Ruggiero et al., Gerontechnology (2023) 22:1
https://doi.org/10.4017/gt.2023.22.1.809.05

Adaptation of a health game for adults over 50 and examination of its acceptability, feasibility, and preliminary impact when implemented with a nutrition education intervention

Laurie Ruggiero PhD[a,*], Perla Chebli PhD MPH[b], Saja Froukh MS RDN[c], Amparo Castillo PhD[d], Erica D. Seltzer DrPH MPH[e], Angela Odoms-Young PhD[f]

*[a]Behavioral Health and Nutrition, College of Health Sciences, University of Delaware, Newark, Delaware, USA; [b]Department of Population Health, Grossman School of Medicine, New York University, New York, New York, USA; [c]Institute for Health Research and Policy, School of Public Health, University of Illinois at Chicago, Chicago, Illinois, USA; [d]Community Health Sciences, School of Public Health, University of Illinois at Chicago, Chicago, Illinois, USA; [e]University of Illinois Cancer Center, University of Illinois at Chicago, Chicago, Illinois, USA; [f]Division of Nutritional Sciences, College of Human Ecology, Cornell University, Ithaca, New York, USA; *Corresponding author: ruggiero@udel.edu*

Abstract

Background: Diabetes impacts greater than 37 million people in the United States. Adults over 45 years, racial-ethnic minorities, and those who are overweight or obese are at increased risk for type 2 diabetes mellitus (T2DM). Digital health games offer one innovative opportunity to engage, educate, and motivate adults at risk for T2DM about healthy lifestyle changes.
Objective: Describe the adaptation of an educational exergame for adults over 50 and examine feasibility, acceptability, and implementation within a health education intervention in African American adults at risk for T2DM.
Method: Mixed methods were used: exploratory adaptation phase involving expert interviews and constituent focus groups; a randomized two-group (nutrition workshop alone vs workshop plus game) pilot exploring adherence and preliminary outcomes (i.e., eating habits, physical activity level, body mass index); and a post-gameplay explanatory component examining acceptability and feasibility.
Results: Exploratory phase findings identified areas for game adaptation, such as modifying graphics and adjusting movement to user preferences and abilities. The pilot sample included 24 African American women with T2DM risk factors (Mean age = 63.1). Preliminary outcomes suggest pre-post intervention changes in the direction of improvement for both groups; however, there were no statistically significant differences between groups. Intervention adherence was slightly higher for the game-plus workshop group. Acceptability and feasibility feedback of the game was generally positive.
Conclusion: Constituent and expert input helped inform game adaptation. Preliminary outcomes and acceptability/feasibility feedback of game implementation within a health education intervention showed promise in engaging adults over 50 with T2DM risk factors about topics of healthy eating and physical activity. Continued research is suggested to develop/adapt health games to promote healthy lifestyle change in diverse older adults (e.g., adults over 65; racial-ethnic minority groups;) and to conduct large-scale studies to evaluate the impact of health games in diverse groups and settings.

Keywords: diabetes prevention, exergame, health education, health game, healthy eating, physical activity

Introduction

Diabetes impacts greater than 37 million people in the United States (U.S.) (Centers for Disease Control and Prevention (CDC), 2022). Adults over 45 years, racial-ethnic minorities, and those who are overweight or obese are at greater risk for type 2 diabetes mellitus (T2DM) (Kalyani, Golden, & Cefalu, 2017; Schnurr, Jakupović, Carrasquilla, et al., 2020; CDC, 2022). Furthermore, diabetes rates increase across ages in adults with prevalence rates of diagnosed diabetes (2017-2020) of 14.5% for adults 45-64 and 24.4% for those 65 and older (CDC, 2022). In addition, the estimated percentage of adults with pre-diabetes increases across ages, including 44.8% of those 45-64 years old and 48.8% of adults 65 or older (2017-2020; CDC, 2020). African Americans represent one racial-ethnic minority group that experiences an increased burden of diabetes with higher rates of age-adjusted incidence and

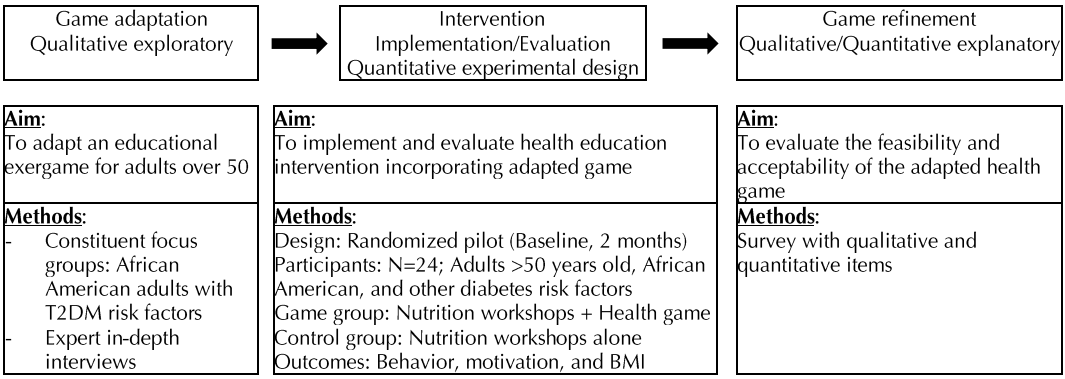

Figure 1. Mixed methods design: Sequential multi-phase

prevalence of diagnosed diabetes in adults over (2017-2018) 18 years of age compared with non-Hispanic whites (CDC, 2022). Research, particularly the Diabetes Prevention Program (Diabetes Prevention Program Research Group, 2002, 2009), has demonstrated that T2DM in those at increased risk may be prevented through engagement in healthy lifestyle behaviors (i.e., healthy eating, physical activity) and weight loss. The increased diabetes burden in these groups underscores the importance of identifying engaging and effective approaches to educating and motivating adults to make healthy lifestyle changes to reduce the risk of diabetes.

