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Effect of Using the Snackability Smartphone Application to Improve the Quality of Snack Intake, General Diet Quality, and Weight among College Students

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EFFECT OF USING THE SNACKABILITY SMARTPHONE APPLICATION TO IMPROVE THE QUALITY OF SNACK INTAKE, GENERAL DIET QUALITY, AND WEIGHT AMONG COLLEGE STUDENTS

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Lukkamol Prapkree

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To: Dean Tomás R. Guilarte
Robert Stempel College of Public Health and Social Work

This dissertation, written by Lukkamol Prapkree, and entitled Effect of Using the Snackability Smartphone Application to Improve the Quality of Snack Intake, General Diet Quality, and Weight among College Students, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Florida International University, 2022

DEDICATION

I dedicate this dissertation to my beloved mother, Pornrut Prapkree, who has attentively supported, encouraged, and pushed me to accomplish my studies throughout my life. Without her great support, I would not have come this far. This work is also dedicated to my respectful major professor, Dr. Cristina Palacios, without whose constant support and guidance this dissertation would not be possible. Also, I would like to dedicate this dissertation to my dear husband, Steward Schwarz, who has always been by my side with love, support, and patience.

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ABSTRACT OF THE DISSERTATION

EFFECT OF USING THE SNACKABILITY SMARTPHONE APPLICATION TO IMPROVE THE QUALITY OF SNACK INTAKE, GENERAL DIET QUALITY, AND WEIGHT AMONG COLLEGE STUDENTS

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College is a challenging period to make healthy food and snack choices and this could lead to poor diet quality and weight gain in the future. The Snackability application (app) was developed using the Social Cognitive Theory for behavior change to help students choose healthy snacks based on the USDA guidelines. The objective of this study was to determine whether the app improved snack, diet quality, and body weight in overweight and obese college students within a two-arm, 12-week randomized controlled trial (RCT). A total of 139 participants completed all baseline measures and were randomized into the control or app groups. Baseline characteristics were similar between groups. Overall, mean age was 21.1 (1.7) years, 84.6% were females, 30.9% were Hispanic, 51.1% had an income less than $50,000, and mean BMI was 30.4 (5.6) kg/m^2. Participants in the app group significantly increased snack score at week 4 (P<0.001) and week 8 (P=0.015) and increased HEI-2015 total score (P<0.001) at week 4, with no significant change in body weight compared to controls. The HEI-2015 component scores, including total vegetables, fatty acids, saturated fats, refined grains, and sodium

significantly improved at week 4 in the intervention compared to controls ($P<0.05$). The results were supported by app compliance, which had the highest app usage during the first 4 weeks but then it significantly dropped after week 4 ($P<0.05$). Furthermore, participants in the app group significantly increased the motivators and reduced the barriers to eating healthy foods and snacks during 12-week study period ($P<0.05$). The Snackability app can be used as a tool to help increase the nutrition behavior of selecting healthy snacks. When college students use the app over time, the app facilitates snacking behavior change, improving snack and diet quality. Future studies should consider increasing the app compliance by incorporating a multicomponent intervention and tailoring the app to match with the preference of college students. Studies with a larger sample size and longer duration may provide more definitive conclusions.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER V

LIST OF FIGURES

FIGURE PAGE

ABBREVIATIONS AND ACRONYMS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ASA24	Automated Self-Administered 24-hours
BMI	Body Mass Index
COVID-19	Coronavirus Disease 2019
DGAs	Dietary Guidelines for Americans
DRI	Dietary Reference Intakes
HEI	Healthy Eating Index
kcal	Kilocalories
kg	kilograms
lb	Pounds
m	Meters
MB-HSBI	Motivators of and Barriers to Health-Smart Behaviors Inventory
NCI	National Cancer Institute
NHANES	National Health and Nutrition Examination Survey
r	Correlation Coefficient
RCT	Randomized Controlled Trial
SCT	Social Cognitive Theory
SD	Standard Deviation
USDA	United States Department of Agriculture

CHAPTER I

INTRODUCTION

The prevalence of overweight and obesity has become a major public health concern in the United States (US), particularly among college students, with more than one-third (~35%) considered overweight and obese in 2021.[1] Weight gain is typical in college students, particularly in the first year of college life.[2–4] The college period is a major transitional stage of life which makes it challenging for college students to make healthy food and snack choices due to the increased independency, expense, stress, and time constraint.[5–8] According to National Health and Nutrition Examination Survey (NHANES) 2017-2018, 95% of Americans age 20 years over consumed snacks on a daily basis, contributing to 23% of their total energy intake, 36% of total sugar intake, 20% of total fat and saturated fat intake, and 13% of total sodium intake per day.[9] Snacking is even higher among college students, with 98% consuming snacks daily, at a frequency of about 4 times per day.[10] In addition, a significant increase in caloric intake per capita per day from snacks was documented from 1977 to 2012 among US adults ($P<0.01$).[11]

It is well documented that most snacks consumed by students are energy-dense and nutrient-poor (unhealthy snacks), which results in a lower diet quality and weight gain.[12–18] However, studies have found that if the snacks consumed are healthy, such as fruits, vegetables, whole grain, nuts, and yogurt, they can be important contributors of nutrients to the daily diet and help improve overall diet quality.[12,15,19–24] Among college students, it is important to understand motivators of and barriers to eating healthy foods and snacks.[5,6,25–27] Therefore, interventions are needed among college students to help

them increase motivation and overcome barriers to eating healthy snacks resulting in improving the quality of the snack intake and overall diet quality and this could lead eventually to a reduction in weight gain.

There are several interventions developed for improving consumption of healthy snacks among college students.[28–40] Most of these interventions have been developed to influence snack choice at the point of purchase in vending machines, such as reducing the price of healthier items, classifying all vending items by a traffic light diet system, providing nutritional information of the snacks, among others, with various levels of success. To our knowledge, there is limited research on interventions using mobile apps to improve snack intake among college students despite the high intake of snacks and abundant app usage in this population. Using mobile apps could be an appealing and accessible tool to help college students make healthy choices when consuming snacks as this group has the highest percentage of smartphone ownership (96%)[41] and app usage (77%)[42] with 10.5 times of using an app per day.[43] In addition, about 59% of smartphone users have downloaded health mobile apps, particularly fitness and nutrition apps.[44] The use of nutrition apps have been positively associated with healthier snacks and beverages intake and body mass index (BMI) in adolescents,[45] in healthy weight adults,[46] and in overweight adults.[47]

To address this gap in knowledge, the Snackability smartphone app was developed to help students choose a healthy snack based on the USDA guidelines "A Guide to Smart Snacks in School".[48] According to this guideline, a healthy snack must have as a first ingredient a whole grain, fruit, vegetable, dairy, or protein food and meet the nutrient standards for calories, calories from fat, fats, sugar, and sodium. A total score

is provided for each snack, which ranges from -1 to 11 points, in which a higher score was more compliant to the USDA guideline and therefore a healthier snack. Because the recommendations from this guideline could be lost in translation when individuals are faced with the decision to choose a snack, the Snackability app could be a practical tool to help college students identify which snacks meet the USDA guidelines, and therefore could be considered, a healthy option.

