjects and Methods

Game description

The educational content of "Creature-101" was derived from the C3 curriculum. C3 is an inquiry-based nutrition science curriculum that is targeted at reducing risk of obesity by promoting healthy eating and PA behaviors. It sought to enhance motivation, increase knowledge in nutrition, and provide skills to achieve and maintain a healthy body within the complex real-life environments. It specifically targeted the following behaviors: reducing intake of SB and increasing water intake, reducing eating out in fast food (FF) restaurants, increasing intake of FV, reducing intake of packaged snacks (PS), and increasing PA. The curriculum produced significant positive changes in consumption of fewer SB and PS, small sizes of FF, and increased PA among the students.³²

"Creature-101" used a game engine called Open Space. A virtual world named Tween was created with avatars, creatures, and different representations of the real world that included a town, a farm, a science center, town houses, etc. OpenSpace was embedded into a social networking structure called Elgg. Through Elgg, students could create their accounts, read messages, customize their avatars, build their profiles, add widgets to their homepage, view their activity lists, and freely navigate and explore the Tween world. Students could also share accomplishments and goals with others. The storyline featured a teen inventor named Murphy who accidentally created a wormhole and found himself in Tween. To befriend the creatures living there, Murphy brought SB, PS, videogames, and TV sets from Earth. The creatures soon became addicted to these foods and sedentary activities and became sick. Murphy, realizing what he had done, decided to save the creatures. Thus, he brought with him a few experts from Earth who might be able to help. They included a dietitian, a food scientist, and an organic farmer. In the storyline Murphy recruits helpers (students) to each adopt a creature and help it regain health (Figure 1 provides screenshots of the game). The students were engaged in a linear progression through game activities that included dialogues with Murphy and the experts, comics, slideshows, videos, and minigames (Table 1). These game activities were intended to help students learn the scientific evidence behind healthful food and activity choices and personal outcomes for their creatures and themselves.

The theoretical framework of "Creature-101" was based on social cognitive^{34–36} and self-determination³⁷ theories. The behavioral change procedures were based on the techniques of Michie et al.³⁸ The students were provided with an "autonomy-supportive" environment as they entered into the game world as "saviors of their creatures." They gradually had to master the challenges of the creature-caretaking processes that intended to instill "competence" and work toward improving their own health and also the health of their creatures (relatedness). Activities such as learning about the role of taste, sugar, and fat in our diets were designed to provide scientific evidence about why the behaviors are important and also aimed to motivate students. Students learned food and nutrition facts about sugar and fat contents of commonly consumed beverages and snacks through

FIG. 1. “Creature-101” game screenshots: (a) “Creature-101” game interface, (b) interactive game dialogue, (c) game creatures, (d) slideshow about sugar, (e) student self-assessment questionnaire, (f) creature energy gauge, (g) minigame on sweetened beverages, (h) student goal-setting, and (i) educational video.

engaging minigames. “Creature-101” also aimed to help students master behavioral skills by setting personal behavioral goals for taking action for themselves through the guided goal-setting feature in the game. The goal-setting feature included two parts: (1) Students assessed their own behaviors by completing brief questionnaires that asked about frequency, amount/time spent, and the time of the day for behaviors targeted in the game. (2) Students set personal goals that were tailored based on their current behaviors and desired change and specific in regard to how much to increase/decreasing frequency, how much to change amount/time spent on the behaviors, and what days of the week and times of the day they would make this change. These factors were expected to lead to self-efficacy beliefs that would enhance personal agency. Continual encouragement and reinforcements were provided through additional activities such as diabetes and clogging of arteries videos that featured scientific evidence related to personal long-term health consequences and reinforcement of motivation.