Digital health games offer an innovative and exciting opportunity to support adults with and at risk of T2DM (Ruggiero, 2015) and multiple studies have examined the use of various health games or gamification approaches in people with diabetes (Shiau, Lim, Cheng, & Lau, 2021; Theng, Lee, Patinadan, & Foo, 2015). Health games also offer an opportunity to both engage and educate people about making healthy lifestyle changes (Baghaej, 2020), such as eating healthfully and getting regular physical activity. Many studies have examined the use of health games in youth focused on healthy eating or physical activity (Baranowski, 2019; Hieftje, 2013; LeBlanc, 2013; DeSMet et al., 2014; Valeriani, Marotta, Liguori, Romano Spica, Valerio, Vitali, & Gallè, 2021; Ruggiero, Seltzer, Dufelmeier, McGee Montoya, & Chebli, 2020) and many others have demonstrated the impact of exergames on various outcomes in diverse adult populations (e.g., Chao, Scherer, & Montgomery, 2015; Drazich, Crane, Szanton, Carlson, Budhathoki, & Taylor, 2020; Hall, Chavarria, Maneeratana, Chaney, & Bernhardt, 2012; Kappan, Mirza-Babaei, & Nacke, 2019; Larsen, Lund, & Langberg, 2013; Tripette, Murakami, Ryan, Ohta, & Miyachi, 2017; Xu, 2020; van 't Riet, 2014). Fewer published studies have examined digital health games that focus on healthy eating or nutrition education in adults (Baranowski, 2019; DeSmet et al, 2014) and to our knowledge, no published studies have included an exergame that incorporates healthy eating and physical activity education to support lifestyle behaviors in adults over 50 at risk of diabetes.

The current study builds upon a health game (MyPlate Picks) originally designed to provide knowledge, facilitate movement, enhance motivation, and encourage healthy eating and physical activity behaviors in youth (Ruggiero et al, 2020). The aim of the current study was to adapt the health game for adults over 50 and explore its feasibility, acceptability, and preliminary impact when delivered along with a best-practice nutrition education workshop in adults over 50 at risk of T2DM. Promising findings in this study could inform future expanded adaptation of the game for independently living adults over 65 and for common settings where they gather, such as senior centers.

Method

The specific aims of this study were:

1. To adapt and tailor a health game (MyPlate Picks) for adults over 50.
2. To conduct a randomized two-group feasibility pilot of the adapted health game implemented within a nutrition education intervention in adults over 50 with risk factors for T2DM to explore preliminary outcomes (e.g., motivation, behavior, BMI), adherence rates, and retention rates to support the development of future large-scale research studies; and
3. To evaluate the feasibility and acceptability of the health game implementation in African American adults over 50 at risk of T2DM.

Design

The study used a mixed-methods sequential research design (Creswell, 2018) (*Figure 1*). A developmental (Exploratory) phase involved a review of the relevant literature on digital health games tailored for older adults, in-depth interviews with consultant experts, and constituent focus groups with adults with risk factors for T2DM. The second phase (Quantitative) involved a rand-

omized two-group (nutrition workshops alone vs nutrition workshops plus game) pilot study with two assessments (pre- and post-intervention). A qualitative and quantitative (Explanatory) survey was conducted following the game intervention to examine acceptability and feasibility.

Original youth game description

The "educational exergame" was originally developed for youth (Ruggiero et al., 2020). The conceptual framework used to guide the original development of the youth game included a focus on the social cognitive theory (Bandura, 1986) (e.g., build self-efficacy – successes with answering educational questions; outcome expectations – clarify benefits of healthy eating and physical activity), game design (e.g., use rewards – points for correct responses), and learning theory (e.g., multiple learning modes – content presented using audio, visuals, and kinesthetic aspects involving stretching to answer questions) (Ruggiero et al., 2020). The health-related goals of the game are to provide knowledge, enhance motivation, incorporate movement, and encourage behavior change related to healthy eating and physical activity. The game was designed to supplement didactic education about healthy eating/nutrition and physical activity. The nutrition education content was designed to educate and engage around healthy eating topics based on the United States Department of Agriculture (USDA) "MyPlate" (USDA) nutrition guide, focusing on the following educational/behavioral messages: "make half your plate fruit and vegetables"; "avoid oversized portions"; and "drink water instead of sugary drinks". Each game round consists of knowledge questions, movement activities, and educational messages. Content is both presented on-screen and using audio. A camera is used to protect the player's image onto the game-play screen. Two core movement components are included in basic gameplay. First, a player has to physically move (e.g., raise arms/stretch) to select (virtually "touch") an answer choice for each educational question projected on a monitor. Second, between question sets, triangles appear in different places on the screen and a player gains points for each triangle "touched" so the faster they touch and the more they touch, the greater their score. At the basic level, players stretch (raise arms) to virtually touch the response choices and triangles, and youth were encouraged to be creative in their movement, such as jumping to touch answers/triangles with their head, lunging left or right, or using dance moves. Between game rounds, educational messages are displayed related to healthy eating or physical activity. The game could be played individually or using a variety of team approaches and either sitting or standing. The player(s) receive/s a score at the end of each round and the full game.

Aim 1: Method and findings

Overview

Three approaches informed game adaptation: a review of literature, consultant interviews, and constituent (user) focus groups. The integrated conceptual framework used to guide the tailoring process included cultural tailoring guidelines (Kreuter, 2003) and game usability examination based on Technology Acceptance Model (Bagozzi, Davis, Warshaw, 1992) (e.g., acceptability, feasibility) (See *Table 1* for key constructs used in adaptation).

Expert consultant interviews

The research team demonstrated the youth game individually to three content expert consultants who were researchers with expertise in health promotion (e.g., physical activity, healthy eating) in older adults. The three researchers and a health game designer were individually interviewed to gather their recommendations for tailoring the game for older adults. The questions were informed by guidelines for cultural tailoring (Kreuter, Lukwago, Bucholtz, Clark, & Sanders-Thompson, 2003) and the Technology Acceptance Model (Bagozzi, Davis, & Warshaw, 1992). Primary interview questions focused on the areas identified in the first column of *Table 1*, such as recommendations for adapting the educational content, game-play approach, appearance (e.g., graphics), and strategies to enhance perceived acceptability and ease of use. Input on game adaptation was also gathered from research team members who were involved in the original development of the youth game.