The app incorporated several constructs from the social cognitive theory (SCT) for behavior change.[49–51] The SCT focuses on individuals that play an active role in their health by translating motivation into action by using the app to help select healthier snack choices and reinforcing adherence to the app through self-efficacy, goal setting, self-monitoring, and self-regulation.[49–51] The SCT also emphasizes on the dynamic interplay between individuals and the environment which mutually influence each other. College students use the app to help identify and select healthy snacks. Then, if they have healthier snacks around them, they are more likely to eat these snacks. According to the literature, integration of constructs in the behavior change theory into intervention strategies could be an effective way to facilitate behavior changes and improve health outcomes.[52,53] In addition, few studies report on the app evaluation including feasibility, acceptability, usability, and satisfaction. The app evaluation helps understand the effectiveness of the app intervention and possible underlying factors that might explain why the intervention succeeded or failed in effecting change in outcomes.[54,55]

The objective of this study was to test the effectiveness of the Snackability app whether the app improved the quality of the snack intake, the diet quality, and body weight and to evaluate the app feasibility, acceptability, usability, and satisfaction among

overweight and obese college students with a two-arm, 12-week randomized controlled trial (RCT).

Specific Aims and Hypotheses

Specific Aim 1

To associate snacking behaviors, such as snacking frequency, snacking time, accessibility and availability of snacks, and knowledge about snacks, with overall diet quality, snack quality reflected by snack score from the Snackability app, and weight status in US overweight and obese college students.

Hypothesis 1a

Higher snacking frequency, accessibility and availability of unhealthy snacks, and a lack of knowledge about choosing healthy snacks will be associated with lower overall diet quality, lower snack quality, and higher BMI.

Hypothesis 1b

Snack quality will be positively associated with overall diet quality.

Hypothesis 1c

Snack quality and over all diet quality will be negatively associated with BMI.

Specific Aim 2

To determine whether the Snackability app intervention improved the quality of the snack intake, the diet quality, and body weight in overweight and obese college students with a two-arm, 12-week randomized controlled trial (RCT).

Hypothesis 2a

The app intervention group as compared to the control group will have a significant improvement in quality of the snack intake at weeks 4, 8, and 12.

Hypothesis 2b

The app intervention group as compared to the control group will have a significant improvement in overall diet quality at week 4, 8, and 12.

Hypothesis 2c

The app intervention group as compared to the control group will have a significant improvement in body weight at week 4, 8, and 12.

Specific Aim 3

To determine whether the Snackability app facilitated behavior change by increasing the motivators and decreasing barriers to eating healthy foods and snacks among overweight and obese college students in a two-arm, 12-week randomized controlled trial (RCT).

Hypothesis 3a

The app group will significantly improve motivators and decrease barriers to eating healthy foods and snacks.

Hypothesis 3b

Higher levels of motivators and decreased barriers will be significantly correlated to the change in quality of snack intake, overall diet quality, and body weight.

Specific Aim 4

To evaluate the feasibility, acceptability, usability, and satisfaction of the app intervention at the end of the study period.

Hypothesis 4a

The app will be considered feasible, usable, satisfactory, and acceptable by 50% or more of the participants.

Hypothesis 4b

The app feasibility, acceptability, and satisfaction and perceived changes in eating healthy snacks will significantly correlate with use of the app.

Hypothesis 4c

The app feasibility, acceptability, and satisfaction and perceived changes in eating healthy snacks will significantly impact quality of snack intake, overall diet quality, and body weight.

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CHAPTER II

LITERATURE REVIEW

Definition of snacks

Snack foods or snacks are foods that are consumed between meals. Snacks could also be considered a light meal at which nutrient-dense or nutrient poor snacks might be consumed.[1–3] However, the definition of snacks still varies. Some current definitions of snacks are based on time of day of an eating occasion (i.e. morning, afternoon, and evening snacks), specific periods of time after a meal (e.g., 15 minutes), type of food consumed, energy content, amount of food consumed (e.g. portion sizes smaller than regular meals), location of food consumed, or a combination of these definitions.[4–6] On US college campuses, undergraduate students perceived snacks as small portions of food packaging, inexpensive and nutrient-poor foods, and a specific set of foods eaten alone, in short eating periods, and standing while eating.[2] Other studies showed that snacks were defined on the basis of time of day, location of food consumption, and food choices.[3,7]

According to American Heart Association, three main factors differentiate snacks from main meals.[8] First, consumers consider main meals as breakfast, lunch, and dinner and other eating occasions as snacks. Second, the times of day considered as breakfast, lunch, and dinner commonly take place between between 6 am and 10 am, 12 pm and 3 pm, and 7 pm and 9 pm, respectively. All other eating occasions besides these times are considered snack times. Third, energy intake differentiates meals from snacks which are over 15% and less than 15% of the daily recommended energy intake, respectively.

Based on the available evidence, this study defined snacks as foods that are consumed between meals. Snacks could also be considered a light meal at which nutrient-dense or nutrient poor snacks might be consumed.[1–3]

Relationship of snack intake with diet quality and weight

Snack choices influence quality of snack intake which affects on diet quality.[9–17] Most snacks consumed by young adults are energy-dense and nutrient-poor considered as unhealthy snacks leading to lower diet quality[9–17] and weight gain.[4,11,12,17–19] A study evaluating the snack patterns in US adults age 20 years and older found that individuals who skipped a meal but ate several snacks had lower quality of nutrient intakes than individuals who ate 3 meals with or without snacks.[20] Also, a study in 1,451 British adults age 19-64 years to assess nutritional quality of meals and snacks using British Food Standards Agency (FSA) nutrient profiling system score found that higher FSA scores of meals and snacks (lower nutritional quality) were associated with unfavorable components of overall diet, such as lower intakes of fruits, vegetables, and nuts and higher intakes of biscuits, cakes, pastries, total fat, and saturated fatty acid.[12] However, the cross-sectional surveys based on data from the National Health and Nutrition Examination Survey (NHANES) in U.S. adults age 20 years and older found a positive association between snack frequency and diet quality assessed by healthy eating index (HEI).[21,22] Another study in US adults age 19 years and older showed that different snack patterns were associated with the intake of saturated fatty acid, added sugars, and sodium.[15] Several snack patterns were associated with higher intake of potassium, calcium, fiber, vitamin A, and magnesium. This study found that there were 5 snacking patterns, such as miscellaneous snacks, vegetables/legumes, crackers/salty snacks, other