During development, the game was piloted tested twice. The first round of piloting was conducted with eight middle school students. Students played the game for 2 hours where they were observed for what activities they participated most in and their level of engagement with different aspects of the game. A focus group with students revealed that students liked the game for its social networking features such as chats and messaging features and the fun element associated with

creature care. However, the students also reported lack of sufficient game activities. The educational value of the game was unclear, and the students failed to link the game to real-life behaviors. A second round of pilot included 43 middle school students from two sixth grade classes at a New York City (NYC) public middle school. The main objective was to assess if the current game structure was adequate to meet the objectives of behavior change. Focus groups and in-class observations showed that the students understood the storyline and saw Murphy as a hero because he was trying to help the creatures. They also indicated that the minigames were fun and an entertaining way to teach them about the sugar and fat in food. They also seemed to understand why it was important to make the behavior changes that were addressed in the game. A formative evaluation of the game was conducted with three classes of seventh grade students ($n=73$). Students played the game for seven sessions. Some issues were identified such as unclear minigame instructions, long dialogues with the game characters, lack of appropriate navigation features in the game, and difficulty with login. All these issues were addressed before the final release of the game.

Study design

The study used a pre- and post-matched pair intervention and control design. It was conducted in NYC public middle

TABLE 1. GAME LEVELS AND SESSION ACTIVITIES OF "CREATURE-101"

<i>Game sessions</i>	<i>Game levels</i>	<i>Session activities</i>	<i>Type of activity</i>	<i>Theory constructs used</i>	<i>Change procedures^a</i>
Session 1	X I	Eat-Move survey: Pretest Selection of avatar and a creature	Survey Activity	Autonomy support	Action planning
	I	Welcome to Tween	Slideshow	Autonomy support	Motivational messaging Action planning
Session 2	I	Creature caretaking	Slideshow	Outcome expectations Competence	Motivational messaging Information about behavior
	II	Understanding taste "Sugar Rush" game	Slideshow Minigame	Outcome expectations Behavioral capability Competence	Motivational messaging Motivational messaging (scientific rationale) Knowledge acquisition/ mastery learning Rewards/points
Session 3	II	Investigating blood sugar (and diabetes)	Short video	Outcome expectations (perceived risk)	Motivational messaging (scientific rationale)
	II	French fry visualization survey (why humans like fat in diet)	Brief survey	Outcome expectations	Motivational messaging (personal consequences)
	II	Fat in chips game	Minigame	Outcome expectations Behavioral capability Competence	Use of imagery Motivational messaging (scientific rationale) Knowledge acquisition/ mastery learning Rewards/points
Session 4	II	Go with the flow video (fat clogging blood vessels)	Short video	Autonomy support Outcome expectations Behavioral capability	Motivational messaging (scientific rationale) Prompts, cues
	II	"Domino Snack" game (snacks are high in fat and sugar)	Minigame	Outcome expectations Behavioral capability Competence	Motivational messaging (scientific rationale) Personal experiment/data collection Skills mastery
	II	Creature energy gauge and behavior bars	Slideshow	Autonomy support Behavioral skill Competence	Skills mastery Problem solving Monitoring Rewards/points
	II	What's wrong with our food system	Video	Outcome expectations (environmental risk perception)	Motivational messaging Information about outcomes
	II	Fruits and vegetables puzzle	Minigame	Outcome expectations Behavioral capability	Motivational messaging Problem solving Rewards/points

(continued)

TABLE 1. (CONTINUED)