User-centered constituent input

Recruitment focused on people who agreed to be re-contacted based on participation in a prior study examining a physical activity intervention in older adults. Prior participants were informed of the study and interested individuals were instructed to call a study number for more information and eligibility screening. The eligibility criteria included risk factors for type 2 diabetes: age between 50 and 65 years; overweight or obese; self-identify as African American or Black, along with English speaking, and not diagnosed with diabetes by self-report. The following exclusion criteria were used: adults with cognitive impairments, based on responding with 3 or more errors on the adapted Mental Status Questionnaire (MSQ; Lesher & Whelihan, 1986); health conditions that precluded participation in a physical activity program based on the Exercise Assessment and Screener for You (EASY; Resnick, et al, 2008) physical activity screener (answered "yes" on any of the screening questions); and non-English speaking. During an orientation/consenting meeting, study staff provided a detailed overview of the study and gave individuals the opportunity to review the written consent form and ask questions.

Table 1. Integrated game tailoring framework and synthesized results

Constructs/strategies, game features	General description	General game tailoring approach	Specific examples of input or adaptations
Educational content	Study focus: Focused on 4 MyPlate related educational messages	Adapted physical activity answer choices and healthy eating content to be appropriate for older adults	- Replaced multiple answer choices, e.g., "Playing a video game" (youth) changed to "watching TV" (adult), and "Playing tag" (youth) changed to "Reading" (adult) - Replaced youth tailored educational messages with ones tailored for adults; adult healthy eating examples: "Stop eating when you're full – restaurant portions are often bigger than MyPlate portions: Pack a doggy bag!"; "Choose whole grain breads, rolls, pastas or rice to get extra fiber"; and "Look for the lower calorie items on the menu". Adult physical activity examples: "Try to fit physical activity into your daily routine! Find a buddy to walk with on your lunch break at work or join a neighborhood walking group. Take the stairs instead of elevator. Do stretches or exercises while watching TV".
Gameplay approach	Study focus: Explore game play options, e.g., individual or multi-player	Included different ways to play the game	- Expressed interest in both individual and multi-player gameplay approaches - Expressed interest in team play for social interaction - Expressed interest in inter-generational game play with grand-children
Cultural tailoring constructs			
Peripheral strategies* "give programs or materials the appearance of cultural appropriateness by packaging them in ways likely to appeal to a given group"	Study focus: Packaging or appearance	Adapted graphics to be adult-oriented	- Replaced cartoon graphic with MyPlate graphic
Evidential* "enhance the perceived relevance of a health issue for a given group by presenting evidence of its impact on that group"	Study focus: data-informed health messages	Adapted educational messages for age group	- Added physical activity educational messages based on current adult recommendations and modified questions and answers, e.g., youth version "try to get at least one hour of physical activity each day" changed to "try to get at least 2 hours and 30 minutes of moderate exercise each week. Also, do muscle-strengthening activities twice each week." (adult version)
Linguistics* "make health education programs and materials more accessible by providing them in the dominant or native language of the target group"	Study focus: Phonetics, audio, literacy level	Adapted audio for older adults	- Replaced child voice narration of game content with adult voice narration
Socio-cultural* "discuss health-related issues in the context of broader social and/or cultural values and characteristics of the intended audience"	Study focus: Informed by population values/beliefs	Adapted educational messages to be relevant to adults	- Added benefits of healthy eating and physical activity for adults - Added focus on weight management, e.g., "exercise is good for your brain and can help you do better in school' (youth) changed to "exercise helps you maintain a healthy weight and strengthen your muscles" (adult)
Constituent* "draw directly on the experience of members of the target group"	Study focus: Informed by stakeholders	Adapted game for user preferences and abilities overall	- See other areas for specific input and adaptations - Game adapted to support gameplay while sitting

Exploratory focus groups (or in-depth interviews as make-ups for the missed group) were conducted with 10 individuals to gather overall input and to obtain specific recommendations for adaptations for adults over 50 (e.g., graphics, music, audio, educational content areas). The youth game was demonstrated prior to the focus group or interview. Qualitative questions were based on the main areas included in *Table 1*, including perceived feasibility, acceptability, implementation, educational messages, appearance (e.g., graphics), audio, movement component, and gameplay approach. Two team members attended all qualitative activities and took detailed notes on responses and observations of participants playing the game. Informed by the constructs in *Table 1*, the two team members reviewed and discussed the qualitative input to identify core themes to guide the adaptation/tailoring of the game. Participants received $25 for participation.

Table 1. Integrated game tailoring framework and synthesized results (cont.)

Constructs/strategies, game features	General description	General game tailoring approach	Specific examples of input or adaptations
Usability constructs			
Usability-perceived usefulness or acceptability**	Study focus: Satisfaction with game elements and engagement	Demonstrated game with adults to obtain feedback on game elements, e.g., content, graphics	Obtained positive feedback on music and background graphics, therefore, music and background graphics were not modified [modified elements are described in other areas]
Usability-ease of use**	Study focus: Game elements related to ease in using game	Demonstrated game with adult volunteers - observed game play - obtained feedback on ease of game play	Encouraged users to tailor movement to own level/ability (e.g., sitting to play as option) Slowed down pace Modified movement instructions Increased text font size for better readability

*The tailoring constructs were based on Kreuter guidelines for cultural tailoring (Kreuter, Lukwago, Bucholtz, Clark, & Sanders-Thompson, 2003)
**Technology usability based on the Technology Acceptance Model (*Bagozzi, Davis, & Warshaw, 1992*).

Exploratory/qualitative results summary

A synthesis of the main themes identified across approaches is presented in Table 1 organized by dimensions of a cultural tailoring framework (Kreuter, Lukwago, Bucholtz, Clark, & Sanders-Thompson, 2003) and Technology Acceptance Model (Bagozzi, Davis, & Warshaw, 1992). Based on these findings, the youth game was adapted for adult users. The content of the game (e.g., questions, educational messages) and graphics were adapted, where needed, to be more adult-focused (*Table 1*). In addition, the child voice used in the audio presentation of content was replaced with an adult voice. Movement instructions were modified to encourage participants to adapt movement to their preferences and ability level, including an option to sit (if needed/desired). Other movement options could be incorporated into the implementation of the game depending on preferences and ability, such as walking in place or standing on one foot during a game round. Other examples of adaptations for ease of use included increasing the font size and slowing the pace of the game (*Table 1*).