grains, and whole fruit that were associated with better diet quality scores as compared to participants with no report of snacking. Furthermore, another study in US adults age 18-60 years found that the percent of snacking energy from fruits and nuts had a significantly positive association with diet quality while the percent of snacking energy from desserts and sweets and sugar-sweetened beverages had a significantly negative association with diet quality assessed by HEI.[17] This study also found that percent of snacking energy from vegetables had a significant association with lower BMI whereas percent of snacking energy from desserts and sweets had a significant association with higher BMI. If snacks are judiciously selected to consume, they will make a valuable contribution of nutrients to the daily diet as snacks can be important contributors of key nutrients (>20%), such as vitamins A, C and E, magnesium, calcium, potassium and fiber.[13–17,23–26] Snacks with high protein, fiber, and nutrient dense have the potential effects on satiety, delayed gastric emptying and intestinal transit, and reduced rate of carbohydrate absorption, and reduced risk for obesity and cardiovascular diseases.[8,15,16,24–26]

The relationship between snack intake, diet quality and weight gain is not consistent. High energy and nutrient poor snack intake has been associated with low diet quality and increased weight in some studies but several studies only found an association between snack intake and diet quality with no impact on body weight or BMI.[14,16–19,27,28] A study conducted among 10,092 UK adults showed that snacking had an inverse association with body fat in individuals with BMI < 25 kg/m^2 but had a positive association with waist circumference and subcutaneous fat thickness in overweight and obese men and women (BMI ≥ 25 kg/m^2).[19] Furthermore, this study

showed that overweight and obese participants consumed more nutrient-poor snack foods, such as crisps, sweets, chocolates and ice-creams and less nutrient-dense snack foods including yogurt and nuts as compared to normal-weight participants. The aforementioned studies found a significantly positive association between snack intake and BMI and waist circumference.[11,12] Lastly, a study in US adolescents age 12-19 years showed that adolescents with normal weight significantly consumed fewer snacks daily and less calories per snack occasion (262 ± 4.41 kcal/snack) as compared to calories per snack occasion in overweight (305 ± 8.84 kcal/snack) and obese (340 ± 10.1 kcal/snack) adolescents.[28] These studies show that snack intake was associated with weight gain. Therefore, it is important to design an intervention to improve quality of snack intake, general diet quality and weight among overweight college students.

The availability and the purchase of snack foods

Snack foods, commonly consumed by young adult college students, are found in various settings, mainly retail stores and vending machines in schools, universities and surrounding areas. In one study, investigators observed 8 vending machines on a university campus and found that users were predominantly students ages 18-24 years and they largely selected less healthy snack food choices (59%) rather than healthier options.[29] The availability and accessibility of snack foods has also been evaluated at the city level. A study that evaluated the availability and accessibility of energy-dense snack foods in 1,082 retail stores in 19 US cities, such as pharmacies, gas stations, and other types of stores, found that snacks were available in 41% of the stores and the most common snacks were candy (33%), sweetened beverages (20%), and salty snacks (17%) which were also easily accessible at the cash register queue.[30]

USDA guideline on healthy snacks

A Guide to Smart Snacks in School (hereafter, Smart Snacks) was established by the USDA as directed by the Healthy, Hunger-Free Kids Act of 2010 and implemented in schools (K1–K12) by July 1, 2014.[31] Smart Snack Standards aligned with the most recent Dietary Guidelines for Americans (DGAs) and science-based recommendations apply to all foods and beverages sold in vending machines, a` la carte, school stores, and snack bars outside of the USDA school meal programs throughout the school day. Smart Snacks aimed to increase the availability of nutrient-dense items, such as vegetables, fruits, whole grains, fat-free or low-fat dairy products, and protein foods and to decrease the availability of high-calorie items with high amounts of fat, added sugars, and sodium.

Based on the Smart Snack Guidelines, a healthy snack must meet 2 principles[32]:

(1) First ingredient must be a whole grain, a fruit, a vegetable, a dairy product, or a protein food or be a combination food that contains at least ¼ cup of fruit and/or vegetable; and

(2) The food must meet the nutrient standards calories (≤200 calories), total fats (≤35% of calories), saturated fat (<10% of calories), trans fat (0 g), sodium (≤200 mg), and sugar (≤35% by weight)

The 2015-2020 DGAs recommended that children, adolescents, and adults should follow a healthy eating pattern to achieve and maintain healthy body weight and reduce the risk of chronic disease by focusing on nutrient-dense foods and limit calories from saturated fats and added sugars and reduce sodium intake.[33] Also, the DGAs identified nutrients of public health concern, such as calcium, potassium, dietary fiber, and vitamin D due to low intake of vegetables, fruits, whole grains, and dairy.

To be consistent with the DGAs, Smart Snack Guidelines for a snack to be healthy, it must have the first ingredient as a whole grain, a fruit, a vegetable, a dairy product, or a protein food.[32] Furthermore, it must meet the nutrient standards for calories (≤200 kcal), total fats (≤35% of calories), saturated fat (<10% of calories), trans fat (0 g), sodium (≤200 mg), and sugar (≤35% by weight). The implementation of the Smart Snack Guidelines will help individuals identify and select healthier snack choices that help better meet the recommendations of the DGAs. If individuals select and consume healthy snacks based on the Smart Snack Guidelines, healthy snacks will help increase nutrients to the daily diet, limit empty calories from fats and sugar, and reduce sodium intake resulting in promoting healthy eating habits and students' long-term health and wellbeing.

In addition to putting a lot of effort into improving the nutritional outcomes of school students, it is important to continue nutrition policies and interventions in college students as well. Therefore, Smart Snack Guidelines should be implemented in college campuses to increase availability and accessibility to healthy snacks and beverages to improve snack and diet quality and body weight among college students.[34] However, the guidelines need to be translated in an easy and practical way for individuals to use when choosing a snack.[15,34] This could be done with a smartphone application (app) as nutritional tool that could make healthy snack intake become simple, convenient, and appealing to young adult college students.