<i>Game sessions</i>	<i>Game levels</i>	<i>Session activities</i>	<i>Type of activity</i>	<i>Theory constructs used</i>	<i>Change procedures^a</i>
Session 5	III	Estimating portion sizes	Slideshow	Behavioral capability Self-efficacy Competence	Skills mastery
	III	Food and activity frequency questionnaires	Short questionnaire	Behavioral capability Competence	Self-monitoring skills mastery
	III	Goal setting (for self)	Short questionnaires	Goal setting Self-efficacy Autonomy Self-regulation	Goal setting Skills mastery
Session 6	IV	Digestion of food (importance of insulin) Energy burn video Calorimetry	Simulation	Outcome expectations	Information about outcomes Motivational messaging
	IV	Human food system	Short science experiment video Short science experiment video Slideshow	Outcome expectations Behavioral capability Behavioral capability	Motivational messaging Information on behavior/outcome Information on behavior/outcome
Session 7	IV	Do you really believe what that commercial says? What's on your plate	Slideshow	Outcome expectations (environmental risk perception) Outcome expectations (environmental risk perception)	Motivational messaging Information on behavior/outcome Motivational messaging Cues/triggers
	IV	Maintain creature's energy balance	Short film	Outcome expectations (environmental risk perception)	Motivational messaging Information on behavior/outcome Cues/triggers
Session 8	IV	Essay	Activity	Autonomy Competency Behavioral skills Outcome expectations (personal consequences)	Self-monitoring Skills mastery Rewards/points Reinforcement of learning
Session 9	X	Eat-Move survey: post-test	Survey		

^aChange procedures derived from social cognitive theory, self-determination theory, and the techniques of Michie et al.³⁸ for behavior change.

schools during the 2011–2012 school year. Eight public middle schools (four schools under each condition) were recruited from the low-income areas of NYC that were matched in pairs based on the percentage of students who received free lunch, reading and math scores on state tests, and ethnicity distribution. The school within a matched pair that scheduled the program first was assigned to the intervention, and the latter was assigned to the control condition. However, two schools enrolled in the control condition did not participate in the study because of conflict with their academic schedules. The schools were not replaced because they dropped out toward the end of the school year. This left four schools in the intervention and two schools in the control condition. Table 2 summarizes the baseline characteristics.

Study participants

All sixth and seventh grade students ($n=710$) of the recruited schools were invited to participate. However, only 590 students were entered into the study because of the two schools that did not participate. The study was approved by the Institutional Review Boards of Teachers College of Columbia University and the NYC Department of Education. Informed consent was obtained from parents and active assent from the students.

“Creature-101” intervention

The students in the intervention played “Creature-101” online, about twice a week for a month in their science/health education classes. There were nine sessions of 30 minutes

TABLE 2. BASELINE COMPARISONS

	Intervention (n=4 groups)	Control (n=2 groups)
School demographics (mean $\pm$ SD) ^a		
Percentage students receiving free lunch	78 $\pm$ 21.4	78 $\pm$ 5.6
Race/ethnicity (percent)		
White	7.50 $\pm$ 8.5	5.50 $\pm$ 6.3
Black	28.75 $\pm$ 15.39	30.50 $\pm$ 14.84
Hispanic	58.25 $\pm$ 15.6	53.50 $\pm$ 20.5
Asian	5.25 $\pm$ 7.08	3.50 $\pm$ 2.12
Test scores (percentage of students at grade level)		
Reading	35.92 $\pm$ 23.07	28.00 $\pm$ 0.45
Mathematics	63.12 $\pm$ 17.4	48.05 $\pm$ 2.75
Participant demographics [n (percent)]		
n	182	159
Age of students (years) ^b		
< 10	1 (0.5)	2 (1.2)
11	118 (64.8)	41 (25.8)
12	52 (28.6)	81 (51.0)
13	10 (5.6)	29 (18.3)
> 13	1 (0.5)	6 (3.7)
Gender		
Male	94 (51.6)	79 (49.7)
Female	88 (48.4)	80 (50.3)
Hispanic/Latino		
Yes	114 (62.6)	102 (64.1)
No	68 (37.4)	57 (35.9)
Baseline characteristic (mean $\pm$ SD)		
Frequency of behaviors ^c		
Sweetened beverages	2.01 $\pm$ 1.09	2.03 $\pm$ 1.10
Water	3.24 $\pm$ 1.16	3.23 $\pm$ 1.24
Processed snacks	2.29 $\pm$ 1.27	2.31 $\pm$ 1.24
Fruits and vegetables	3.05 $\pm$ 1.19	2.93 $\pm$ 1.27
Recreational screen time	3.22 $\pm$ 1.31	3.33 $\pm$ 1.37
Physical activity	2.80 $\pm$ 1.28	2.73 $\pm$ 1.31
Baseline amount/time spent on behavior		
Sweetened beverages	1.69 $\pm$ 0.85	1.76 $\pm$ 0.86
Water	3.15 $\pm$ 0.97	3.22 $\pm$ 1.05
Processed snacks ^d	1.72 $\pm$ 0.66	1.89 $\pm$ 0.69
Fruits and vegetables	2.60 $\pm$ 0.92	2.60 $\pm$ 0.94
Recreational screen time	2.95 $\pm$ 1.33	3.09 $\pm$ 1.35
Physical activity	2.87 $\pm$ 1.39	2.75 $\pm$ 1.26