Aim 2: Feasibility and implementation pilot study method

Recruitment and consenting process

Recruitment efforts used multiple approaches: through a large Church and its surrounding community; through a senior festival, and from prior study participants as in Aim 1. Recruitment conducted through the community used flyers, posters, and informational sessions. Interested individuals were instructed to call a study number for more information and eligibility screening. Inclusion/exclusion criteria and the informed consent process were the same as used in Aim 1. A $25 incentive was provided for completing the pre-assessment and $30 for the post-assessment. Small additional incentives (e.g., pens, measuring cups, and mugs) were provided during the program sessions to promote retention.

Assessment measures

Questionnaire assessments and anthropometric measurements (e.g., body weight/height) were conducted at baseline and post-intervention (2 months).

Weight was measured using a digital scale and height was measured using a stadiometer in accordance with the CDC's recommendations for standing height assessment (CDC, 2020).

Eating habits were assessed using the Visually-Enhanced Food Behavior Checklist (VEFBC). The VEFBC is designed for low-literate populations using visual information processing theories (Townsend, 2008) and measures medium-term changes in dietary habits. For the purposes of this study, two variables were examined: a) daily intake (cups) of fruits and vegetables (i.e., a composite score of daily intake of fruits and daily intake of vegetables; range = none to 6 or more) and b) self-rated eating habits (range = 0 - 10; poor = 0 to excellent = 10).

Physical activity patterns were assessed using the short version of the International Physical Activity Questionnaire (IPAQ) which has demonstrated validity in African American adults (Wolin, 2008). For this study, the overall categorical scoring approach (low/moderate/high) was used, in accordance with the IPAQ scoring Protocol for Short Form (IPAQ Research Committee, 2005).

Behavioral motivation questions included stage of change (SOC) items related to seven healthy eating behaviors (i.e., eat ≥ 5 fruit/vegetables/day; make half grains, whole grains; avoid high-fat protein; vary protein; avoid high-fat dairy, avoid sugary beverages; drink water instead of sugary beverages) to assess motivation (i.e., readiness) or achievement of behavioral goals (items developed for current study based on Nigg, et al., 1999). The SOC items were combined into an overall SOC index by summing the score across all SOC items (range = 0 to 28; i.e., "precontemplation" was coded as "0", "contemplation" as "1", "preparation" as "2", "action" as "3", and "maintenance" as "4"). Confidence items across the same behavioral areas as SOC (except water intake which was inadvertently omitted) had a five-point response scale, ranging from "not at all confident" to "extremely

Table 2. Baseline characteristics of study participants (n=24)

Variable	Total sample	Game group	Workshop group
Sample size, n	24	13	11
Age, years, M (SD)	63.1 (1.8)	62.8 (2.2)	63.5 (1.1)
Body Mass Index, kg/m^2	34.6 (6.9)	34.3 (7.1)	35.0 (7.0)
Physical activity level (IPAQ) n (%)			
Low	10 (41.7)	6 (46.2)	4 (36.4)
Moderate	5 (25.0)	3 (23.1)	3 (27.3)
High	8 (33.3)	4 (30.8)	4 (36.4)
Eating habits (VEFBC)			
Daily servings of Fruits/Vegetables, M (SD)	2.2 (1.0)	2.1 (1.0)	2.2 (1.1)
Self-rated eating habits M (SD)	5.7 (1.7)	5.5 (1.9)	6.0 (1.3)
Stage of Change Index M (SD)	18.4 (7.3)	16.9 (7.4)	20.1 (7.2)
Confidence index M (SD)	16.6 (4.7)	16.1 (5.0)	17.3 (4.5)

confident". The confidence individual item scores were combined into an overall confidence index by summing the score across all six items (range = 0 to 24; i.e., "not at all confident" was recorded as "0", "somewhat confident" as "1", "moderately confident" as "2", "very confident" as "3", and "extremely confident" as "4").

Adherence was measured by a count of the sessions attended from a total of six (range = 0 – 6). All data were collected using paper surveys completed by participants. The retention rate was measured by the number of participants who completed both pre and post-measurements.

Study randomization and intervention implementation procedure

Randomization to the two groups (nutrition education workshop; workshop plus gameplay) occurred following baseline assessment. Both intervention groups participated in six weekly workshop sessions. Each weekly nutrition education workshop lasted 45-60 minutes and the workshop plus gameplay lasted 75-90 minutes.

Nutrition education workshop intervention

Eat Healthy, Be Active Community Workshops (EHBA) is six-workshop series developed by the US Department of Health and Human Services (US DHHS) Office of Disease Prevention and Health Promotion based on the Dietary Guidelines for Americans (USDHHS, 2018) and the Physical Activity Guidelines for Americans (USDHHS, 2018).

The sessions covered healthy eating, physical activity, and weight management topics and were facilitated by a dietetic intern (SF). Each workshop contained learning objectives, educational messages, hands-on activities, discussion, and educational handouts.

Gameplay procedure

The adapted game was played with teams of three, with each team member playing one game round. Occasionally, adjustments were made to include teams of two people or for individual gameplay, where needed or requested. The game was projected onto a large monitor for team gameplay. Participants were able to play either standing or sitting. Teams were encouraged to support other team members in answering game questions (e.g., cheering, helping with answers, etc.).

Analyses

Basic descriptive analyses were conducted on demographic characteristics, preliminary outcomes, adherence rates, and retention rates. Exploratory group comparisons were conducted using t-tests or Chi-square tests, as appropriate for primary (behavior, stage of change, confidence) and secondary (BMI) outcomes.

Results

Overview

Participants

A total of 75 interested individuals were screened for eligibility; 42 were eligible; and 24 enrolled and were randomized (game group, n=13; workshop group, n=11). At 2 months, 4 participants (two per group) were lost to follow-up.