Diet quality reflected by the Healthy Eating Index

The Healthy Eating Index (HEI) is a measure of diet quality from individual dietary intake to see how well the diets comply with the U.S. Dietary Guidelines for

Americans (DGAs).[35] The Healthy Eating Index-2015 (HEI-2015) evaluates a set of foods in accordance with Dietary Guideline for Americans 2015-2020.[35] The higher the HEI-2015 score, the more consistent with the Dietary Guidelines for Americans (DGA) 2015-2020. HEI-2015 consists of 13 components which are categorized into adequacy and moderation. Adequacy components include total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids. Moderation components include refined grains, sodium, added sugars, and saturated fats. HEI-2015 was designed to have score from 0 to 100, in which the higher score, the better diet quality by increasing food intake from adequacy components and decreasing food intake from moderation component.[35] The calculation of HEI-2015 is amount of each food group per 1,000 kcal in the total mix of foods, except fatty acids which is a ratio of unsaturated to saturated fatty acids. The mean HEI-2015 total score in US college students from the previous study was 63.4 (9.0) with no significant difference among the three body fat category groups (under-fat, normal, and over-fat/obese).[36]

Effects of smartphone apps on making snacking and dietary behavior change

There are a number of smartphone apps available in the market related to health and nutrition. Recent statistics show that about 59% of smartphone users had downloaded health mobile apps which the most common used apps were fitness and nutrition.[37] Users with younger age, higher income and education, and BMI in the obese range were more likelihood to use health apps.[37]

There are several techniques used in health app to achieve behavior change. The behavior change techniques included in the app “provided instruction” (83% of the apps), “set graded tasks” (70%), and “prompted self-monitoring” (60%) were associated with

increase in intervention effectiveness.[38,39] In addition, a systematic review and meta-analysis reported that behavior change techniques were mainly utilized in the app interventions on nutrition behaviors and related health outcomes, including feedback, goal setting, self-monitoring, shaping knowledge by providing information, and social support, which showed positive outcomes on individual and group-based interventions.[40] These behavior change techniques connect to the constructs of nutrition education theories, such as observational learning, knowledge and skill to perform behavior, attitude, intention, goal setting, feedback on performance, self-efficacy, self-monitoring, self-regulation, and social support, which are integrated to develop the theory-based app intervention to reduce barrier, increase motivation and adherence, and facilitate behavior change. A study using a nutrition/diet related mobile apps that incorporated theoretical constructs found dietary behavior changes, such as increase in actual goal setting, frequency, and consistency of eating healthy foods, and app engagement.[39]

App engagement is also important to influence behavior change; however, there is a 30 day threshold for the use of the app.[41] A cross-sectional analysis of users of the Lose It! Mobile app found that users (n = 1,011,008) were engaged with the app for 29 days.[42] With subgroup analysis, user engagement was varied ranging from 3.5 to 172 days due to customization of diet and exercise. The more the app personalize, the more users engage. Also, a review of web-based interventions showed that adherence rate was about 50%.[43] A similar adherence rate was found in the 14-week study testing the eBalance app, with an adherence rate in the app intervention group of 56%, with a gradual decline in the app use.[44] In addition, frequency of app use (average 2.7 days/week) was significantly associated with a higher success score of maintaining the healthy lifestyle from using the

app. Similarly, a 4-week study period of self-monitoring app for vegetable intake showed that app engagement was declined over time which limited the overall usage and intervention effectiveness.[45] This study did not find the benefit of gamification. Moreover, the gamified app group had the highest dropout at the first week. This means that gamification, such as points, levels, or leaderboards is not motivating for all users. Furthermore, the studies suggested that personal support with the app and tailored or personalized incentives matched with user preference should be considered to increase the adherence which would probably improve outcomes even more.[42,44,45]

A variety of developed apps relating to diet, nutrition, and weight have successfully shown the positive change in dietary intake and weight management. For example, a study evaluating different diet self-monitoring methods (paper journal, app, or website) in 96 overweight and obese adults ages 18 – 60 years during 6 months found that the app group had significantly less energy intake than the paper journal group at 6 months.[46] Another study testing the effectiveness of a web-based and mobile phone-based interventions compared to a print-based intervention among 301 participants found that both the web and mobile-based interventions improved overall dietary behaviors by consuming higher fiber, lower fat milk at 3 months and 9 months.[47] Another study tested the lifestyle program with telephone support (TXT2BFiT) for 12 weeks in 250 young adults with a high risk of weight gain.[48] The intervention group received 8 motivational text messages per week based on the transtheoretical model of behavior change, 5 personalized coaching calls, weekly emails to reinforce the messages, a diet booklet, and access to an app with nutrition education and self-monitoring, community blog, and supportive resources. The intervention group significantly reduced weight, sugar-

sweetened beverages intake, and energy-dense meals, and increased vegetable consumption as compared to the control group at 12 weeks. Adherence to text messages and coaching calls in the intervention group was 90%. Furthermore, another study tested the "eBalance" web-based app, an app for self-management to achieve a healthy lifestyle based on the guidelines published by the Israel Ministry of Health and the Dietary Guidelines for Americans 2010 and the control system theory of self-regulation, in 99 healthy adults ages 18 years and older for 14 weeks.[44] The app enables the users to monitor their dietary intake and physical activity by receiving real-time feedback from the app by monitoring calorie intake and expenditure and comparing nutrient intake with the DRI. The intervention group had significant mean weight change and significant increase in diet quality scores, knowledge scores, success scores (success in maintaining healthy lifestyle) at 14 weeks. The app frequency of use had positive significant relation to a higher success score.

Evaluation of available nutrition related smartphone apps in the market

There are a number of smartphone apps available in the market related to health and nutrition. From smartphone app search, there are several apps available to calculate calorie and portion sizes, track diet, weight, etc. Therefore, we conducted a thorough search in November 2017 to identify an app that could specifically evaluate if snacks complied with the USDA Guideline and provide a score for individuals to identify if the snack was healthy. The search objectives included: 1) List/describe apps that identify healthy snacks and/or foods, assuming that snacks are included 2) List/describe apps that have a scannable bar code, which can be used to identify healthy snacks. Our search identified a total of 22 apps that aided in the identification of healthy snacks. The apps

were categorized as being of little similarity, some similarity, and very similar to the developed app. Apps were determined to be the least similar when they provided healthy ideas for food selections while lacking the ability to score the food product. Fourteen apps had some similarity because they were designed to help users select healthy snacks (specifically). However, they also failed to provide a snack score. There were only 3 apps (Fooducate, Shopwell, and GoodGuide) were determined to be very similar to the developed app as they could provide a snack score. Fooducate is largely based on opinion rather than expert advice and food search terms must match exactly; Shopwell includes weight management, food allergies, dietary restrictions, and several nutritional goals; and GoodGuide rates both food and nonfood products based on health, environment, product management and social performance. These features can be overwhelming to the user. Consequently, there are no available apps to specifically provide a simple guide to identify if a snack is healthy or not based on the current USDA guidelines for snacks.

Development of the Snackability app

The "Snackability" app was developed in collaboration between the Department of Dietetics and Nutrition (Dr. Cristina Palacios and her research team) and the Vertically Integrated Projects (VIP), School of Computing and Information Sciences at Florida International University (FIU) based on the USDA guidelines "A Guide to Smart Snacks in School"[29] by using social cognitive theory for behavior change. The research team collaborated, gathered the information, and designed algorithms for the app.