^aThere were no significant differences in school demographics between the intervention and control groups.

^bThe age of students in the control group was significantly higher than the intervention group: $F_{1,374}=62.60$, $P<0.00$.

^cNumber of items, Cronbach α values for the scales: sweetened beverages, 8, 0.8; water, 6, 0.5; processed snacks, 8, 0.8; fruits and vegetables, 4, 0.7; recreational screen time, 4, 0.7; and physical activity, 6, 0.8.

^dThe amount of processed snacks consumption was higher in the control group ($P=0.008$).

SD, standard deviation.

each. Each student was assigned with a unique user identification and password that he or she used to log-in to play the game. Students had to complete a set of activities to make progress in the game. Activities ranged from 1 to 63 and were divided into four game levels. The levels were as follows: Completion of Level-I with Activities 1–9 indicated that the students signed into the game, created their avatars, and creatures and learned about the purpose of the game. Level-II was completed with Activities 10–32, indicating that the students had learned about the benefits of drinking water, eating FV, and doing PA. They also learned how foods high in sugar and fat affect health, sugar content in a variety of sweetened drinks, fat content of chips, and sugar and fat content of processed PS. Completion of Level-III with Activities 33–51 indicated that the students had analyzed their own eating and PA behaviors and had set personal goals for themselves. Completion of Level-IV with Activities 52–63 indicated that students attained energy balance of their creatures, reported on their own goal progress, and completed the game by writing their essays about what they learned in the game.

Control group intervention

Students in the control group played “Whyville”³⁹ once a week for a month. “Whyville” is a popular online game for students between the ages of 8 and 15 years. Its goal is to engage its users in learning about a broad range of topics, from science and business to art and geography.^{39,40} The user identifications and passwords were provided by the creators of “Whyville,” Numedon Inc. (Pasadena, CA). All networking activities were deactivated. Researchers selected eight minigames (that excluded nutrition games) that matched with the standard science/health curriculum of NYC and were approved by the teachers.

Outcome measures and data collection

The primary outcome was to assess if “Creature-101” was effective at promoting the targeted EBRBs in the game. A 41-item online instrument called Eat-Move was developed to measure frequency and amount of the targeted behaviors and the demographic variables. The items were modified from two pre-existing instruments.^{32,41} The frequency items were selected from the Beverage and Snack Questionnaire (BSQ), which matched the targeted behaviors of the study. The amount of food items and the recreational screen time activity items were selected from the Eat Walk survey. The response scales for the frequency items were reduced from a 7-point scale from the BSQ to a 5-point scale. The scales for the amount of food items and recreational screen time activities were recreated. The PA items with their response scales were created. The instrument contained text plus colored photographs to improve understanding of the questions, facilitate comprehension of text, increase attention, and add pleasure to the evaluation process.⁴² There were 28 items measuring food intake, 10 measuring PA, and 3 items for demographic variables with multiple-choice responses. The instrument was piloted twice, and the final version was used in the study. The mean for the Flesch Kincaid scores of all items in the final instrument was 3.69 ± 1.29 . The instrument showed moderate validity and reliability when compared with other validated instruments reported in the literature.^{32,41,43} The Cronbach