Demographics

Study participants were 63.1 years old on average (SD=1.8; range=57–65), all female, and all African American/Black. Baseline characteristics by intervention group are provided in *Table 2*.

Baseline BMI, physical activity, eating behaviors, SOC, and confidence

Baseline values are shown in *Table 2* for both groups. The mean total group characteristics at baseline included: BMI of 34.6 kg/m2 (SD=6.9, range=25.2–48.2); 41.7%, 25.0%, and 33.3% had low, moderate, and high levels of physical activity, respectively; consumed an average of 2.2 (SD=0.10, range=1.0–4.5) servings of fruits and vegetables daily; rated their eating habits as an average of 5.7 out of 10 (SD=1.68; range = 2–8); had an average SOC index score of 18.4

Table 3. Changes in outcomes by intervention group (n=20)

Outcomes	Game group	Workshop group
Body Mass Index, kg/m^2	–0.46	–0.15
Daily servings of Fruit/Vegetables	+0.9	+0.67
Self-rated eating habits	+1.34	+0.22
Stages of Change Index (0-24)	+4.5	+0.7
Confidence Index (0-24)	+0.5	+1.3

(SD=7.3; range=3.0–28.0); and had an average confidence index score of 16.6 (SD=4.7; range=7.0–24.0). In general, participants were obese, had low-moderate levels of physical activity, and consumed few fruits and vegetables per day. T-test comparisons showed no statistically significant differences in baseline measures between intervention groups.

Change in outcomes

As shown in *Table 3*, descriptive statistics for change in outcome measures across time suggest both groups showed change toward improvement for most measures, however, there were no statistically significant differences between groups. Though not significantly different, the game group had relatively large changes in stage of change and self-rated eating habits.

Adherence

Mean adherence out of six sessions was 3.9 (65%) and 3.5 (58%) sessions in the game group and the workshop group, respectively.

Retention

Retention rates (completed study) were 84.6% and 81.8% in the game group and the workshop group, respectively.

Aim 3: Explanatory mixed methods and findings

Participants and procedure

Participants included in Aim 3 were the subset of individuals from Aim 2 who were in the game group (N=13). A survey developed by the authors addressed user acceptability, feasibility, and perceived usefulness of various aspects of the game (*Table 4*). The survey included qualitative and quantitative questions.

Analyses

Descriptive statistics were used to summarize the quantitative results from the post-intervention usability/acceptability survey (*Table 4*). The qualitative feedback was summarized and reviewed by research team members to identify themes and representative quotes.

Findings

As shown in *Table 4*, the quantitative survey responses for feedback on the acceptability, feasibility, and perceived usefulness of the game indicated consistently positive responses. For example, the average overall acceptability rating was 8.9 (out of 10), and negative response options was rarely endorsed.

Qualitative feedback from participants in open-ended questions was also favorable with example quotes: *"The game was very helpful to me and I think it would be helpful to others the way it is"*; *"I enjoyed it and would do it again and tell others about it"* and *"overall the game is great, I think it gets a person to start looking at their diet and tricky way to get a person to move."* The main themes for improving the game were to improve the graphics (e.g., "more vibrant colors"; "extra pizazz") and include more information on the score throughout the game.

Discussion

This paper described the process and findings of adapting an existing youth-focused exergame for adults over 50. It also examined the initial acceptability, feasibility, and implementation of the adapted game in combination with a nutrition workshop for African American individuals with risk factors for T2DM. This discussion will focus on the findings relevant to the adaptation and usability of one health game tailored for adults, the strengths and limitations of the current work, and directions for future game development and research.

One important aspect of this study was its use of an integrated conceptual framework to guide the adaptation of the digital health game for an adult population over 50. Adult adaptation was informed by cultural tailoring guidelines (Kreuter, 2003) and the evaluation was guided by the Technology Acceptance Model. This approach aligns with the recommendations for developing games for health (Baranowski, 2019) and the use of an exergame format is consistent with the recommendations of a recent systematic review of digital games in the aging population (Xu, 2020). Future digital game development should continue to incorporate evidence-based health promotion guidelines and appropriate theoretical frameworks from various disciplines to support game tailoring.

The process and findings from the formative work, especially including in-depth consultant interviews and constituent user-centered focus groups were critical in the adaptation of the game for adults over 50. The use of theoretical frameworks to guide this phase was critical in organizing the process and the findings. The results shown in *Table 1* demonstrate that many aspects of the youth game were appropriate and acceptable to adults, while other aspects needed to be specifically tailored for this age group. For example, the physical activity and healthy eating con-

Table 4. Game acceptability/usability

Acceptability scale rating (10-point scale; 1 to 10: higher is more positive)	8.9 (SD = 1.4; n = 10)
Acceptability Likert responses	**N (%)**
How would you rate this game as a tool to teach adults trying to lose weight about healthy eating, PA, and weight management?	
Very good	8 (80)
Somewhat good	2 (20)
"Very bad" to "Slightly good" response options	0 (0)
Likeliness of recommending the game to a friend	
Extremely likely	4 (40)
Somewhat likely	4 (40)
Slightly likely	0 (0)
Slightly unlikely	0 (0)
Somewhat unlikely	1 (10)
Extremely unlikely	1 (10)
How easy/difficult was it to understand the instructions?	
Extremely easy	6 (60)
Somewhat easy	3 (30)
Slightly easy	1 (10)
"Extremely difficult" to "Slightly difficult" response options	0 (0)
How easy/difficult was it to understand the educational content?	
Extremely easy	5 (50)
Somewhat easy	4 (40)
Slightly easy	1 (10)
"Extremely difficult" to "Slightly difficult" response options	0 (0)
How enjoyable/not enjoyable was playing MPP?	
Extremely enjoyable	8 (80)
Somewhat enjoyable	1 (10)
Slightly enjoyable	1 (10)
All "unenjoyable" response options	0 (0)
How comfortable/uncomfortable were you while doing the physical movements?	
Extremely comfortable	9 (90)
Somewhat comfortable	1 (10)
Slightly comfortable through all "uncomfortable" response options	0 (0)
Satisfaction with PA topic	
How satisfied/dissatisfied were you with the PA topics?	
Extremely satisfied	10 (100)
"Extremely dissatisfied" to "somewhat satisfied" response options	0 (0)
How personally useful/not useful did you find the PA topics?	
Extremely useful, n (%)	5 (50)
Very useful, n (%)	5 (50)
"Not at all useful" to Moderately useful response options	0 (0)
How helpful/not helpful was the game in improving your PA knowledge?	
Extremely helpful	3 (30)
Very helpful	4 (40)
Moderately helpful	1 (10)
Slightly helpful	2 (20)
Not at all helpful	0 (0)
How helpful/not helpful was the game in improving your motivation to do PA?	
Extremely helpful	2 (20)
Very helpful	6 (60)
Moderately helpful	1 (10)
Slightly helpful	1 (10)
Not at all helpful	0 (0)

Table 4. Game acceptability/usability (cont.)