The Snackability app allows users to search for a snack (scan barcode or type snack name), add a portion size consumed based on a portion size guide, and then provide a simple score and feedback.[49] The score ranges from -1 to 11 points. The higher

the score, the more compliant the snack is to the guideline; therefore, the healthier the snack is. The app also provides a breakdown score to allow users learn about which component the selected snack does not score well and a specific feedback message on how to improve the score. In addition, the app provides gamification features as self-motivation (level up and achievement gained) and reporting features as goal-setting and self-monitoring (average daily score and consumed snack history). Several app features were improved as suggested from pilot testing in college students for two weeks.[49] Participants also considered the app to be feasible, usable, and acceptable with good satisfaction.

Theoretical framework for the Snackability app development and intervention

The underlying theoretical framework for this study is the Social Cognitive Theory (SCT). The SCT states that the how and why people change behavior is the product of the dynamic interplay of personal factors, behavior, and environment.[50–52] The SCT helps analyze and understand human thought, motivation, behavior, and environmental factors, such as physical and social environments in order to design activities to empower and facilitate people for changing behavior and taking action. The SCT consists of the main constructs as the following.

(1) Reciprocal determinism: Environments can influence individuals and groups, but individuals and groups can also influence environments and regulate their own behavior. They are mutually influenced with each other.

(2) Outcome expectations: Changing expectation and values of the consequences of the behavior choices

(3) Self-efficacy: Belief in personal ability to perform behaviors that bring desired outcomes

(4) Collective efficacy: Belief in groups ability to perform behaviors that bring desired outcomes

(5) Observational learning: Learning to perform a new behavior through interpersonal or media displays, especially peer modeling

(6) Incentive motivation: Use and Misuse of rewards and punishments to modify behavior

(7) Facilitation: Providing tools, resources, or environmental changes that make new behaviors easier to perform

(8) Self-regulation: Controlling oneself to achieve behavioral goal(s) through feedback, goal setting, self-monitoring, self-reward, self-instruction, and enlistment of social support

(9) Moral disengagement: Ways of thinking about harmful behaviors by disengaging self-regulatory moral standards

The constructs of the SCT were applied to the Snackability app intervention as described in Table 1.

Table 1. The constructs of the social cognititve theory applied to the Snackability app intervention study

Constructs	Activities
Reciprocal determinism	Participants use the Snackability app to help identify if a snack is healthy or not. At the same time, the app may influence participants to purchase healthy snacks. Then, if participants have healthier snacks around them, they are more likely to eat the

Constructs	Activities
	snacks that are there. When participants use the app over time, the app helps improve snacking behavior by creating environment that promotes healthy snack intake.
Positive outcome expectation	They expect to improve snacking habits relating to better health outcomes. The app provides snack score and feedback. The higher score, the healthier snack is. The score feedback and specific feedback messages make participants know that the snack is healthy to consume.
Negative outcome expectation	Participants use the app to help select healthy snacks that far outweigh from unhealthy snacks. The app will show the breakdown score of the total snack score and the specific feedback message based on the lowest breakdown score. The specific feedback message makes users aware of why this snack is unhealthy and cause negative health effect.
Self-efficacy	Participants use the app to help identify if a snack is healthy or not before purchasing, selecting, or consuming snacks. The app provides snack scores and feedback message so that participants can set a goal to improve the snack scores over time and keep track of their snack intake through the app. This will reinforce participants to increase motivation and adherence of using the app every snack occasion to improve and maintain healthy snack intake by using the app over time.
Observational learning	Researchers will instruct participants to download the app and use the app at every snack occasion. They also learn to use the features in the app, including portion size guide.
Incentive motivation	The app provides gamification features, such as red and gold apples, level-up, and achievement gained. For example, if participants consume a snack that has a score > 8 points, they will gain a point toward the level-up gamification feature. There are several cards for achievement gained, such as kalorie killa, saltbae, slim shady, fructose fighter, etc. These can help enhance self-motivation and app engagement
Facilitation	The snack score and nutrition information, including portion size guide they get on the app would be facilitation.
Self-regualtion	The app provides the total score, breakdown score, and feedback message for participants. The app also provides the reporting features, such as daily average score report (graph) and consumed history of snacks as goal-setting and self-monitoring. Gamification features in the app help facilitate users to achieve their goal of snack intake and improve quality of snack intake and snacking behavior over time.

Integration of constructs in the behavior change theory into intervention strategies could be an effective way to facilitate behavior changes to help participants take action. The combination of intervention strategies or multi-component intervention using diet and physical activity apps could significantly increase behavior change and improve health outcomes.[53] Nutrition-related health apps have the anticipated benefits for behavior change, especially app engagement, convenience, and easy to use app which can reduce barriers and increase adherence.[39] Furthermore, app features and behavior change techniques have been applied to nutrition and health behavior change apps to increase value and user engagement. From qualitative studies, college students value apps that are simple, pleasant to use, require low effort, enable goal-setting and self-monitoring, provide feedback, advice on how to change behavior, alerts/reminder (not too often), and tracking functions, clearly shown how apps work, and are developed by experts or academics.[49,54,55]

By integrating all these features together in one app while keeping the difficulty of the task low and taking into consideration of our smartphone app search, this app will be expected to improve quality of snack intake, general diet quality, and weight.

Use of the ADDIE model in development and pilot testing of the Snackability app

The app was developed following "Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model".[56] This model consists of 5 phases:

(1) Analysis phase was to analyze all the apps currently available in the market

(2) Design phase established the goal and objectives of the app

(3) Development phase was to develop snack database and design the app

(4) Implementation phase was to perform a pilot testing of the app

(5) Evaluation phase was to evaluate the app and results of evaluation were used to improve the app before the final version of the app

Several tasks were completed in the development of the app. Briefly, we obtained a comprehensive snack database from snacks available in vending machines and shops at Florida International University, which was stored in MySQL workbench. In addition to our own snack database, we connected with the USDA Food Composition Database by using NDB API to get REST access to this database. We also reviewed the USDA guideline for healthy snacks and designed our own algorithm to score each snacks. A score ranging from 0-10 points was designed taking into account the first ingredient, the nutrient standard by portion size, and the processing of foods which score ranging from -1 to 1 was subtracted or added depending on the processed food classification. The final score ranged from -1 to 11 points. The higher the score, the more compliant it is to the guideline; therefore, the healthier the snack is. Table 2 shows the scoring system designed.