scores for the behaviors were between 0.5 and 0.8. Criterion validity ranged from 0.1 to 0.8 for food items (with the majority between 0.6 and 0.8) and 0.2 and 0.5 for PA items (with the majority between 0.3 and 0.5). Test-retest correlations were between 0.3 and 0.9 (the majority between 0.6 and 0.9). The instrument was delivered through Survey Monkey (Survey Monkey Inc., Palo Alto, CA). Students used their game user identifications to log on to the survey. It was self-administered in the classrooms under supervision of research assistants and was completed in 15 minutes. Data were imported from Survey Monkey as Excel[®] (Microsoft[®], Redmond, WA) spreadsheets. All the students consented to participate in the study to play the game.

Data analysis

The outcome variables were analyzed using an analysis of covariance model with group (intervention and control) as fixed independent variables and the respective pretest scores as covariates. The control group consisted of both sixth and seventh graders, whereas the intervention group consisted of sixth graders only, resulting in a significant age difference between the groups. However, age was not associated with target behaviors at baseline (χ^2 analysis) and hence was not included as a covariate in the analysis of covariance models. Additional *post hoc* analyses were conducted to assess the robustness of the outcomes. For hypothesis testing, significance was set at $P < 0.05$. Statistical Package for Social Sciences software (version 20, 2012; SPSS Inc., Chicago, IL) was used for data analysis.

Results

Baseline characteristics

The intervention group consisted of 359 sixth grade students from four schools, and the control group had 172 students (sixth and seventh graders) from two schools. The mean (standard deviation) age of the students was 11.3 (0.74) years. The students were approximately 50 percent male and 63 percent Hispanics. Both groups were similar at baseline (Table 2).

Implementation of “Creature-101” in the intervention group

The students in the intervention group completed all nine sessions of the intervention. The first and last sessions were used for pre- and post-test surveys, and seven sessions were used for playing “Creature-101.” However, only 64 percent of students completed all game activities (i.e., completed all four game levels) and were included in the analysis (Fig. 2). This ensured that students received the educational content of the intervention, set their own real-life food and activity goals, and had time to work through them to be able to make changes in the behaviors they chose. The common reasons for noncompletion included absenteeism, loss of Internet connectivity, and slow downloading of the game activities. There were no differences between game completers and non-completers as assessed at baseline (data not shown).

Implementation in the control group

The students in the control group completed four sessions of the intervention in 1 month. Data were collected during the

FIG. 2. "Creature-101" consort statement for participant recruitment.

first and last sessions, and "Whyville" was played in the remaining two sessions. Most students were reluctant to play "Whyville," and the teachers did not approve of using more classroom instruction time for "Whyville." This led to an unequal dose of intervention between the groups.

Behavioral outcomes

This efficacy study compared data between students in the intervention group who played "Creature-101" in its entirety and the control group. Students who played "Creature-101" reported significant decreases in frequency ($P=0.011$) and amount ($P=0.007$) of SB and frequency ($P<0.000$) and amount ($P=0.040$) of PS intake. The effect sizes were small (partial η^2 for SB=0.02 and 0.02, respectively, and partial η^2

for PS=0.04 and 0.013, respectively). However, students did not report increase in FV, water intake, or PA or decrease in recreational screen time activities (Table 3). When data were analyzed excluding all seventh grade students in the control group, the results were similar. Students (intervention $n=182$, control $n=85$) who played "Creature-101" reported decreases in frequency ($P=0.022$) and amount ($P=0.001$) of SB and frequency ($P=0.013$) and amount ($P=0.066$) of PS intake. A secondary analysis also compared all students (completers and noncompleters) who played "Creature-101" ($n=359$) with the control group ($n=172$). Results showed that students in the intervention group reported a significant decrease in frequency of PS ($P<0.000$). Positive trends ($P<0.1$) were noted for consuming fewer SB ($P=0.082$) and smaller sizes of SB ($P=0.098$) and PS ($P=0.098$). A three-way analysis