Acceptability scale rating (10-point scale; 1 to 10: higher is more positive)	8.9 (SD = 1.4; n = 10)
Acceptability Likert responses	**N (%)**
Satisfaction with nutrition topics	
How satisfied/dissatisfied were you with the nutrition topics?	
Extremely satisfied	8 (80)
Somewhat satisfied	2 (20)
Slightly satisfied	0 (0)
"Slightly" through "Extremely dissatisfied" response options	0 (0)
How personally useful/not useful did you find the nutrition topics?	
Extremely useful	8 (80)
Very useful	2 (20)
Moderately useful	0 (0)
Slightly useful and Not at all useful	0 (0)
How helpful/not helpful was the game in improving your knowledge of a healthy diet?	
Extremely helpful	4 (40)
Very helpful	4 (40)
Moderately helpful	2 (20)
"Slightly helpful" and "Not at all helpful"	0 (0)
How helpful/not helpful was the game in improving your motivation to eat a healthy diet?	
Extremely helpful	3 (30)
Very helpful	5 (50)
Moderately helpful	2 (20)
"Not at all helpful" and "Slightly helpful" response options	0 (0)
Satisfaction with weight management topics	
How satisfied/dissatisfied were you with the weight management topics?	
Extremely satisfied	7 (70)
Somewhat satisfied	3 (30)
"Extremely dissatisfied" to "Slightly satisfied" response options	0 (0)
How personally useful/not useful did you find the weight management topics?	
Extremely useful	8 (80)
Very useful	2 (20)
"Not at all useful" to "Moderately useful" response options	0 (0)
How helpful/not helpful was the game in improving your knowledge of weight management?	
Extremely helpful	3 (30)
Very helpful	5 (50)
Moderately helpful	0 (0)
Slightly helpful	2 (20)
Not at all helpful	0 (0)
How helpful/not helpful was the game in improving your motivation to lose weight?	
Extremely helpful	5 (50)
Very helpful	2 (20)
Moderately helpful	1 (10)
Slightly helpful	1 (10)
Not at all helpful	1 (10)

Note: There were multiple response options for each question with parallel negative and positive options (e.g., Extremely satisfied, Somewhat satisfied, Slightly satisfied, Slightly dissatisfied, Somewhat dissatisfied, Extremely dissatisfied). In many cases the negative options were not used, therefore response options were combined, where appropriate, in the table.

tent were modified to be consistent with national recommendations and the needs of adults in this age group. In addition, based on stakeholder input, some game features (e.g., music, question background graphics) of the youth game version were not modified, while others were modified (e.g., cartoon-like home screen, font size, movement instructions). This phase also gathered beneficial input to inform the implementation of the game. For example, adults over 50 ex-

pressed their interest in team gameplay for the social aspect, so this approach was used in the implementation phase of the study. These findings underscore the value of using theory and stakeholder input in developing health games.

The findings from the randomized implementation pilot will guide the development of future large-scale research projects. For example, the similar (or slightly better) adherence and retention rates for the nutrition workshop plus game group (vs workshop alone) are encouraging for developing future studies that use the health game to enhance other health education interventions in adults over 50. The adherence in the game group is notable since this group also required a greater time commitment. These results underscore the potential value of the game for engaging participants and the need for further large-scale research to help understand the impact.

The feedback on the usability of the game (e.g., feasibility, acceptability) was positive overall. Specifically, the feedback on the feasibility of game implementation was encouraging (e.g., 100% felt instructions and educational content were easy to understand); and acceptability questions indicated consistently positive feedback. Examples of acceptability feedback include: 80% indicated that they would be likely (i.e., somewhat-extremely likely) to recommend it to friends and 100% rated it as a good (i.e., somewhat to very good) tool to teach adults trying to lose weight about healthy eating, physical activity, and weight management. In addition, 100% were satisfied with the physical activity, nutrition, and weight management topics included in the game. Although generally very positive, there was more variability in responses to questions about increasing knowledge and improving motivation for behavior change. Overall, while the findings supported the feasibility and acceptability of the game, they also identified areas for continued improvement to help achieve greater motivational and behavioral outcomes related to healthy eating and physical activity in this age group.
These findings are promising overall and support the use of an educational exergame as one innovative approach, particularly in combination with a nutrition education workshop, to engage, educate, and motivate adults over 50 at risk for type 2 diabetes (T2DM) about healthy lifestyle changes that may lower diabetes risk. Future development and research are suggested to focus on the development/adaptation of health games to reach groups at risk of T2DM, especially adults over 65 who represent the age group at greatest risk of pre-diabetes and diabetes.

Research strengths and limitations
The study focused on the adaptation of a health game originally developed for youth and the examination of the implementation of the adapted game in adults over 50 with risk factors for T2DM. This study was unique in its focus on examining the game in the context of reaching and impacting African American adults with risk factors for T2DM. The game adaptation process had multiple strengths including a systematic approach to tailoring the game, especially including being informed by theory, prescreening participants for cognitive functioning (Xu, 2020), and use of qualitative research methods to address game adaptation. Another strength was the sequential multi-phase (exploratory, experimental design, explanatory) mixed methods design.