Table 2. Scoring system for the Snackability app

Principle	Score
1. First ingredient is a fruit, a vegetable, a dairy product, or a protein food; or be a combination food that contains at least ¼ cup of fruit and/or vegetable	2
2. Nutrient standard for:	
Calories ≤ 200 calories	
1.0 – 50.0 Kcal	2
50.1 – 100.0 Kcal	1.5
100.1 – 150.0 Kcal	1
150.1 – 200.0 Kcal	0.5
> 200.0 Kcal	0
Total Fat ≤ 35% of calories[1]	
0 – 20.0%	1
20.1 – 35.0%	0.5
>35.0%	0
Saturated Fat <10% of calories[2]	
0 – 4.9%	1
5.0 - 9.9%	0.5
≥ 10%	0
Trans Fat 0 g	
Trans Fat 0 g	1
Trans Fat > 0 g	0
Sodium ≤ 200 mg	
0 – 140.0 mg	1
140.1 – 170.0 mg	0.5
170.1 – 200.0 mg	0.25
> 200 mg	0
Sugar ≤35% by weight	
0 – 14.9%	2
15.0 – 19.9%	1.5
20.0 – 24.9%	1
25.0 – 35.0%	0.5
> 35%	0

Principle	Score
TOTAL	**10**
Processed food classification	
Minimally processed foods (Edible foods with no food additives)	1
Slightly processed foods (Edible foods with 1 food additive)	0.5
Moderately processed foods (Edible foods with 2-3 food additives)	0
Highly processed foods (Edible foods with 4-5 food additives)	- 0.5
Ultra processed foods (Edible foods with >5 food additives)	- 1

[1]The total fat score was modified for yogurt and cheese as 1 point if 0-45%, 0.5 points if 45.1-65%, and 0 points if > 65% of calories and for nuts/seeds/avocado as 1 point if 0-80%, 0.5 points if 80.1-90%, and 0 points if > 90% of calories.
[2]The saturated fat score was modified for yogurt/cheese as 1 point if 0-25%, 0.5 points if 25.1-30%, and 0 points if > 30% of calories.

For yogurt/cheese and nuts/seeds/avocado, the scoring was changed as these snacks get low total scores from the app due to low scores of total fat and saturated fat. Even though yogurt/cheese have high total fat and saturated fat, they are considered as healthy snack.[35,57,58] Also, nuts/seeds/avocado have high total fat because these snacks are high in monounsaturated fatty acids and polyunsaturated fatty acids which are healthy fats.[8,12,25,26,35]

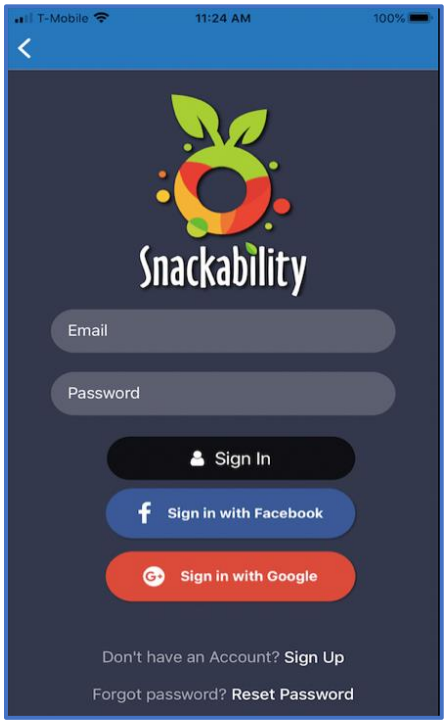
Features of the Snackability app

The Snackability app allows users to search for a snack (scan barcode or type snack name) (see Figure 1). The searching results are shown from both our own snack database (based on the snacks found at FIU) and the USDA database. Then, users select a snack and add the portion size based on the package. If the snack is not packaged, the app has a portion size guide to help them estimate the portion size that they will consume. The snack score is automatically calculated, showing the total score and the breakdown

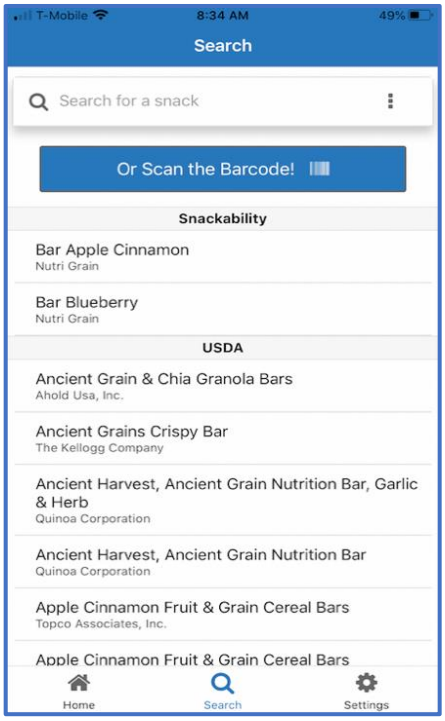
score. It also provides specific feedback on how to improve the score, based on the lowest score from each criteria. To increase motivation and app engagement, the app provides reporting components (average daily score report and consumed snack history) and gamification components (level up and achievement gained), which are commonly-used behavior change techniques, such as goal-setting, self-monitoring, self-motivation. Additionally, on the settings page of the app, users can submit a new snack to the administrators, giving feedback or comments about the app to the administrators. They can also specify if they have an allergy; if so, the app will alert the users when they choose a snack that contains the selected allergic ingredient. The app was developed for both Android and iOS platforms. Figure 1 shows the interface of the Snackability app.