TABLE 3. IMPACT OF "CREATURE-101" ON ENERGY BALANCE-RELATED BEHAVIORS

Behaviors, scale (number of items)	Intervention (n=182)	Control (n=159)	F ^a	P
Sweetened beverages				
Frequency (4) ^b	1.64±1.09	1.97±1.19	6.62	0.011
Amount (4) ^c	1.43±0.87	1.76±0.97	7.46	0.007
Water				
Frequency (3) ^b	3.16±1.29	3.12±1.34	0.16	0.694
Amount (3) ^d	3.09±1.13	3.32±1.24	1.45	0.229
Processed snacks				
Frequency (4) ^b	1.79±1.24	2.21±1.36	13.39	<0.000
Amount (4) ^e	1.67±0.65	1.89±0.69	4.26	0.040
Fruits and vegetables				
Frequency (2) ^b	3.00±1.20	2.77±1.29	1.58	0.210
Amount (2) ^f	2.67±0.85	2.77±1.29	0.47	0.492
Recreational screen time				
Frequency (2) ^b	2.90±1.43	3.05±1.37	0.99	0.320
Time spent (2) ^g	2.60±1.32	2.86±1.31	3.32	0.069
Physical activity				
Frequency (3) ^b	2.76±1.44	2.99±1.27	2.57	0.110
Time spent (3) ^h	2.96±1.35	2.95±1.50	0.74	0.388

Data are mean±standard deviation values. $P<0.05$ was considered to indicate a significant difference.

^aResults based on analysis of covariance with group (intervention/control) as the fixed factor and respective pre-intervention scores as covariates.

^bThe frequency scale ranged from 0 to 5, where 0=never drink this, 1=about 1–2 times per week, 2=about 3–4 times per week, 3=about 5–6 times per week, 4=about once per day, and 5=more than 2 times per day.

^cThe amount scale (each time) ranged from 0 to 4, where 0=never drink this, 1=less than 12 ounces, 2=about 12 ounces, 3=about 20 ounces, and 4=more than 20 ounces.

^dThe amount scale (each time) ranged from 0 to 4, where 0=never drink this, 1=less than 8 ounces, 2=about 8 ounces, 3=about 16 ounces, 4=about 20 ounces, and 5=more than 20 ounces.

^eThe amount scale (each time) ranged from 0 to 3, where 0=never eat this, 1=small, 2=medium, and 3=large.

^fThe amount scale (each time) ranged from 0 to 4, where 0=never eat this, 1=less than ½ cup, 2=about ½ cup, 3=about 1 cup, and 4=more than one cup.

^gThe time spent scale (each time) ranged from 0 to 5, where 0=never, 1=less than 1 hour, 2=between 1 and 2 hours, 3=between 2 and 3 hours, 4=between 3 and 4 hours, and 5=more than 4 hours.

^hThe time spent (each time) ranged from 0 to 5, where 0=never, 1=between 0 and 15 minutes, 2=between 16 and 30 minutes, 3=between 31 and 45 minutes, 4=between 46 and 60 minutes, and 5=more than 60 minutes.

of variance was conducted to see if there was a difference among the game completers, noncompleters, and the control group. Results showed that the game completers showed significant positive outcomes compared with the noncompleters and the control group in terms of frequency ($P=0.007$) and amount ($P=0.014$) of SB and frequency ($P=0.001$) of PS (data not shown).