The study also had limitations. For example, game adaptation would have benefitted from the earlier inclusion of a constituent co-designer to systematically participate in each phase of the study to provide input from a potential game user perspective. The implementation pilot had common limitations of game studies with adults (Xu, 2020), most notably sample size, therefore, the interpretation of outcomes should be considered within the context of the small sample size and study design. In addition, although all genders were eligible, only females enrolled and the age range was 50-65, thereby limiting generalizability to these groups. These limitations should be addressed in future research, including expanding to other racial-ethnic groups and older age ranges and developing strategies to support broader recruitment.

Conclusions
The game adaptation process and lessons learned may help inform the development of health games for adults over 50. The findings regarding usability provide preliminary support for use of this health game in adults over 50 with T2DM risk factors. Future plans are to continue the development and expansion of educational exergames to promote healthy lifestyle change in diverse older adults (e.g., racial-ethnic minority groups; adults over 65) and to conduct large-scale studies to evaluate the impact of health games in diverse groups and settings reaching independently living older adults, such as senior centers.

Acknowledgements
The research team would like to acknowledge and thank the University of Illinois at Chicago Roybal Center for Health Promotion and Translation, including the Advisory Committee; Circle1 Team; UIC Chicago Partnership for Health Promotion team; the Apostolic Pentecostal Church of Morgan Park; and our project participants, students, and expert con-

sultants. The research study was conducted at the University of Illinois at Chicago. All authors were at the University of Illinois at Chicago during the implementation of the research study.

Grant funding
The study was funded by the National Institute on Aging (P30AG022849) to the University of Illinois at Chicago Midwest Roybal Center for Health Promotion and Translation grants. The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official views of the funders. The funder had no role in study design; in the collection, analysis, and interpretation of data; writing of the manuscript; and in the decision to submit the manuscript for publication.

Human subjects approval
Approval for this study was obtained from the University of Illinois at Chicago Office for the Protection of Research Subjects.

References

American Diabetes Association. (Last retrieved August 19, 2022). Diabetes Risk Test. Retrieved from https://diabetes.org/tools-support/tools-know-your-risk

Baghaei, N., Fowler, A., & Maddison, R. (2020). Supporting disease prevention and lifestyle changes through gaming. Games for Health Journal. 9(6), 381-388. https://doi.org/10.1089/g4h.2020.0161

Bagozzi, R. P.; Davis, F. D.; Warshaw, P. R. (1992). Development and test of a theory of technological learning and usage. Human Relations, 45(7), 660–686. https://doi.org/10.1177/001872679204500702

Bandura, A. Social Foundations of Thought and Action: A Social Cognitive Theory (1986). Englewood Cliffs, NJ: Prentice Hall.

Baranowski, T., Ryan, C., Hoyos-Cespedes, A., & Shirong Lu, A. (2019). Nutrition Education and Dietary Behavior Change Games: A Scoping Review. Games for Health Journal, 8(3), 153-176. https://doi.org/10.1089/g4h.2018.0070

Centers for Disease Control and Prevention (CDC) (2022). National Diabetes Statistics Report. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services; 2020. Retrieved on May 05, 2023 from https://www.cdc.gov/diabetes/data/statistics-report/index.html

Centers for Disease Control and Prevention. (2020). National Center for Health Statistics. NHANES III Anthropometric Procedure Manual. Retrieved on May 05, 2023 from https://wwwn.cdc.gov/nchs/data/nhanes/2019-2020/manuals/2020-Anthropometry-Procedures-Manual-508.pdf

Centers for Disease Control and Prevention (CDC). Prevalence of Both Diagnosed and Undiagnosed Diabetes. Retrieved on May 05, 2023 from https://www.cdc.gov/diabetes/data/statistics-report/diagnosed-undiagnosed-diabetes.html

Chao, Scherer, Y. K., & Montgomery, C. A. (2015). Effects of Using Nintendo WiiTM Exergames in Older Adults: A Review of the Literature. Journal of Aging and Health, 27(3), 379–402. https://doi.org/10.1177/0898264314551171

Creswell, J.W. & Plano Clark, V.L. (2018). Designing and Conducting Mixed Methods Research Third Edition. Sage Publications, Los Angeles, CA.

DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., Crombez, G., Poels, K., Van Lippevelde, W., Bastiaensens, S., Van Cleemput, K., Vandebosch, H., & De Bourdeaudhuij, I. (2014). A meta-analysis of serious digital games for healthy lifestyle promotion. Preventive medicine, 69, 95–107. https://doi.org/10.1016/j.ypmed.2014.08.026

Drazich, LaFave, S., Crane, B. M., Szanton, S. L., Carlson, M. C., Budhathoki, C., & Taylor, J. L. (2020). Exergames and Depressive Symptoms in Older Adults: A Systematic Review. Games for Health, 9(5), 339–345. https://doi.org/10.1089/g4h.2019.016

Hall, A.K., Chavarria, E., Maneeratana, V., Chaney, B.H. & Bernhardt, J.M. (2012). Health benefits of digital videogames for older adults: a systematic review of the literature. Games for Health Journal, 1(6), 402-410. https://doi.org/10.1089/g4h.2012.0046

Hieftje, K., Edelman, E. J., Camenga, D. R., & Fiellin, L. E. (2013). Electronic Media-Based Health Interventions for Behavior Change in Youth: A Systematic Review. JAMA Pediatrics, 167(6), 574–580. https://doi.org/10.1001/jamapediatrics.2013.1095

IPAQ Research Committee. (2005). Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms. Retrieved from https://sites.google.com/view/ipaq

Kalyani, R.R., Golden, S.H., Cefalu, W.T. (2017). Diabetes and Aging: Unique Considerations and Goals of Care. Diabetes Care, 40(4), 440-443. https://doi.org/10.2337/dci17-0005

Kappen, D.L., Mirza-Babaei, P., & Nacke, L.E. (2019). Older Adults' Physical Activity and Exergames: A Systematic Review. International Journal of Human–Computer Interaction, 35(2), 140-167, https://doi.org/ 10.1080/10447318.2018.1441253

Kreuter, M.W., Lukwago, S.N., Bucholtz, R.D., Clark, E.M., & Sanders-Thompson, V. (2003). Achieving cultural appropriateness in health promotion programs: targeted and tailored approaches. Health Educ Behav. 30(2), 133-46. https://doi.org/10.1177/10901981022510 21. PMID: 12693519