Figure 1. Interface of the current 4th version of the Snackaiblity app

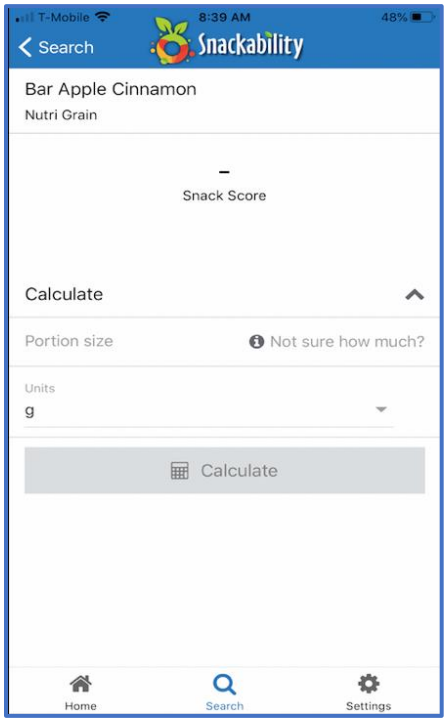
Snackability sign in page



Searching for a snack

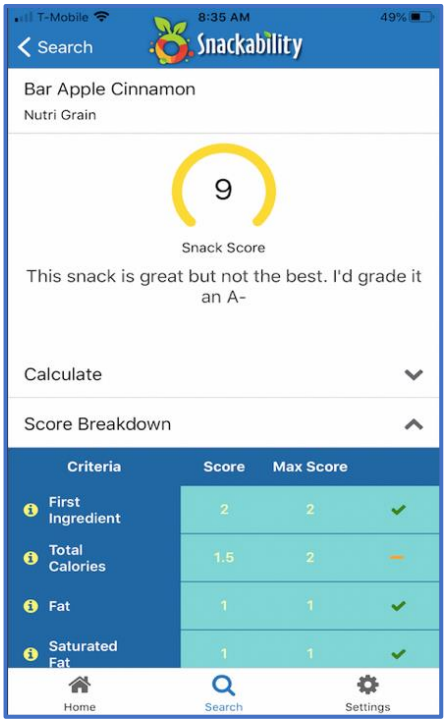


Choosing portion size



Portion size guide

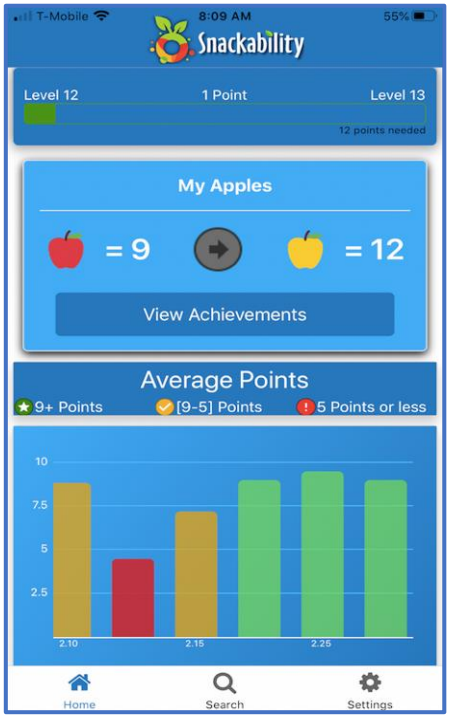
Total snack score & Feedback



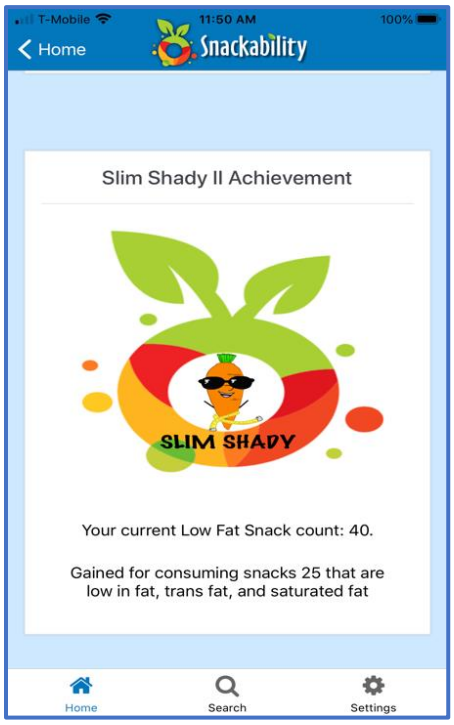
Breakdown scores & Specific feedback

Consumed button

Gamification

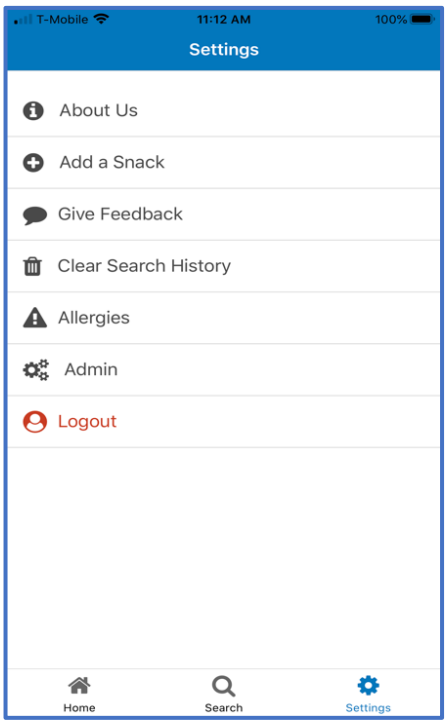


Achievement gained

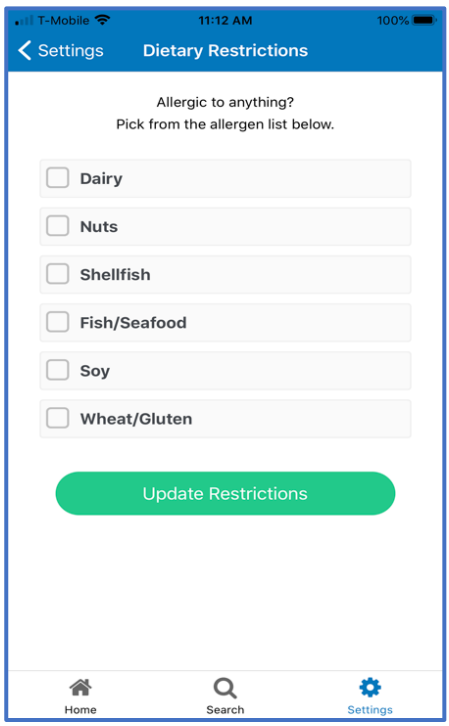


Score report & Consumed history

Setting page



Allergen restriction



Pilot testing of the Snackability app aimed to evaluate feasibility, usability, satisfaction, acceptability and explore experiences and feedbacks of the app among college students during 2 weeks.[49] We first recruited 12 participants to test the first version of the App among college students at FIU. Participants used the app for 2 weeks and then participated in a focus group to gain insight and explore experiences and feedbacks on the app. Based on these comments and suggestions, the app was improved and most of the features suggested were included. The 2nd version was also pilot tested among 8 college students in a similar way and suggestions were included in the 3rd and current version of the app. Most were satisfied, and considered the app to be feasible, usable and acceptable.

In summary, snack intake is popular among youth and plays an important role in their daily energy and nutrient intake. Due to the high availability and accessibility of unhealthy snacks and the lack of translation of the USDA guideline for healthy snacks, the smartphone app could be very appealing to youth to translate the guideline at the moment of choosing a snack. The intervention, which is based on the SCT, was implemented through the app. The app engagement features were designed to facilitate behavior change and improve nutrition-related health outcomes. Therefore, testing the Snackability app will fill the gap of identifying if a snack is healthy or not and helping to improve snacking behavior over time. At the end of the trial, if the Snackability app shows the improvement of the quality of snack intake, the general diet quality, and weight, then it could be promoted as a feasible and practical nutrition tool to help students in all U.S. college campus to be more motivated in choosing and consuming healthy snacks, leading to improve diet quality and prevent weight gain as a public health priority.