Discussion

Results of this efficacy study showed that "Creature-101" was effective at decreasing frequency and amount of SB and PS intake among intervention students. However, no changes were seen in water and FV intake or PA. There are few serious

games in the field of nutrition education that target middle school adolescents. Prior such games have focused primarily on FV consumption, whereas "Creature 101" addressed a range of behaviors, making direct comparisons difficult. However, an earlier study with fourth graders found a robust impact on FV intake.²⁹ Of games for middle school students, one study directed at fruit juice and low-fat vegetable consumption found positive results for fruit juice but not for vegetables.³⁰ Another found positive pre- to post-test differences in the intervention group for both FV and PA.⁴⁴ A third focused on three behaviors: Increasing FV intake, water intake, and moderate to vigorous PA.³¹ Study outcomes showed that students increased their FV intake. No changes were observed for the other behaviors. In contrast, "Creature-101" did not find changes in FV but did find improvements in other behaviors (SB and PS) that were not measured in these studies.

Although "Creature-101" focused on several behaviors, the game actually had many more activities associated with SB and PS. This may explain to a large extent why changes were observed for these behaviors only and not the others. Duration of the intervention may also have affected overall outcomes as it entailed merely 3½ hours of game play. Earlier games that showed positive outcomes in students' FV intake entailed 4–12 hours of gameplay.^{29,31} C3, on which the game is based, was delivered in approximately 24 hours.³² Hence, given the brief intervention time the results are encouraging.

This study had several strengths. "Creature-101" was self-explanatory, and the protagonist Murphy helped students to move from one activity and from one game level to another. This reduced burden from teachers from having to create lesson plans on a daily basis or be actively involved during the intervention, making the implementation process easy. The study was implemented and tested during real classroom lessons, unlike other games. Students in the study were not provided with incentives, but most students when asked reported that they enjoyed and willfully played the game.

The study had several limitations. It used a pre-post intervention-control design as opposed to a randomized control trial. This method was chosen as the game development took longer than anticipated, and time between game implementation in schools and project timeline did not allow enough time to get approval from all schools and then randomize. Data were self-reported by students and could be subject to recall bias and misreporting, but as changes were observed for some behaviors and not others, we can rule out the possibility of social desirability bias. The validated instruments used in the study showed moderate validity and reliability. Hence, there may be errors in measurement, and the results obtained can be considered as suggestive evidence only. Measurement issues could also have contributed to the small effect sizes reported in the study. In addition, as for all food frequency questionnaires, the instrument used in this study assessed changes in the targeted behaviors from pre- to post-intervention and compared them between the groups. It did not provide estimates of actual intakes. The intervention dose was different under both experimental conditions. The treatment group had seven sessions of gameplay, and the control group had only two sessions of gameplay. However, we cannot predict how this difference may have impacted study outcomes. Finally, multilevel analyses considering

students nested within schools were not conducted because of small sample size. Further evaluation is warranted.

Future perspectives

Besides SB and PS consumption, "Creature-101" also targeted behaviors such as increasing consumption of water and FV, decreasing recreational screen time activities, and increasing PA. However, there were not many game activities addressing these behaviors. Future versions of the game should include more activities addressing these behaviors and test its efficacy. The social networking features that were designed to be a unique component of the game had to be disabled because pilot testing found that students were more involved in chatting and messaging each other unrelated to the game, rather than playing the game itself. It was also felt that strict monitoring of the game Web site would be required and more security be provided to students if this feature was to be used in schools. Future studies may incorporate social networking features into games with caution and provide ways to minimize student distractions.

Conclusions

This study shows that a virtual world serious game shows promise at promoting healthy dietary behaviors among middle school adolescents. Research in this area can investigate a variety of urgent problems that can be addressed with behavior change programs, such as which features of a story or narrative are critical to immersing the participant in the game, which aspects of an avatar are necessary to optimize learning, and which specific activities can be used to maximize behavior changes. The efficacy of social networking at promoting EBRBs in this age group should also be tested. The study also has implications for practice. Such educational games can be used in schools as enrichment activities or in afterschool programs. Once developed, they can be implemented with a minimum of resources in these settings. They can also be played alone at home, expanding the venues for nutrition education. Consequently, serious educational games offer a potentially effective venue for nutrition education.

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