Larsen, Schou, L., Lund, H. H., & Langberg, H. (2013). The Physical Effect of Exergames in Healthy Elderly—A Systematic Review. Games for Health, 2(4), 25–212. https://doi.org/10.1089/g4h.2013.0036

LeBlanc AG, Chaput JP, McFarlane A, Colley RC, Thivel D, et al. (2013). Active Video Games and Health Indicators in Children and Youth: A Systematic Review. PLOS ONE 8(6): e65351. https://doi.org/10.1371/journal.pone.0065351

Lesher, E. L., & Whelihan, W. M. (1986). Reliability of mental status instruments administered to nursing home residents. Journal of Consulting and Clinical Psychology, 54(5), 726–727. https://doi.org/10.1037/0022-006X.54.5.726

Nigg CR, Burbank PM, Padula C, Dufresne R, Rossi JS, Velicer WF, Laforge RG, Prochaska JO. (1999). Stages of change across ten health risk behaviors for older adults. Gerontologist.39(4):473-82. https://doi.org/10.1093/geront/39.4.473.

Resnick, B., Ory, M. G., Hora, K., Rogers, M. E., Page, P., Bolin, J. N., Lyle, R. M., Sipe, C., Chodzko-Zajko,

W., & Bazzarre, T. L. (2008). A proposal for a new screening paradigm and tool called Exercise Assessment and Screening for You (EASY). Journal of aging and physical activity, 16(2), 215–233. https://doi.org/10.1123/japa.16.2.215

Ruggiero, L. (2015). Diabetes Prevention and Management: What Does a Serious Game Have to Do with It?." (Editorial). Games for Health Journal, 4(5), 333–334. http://doi.org/10.1089/g4h.2015.0055

Ruggiero, L., Seltzer, E. D., Dufelmeier, D., McGee Montoya, A., & Chebli, P. (2020). MyPlate Picks: Development and Initial Evaluation of Feasibility, Acceptability, and Impact of an Educational Exergame to Help Promote Healthy Eating and Physical Activity in Children. Games for health journal, 9(3), 197–207. https://doi.org/10.1089/g4h.2019.0056

Schnurr, T.M., Jakupović, H., Carrasquilla, G.D. et al. (2020). Obesity, unfavourable lifestyle and genetic risk of type 2 diabetes: a case-cohort study. Diabetologia 63, 1324–1332 https://doi.org/10.1007/s00125-020-05140-5

Shiau, C., Lim, S. M., Cheng, L. J., & Lau, Y. (2021). Effectiveness of Game-Based Self-Management Interventions for Individuals with Diabetes: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Games for health journal, 10(6), 371–382. https://doi.org/10.1089/g4h.2020.0203

The Diabetes Prevention Program (DPP) Research Group, Knowler, W. C., Fowler, S. E., Hamman, R. F., Christophi, C. A., Hoffman, H. J., Brenneman, A. T., Brown-Friday, J. O., Goldberg, R., Venditti, E., & Nathan, D. M. (2009). 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. Lancet, 374(9702), 1677–1686. https://doi.org/10.1016/S0140-6736(09)61457-4.

The Diabetes Prevention Program (DPP) Research Group (2002). The Diabetes Prevention Program (DPP): description of lifestyle intervention. Diabetes care, 25(12), 2165–2171. https://doi.org/10.2337/diacare.25.12.2165

Theng, Y.L., Lee, J.W.Y., Patinadan, P.V., Foo, S.S.B. (2015). The use of videogames, gamification, and virtual environments in self-management of diabetes: A systematic review of evidence. Games for Health Journal, 4 (5), 352-361. http://doi.org/10.1089/g4h.2014.0114

Townsend MS, Sylva K, Martin A, Metz D, Wooten Swanson P. (2008). Improving readability of an evaluation tool for low-income clients using visual information processing theories. J Nutrition Education Behavior, 40,181-186. https://doi.org/10.1016/j.jneb.2007.06.011

Tripette J, Murakami H, Ryan KR, Ohta Y, Miyachi M. (2017). The contribution of Nintendo Wii Fit series in the field of health: a systematic review and meta-analysis. PeerJ 5:e3600. https://doi.org/10.7717/peerj.3600

United States Department of Agriculture. What is MyPlate? Retrieved on May 2, 2023 from https://www.myplate.gov/

United States Department of Health and Human Services. Office of Minority Health. Diabetes and African Americans. Retrieved on May 2, 2023 from https://www.minorityhealth.hhs.gov/omh/browse.aspx?lvl=4&lvlid=18

United States Department of Health and Human Services (2018). Office of Disease Prevention and Health Promotion. Eat Healthy, Be Active Community Workshops. Publication No. U0017. Retrieved from https://health.gov/sites/default/files/2019-09/DGA_Workshops_Complete.pdf

United States Department of Health and Human Services (2018). Physical Activity Guidelines for Americans, 2nd edition. Washington, DC: U.S. Department of Health and Human Services; 2018. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf

Valeriani, Protano, C., Marotta, D., Liguori, G., Romano Spica, V., Valerio, G., Vitali, M., & Gallè, F. (2021). Exergames in Childhood Obesity Treatment: A Systematic Review. International Journal of Environmental Research and Public Health, 18(9), 4938–. https://doi.org/10.3390/ijerph18094938

van 't Riet, J., Crutzen, R., & Lu, A. S. (2014). How Effective Are Active Videogames Among the Young and the Old? Adding Meta-analyses to Two Recent Systematic Reviews. Games for health journal, 3(5), 311–318. https://doi.org/10.1089/g4h.2014.0005

Wolin, K. Y., Heil, D. P., Askew, S., Matthews, C. E., & Bennett, G. G. (2008). Validation of the International Physical Activity Questionnaire-Short among Blacks. Journal of physical activity & health, 5(5), 746–760. https://doi.org/10.1123/jpah.5.5.746

Xu, W., Liang, H., Baghaei, N., Berberich, B.W., & Yue, Y. (2020). Health benefits of digital videogames for the aging population: A systematic review. Games for Health Journal. 9(6), 389-404. https://doi.org/10.1089/g4h.2019.0130