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CHAPTER III

SNACKING BEHAVIOR IS ASSOCIATED WITH DIET QUALITY, SNACK QUALITY, AND BODY WEIGHT IN US COLLEGE STUDENTS

Introduction

The prevalence of overweight and obesity has become a major public health concern in the United States (US),[1] particularly among college students, with more than one-third (~35%) considered overweight and obese in 2021.[2] Weight gain is typical in college students, particularly in the first year of college life.[3–5] While the prevalence of overweight and obesity has risen, mean energy intake from snacks has significantly increased in recent years,[6] especially higher among overweight and obesity compared to normal weight.[7–9] According to the National Health and Nutrition Examination Survey (NHANES) 2017-2018, 95% of Americans ages 20 years and older consumed snacks on a daily basis, contributing to 23% of their total energy intake, 36% of total sugar intake, 20% of total fat and saturated fat intake, and 13% of total sodium intake per day.[10] Snacking was even higher among college students, with 98% consuming snacks daily, at a frequency of about 4 times per day.[11]

The association between snacking behavior with snack quality, diet quality, and weight remains unclear.[12–20] Some studies found that snacking was associated with diet quality and/ or weight gain[12–14,17,20] whereas others found no associations.[15,16,18,19] It is well documented that most snacks consumed are energy-dense and nutrient-poor considered unhealthy snacks that have been associated with lower diet quality and higher body mass index (BMI).[13,14,18,20–23] However, several studies have found that if the snacks

consumed are healthy, such as fruits, vegetables, whole grain, nuts, and yogurt, they can be important contributors of nutrients to the daily diet, help improve overall diet quality,[15,21,24–28] and even been associated with lower BMI.[18,24]

Snacking behavior, such as snacking time, accessibility/availability of snacks, knowledge about healthy snacks, and reasons for snacking may influence snack choices and thus snack quality, overall diet quality, and even body weight.[23,28–33] However, snacking behavior among those of normal weight may be different from snacking behavior among those who are overweight and obese and from an intervention perspective, the latter will be most important. Therefore, it is important to understand the impact of snacking behavior on snack and diet quality and body weight in order to devise and employ effective intervention to improve snack and diet quality resulting in appropriate weight loss.[7–9,33] Additionally, this is important as studies have found that the COVID-19 pandemic led to a significant increase in snacking.[34,35] To the best of our knowledge, the relationships among snacking behavior, snack and diet quality, and body weight have not been studied well among college students with overweight and obesity despite high prevalence of overweight and obesity and high snack intake in this population.

Therefore, the present study evaluated the cross-sectional associations between snacking behavior, such as snacking frequency, snacking time, accessibility and availability of snacks, knowledge about snacks, and reasons for snacking with snack quality, overall diet quality, and body weight among US college students with overweight and obesity. It also explored the associations between snack quality, overall diet quality, and body weight. It was hypothesized that a higher snacking frequency, accessibility and

availability of unhealthy snacks, and lack of knowledge about choosing healthy snacks, would be associated with lower snack quality, lower overall diet quality, and higher BMI. Additionally, snack quality would be related to overall diet quality and body weight in this sample.

Methods

Study design

A cross-sectional secondary analysis of participants' baseline data obtained from the "Snackability trial" conducted at various US colleges from June 2020 to June 2021 (NCT05302830) was studied. Briefly, this trial tested the effects of having access to the Snackability Application (app),[36] an app that scores the snacks consumed based on how healthy are using the USDA guidelines on snacks. The study was approved by the Institutional Review Board at Florida International University (FIU; approval number IRB-20-0275). Written informed consent was obtained from all participants prior to study commencement.

Study participants

Students were eligible to participate in this study if they were 18-24 years, non-nutrition majors, overweight or obese (BMI >25 kg/m^2), owned a smartphone with Android or iOS platforms, had access to an internet connection to use the app, and were willing to participate in a clinical trial for 3 months. Participants were excluded if they were currently enrolled in a weight loss and/or nutrition program, were nutrition students, taking any medications known to influence weight, and were pregnant or breastfeeding.

Recruitment process

Participant recruitment was done by email, webpage, and social media. Data was collected using Qualtrics, a secured web-based survey. The electronic flyer was sent to faculty and staff in several universities in US via email to ask them to distribute it to their students. Also, the flyer was posted on the Snackability webpage and social media. Interested students clicked on a link in the flyer that led them to the screening form. Each eligibility criteria were automatically assessed in a stepwise progression; if they met all the criteria, then they were automatically led to the online consent form. Once participants signed the informed consent, they automatically proceeded with the baseline questionnaires. Then, the researcher contacted participants via their university emails with information on how to complete and submit the three 24-hour (h) dietary recalls and weight.

Measurements

1. Socio-demographic questionnaire: Participants completed questions about age (in years), gender (male, female, or other), race/ethnicity (White, Black, Hispanic/Latino, Asian, Other), and household income (<$50,000, $50,000-$100,000, or >$100,000) via Qualtrics.
2. Body measures: Body weight and height was reported by participants using a standardized protocol with written and video instructions to measure body weight at home. Participants were instructed to perform the measurements in the morning, after voiding and before eating or drinking, wearing only light underclothing and barefoot, and to place the scale on a hard and flat surface floor. Before weighing, participants were asked to calibrate the scale following the instructions shown in the video.

Participant reported their weight with 1 decimal in kilograms (kg) or pounds (lb) in duplicate and height in inches via Qualtrics.

3. Diet and snack quality: This was assessed from three non-consecutive 24-h dietary recalls (two during weekdays and one during the weekend) collected and analyzed by the Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool, version 2020, developed by the National Cancer Institute (NCI).[37] Participants received the quick start guides for 24-h recalls from ASA24 via email to help them complete the dietary recalls. To report a meal or snack on the ASA24 website, participants were able to select a meal (breakfast, brunch, lunch, dinner, or supper) or snack and time of the meal or snack consumed. Participants were instructed to enter snacks as referred to foods consumed between meals. The first recall was done together with the trained researchers via phone or Zoom call. The second and third dietary recalls were self-administered using ASA24. Energy and nutrient (protein, total fat, carbohydrate, total sugars, sodium, and total saturated fatty acids) intake from overall diet and snacks was obtained from ASA24 output and the data was averaged from the three recalls. The trained researcher checked the mean of the 24-h recalls before all analyses. Participants with a reported mean energy intake below 600 (female) or 650 (male) kcal/d or above 4400 (female) or 5700 (male) kcal/d were excluded.[38]

    - For the overall diet quality, the Healthy Eating Index (HEI)-2015 total score was calculated by the simple HEI scoring algorithm method.[39] The HEI-2015 total score consists of the sum of 13 components: 9 adequacy components (total vegetables, greens and beans, total fruits, whole fruits, whole grains, dairy, total

protein foods, seafood and plant proteins, and fatty acids) and 4 moderation components (refined grains, sodium, saturated fats, and added sugars). The HEI-2015 total score ranges from 0 to 100, in which a higher score is a better diet quality and more consistent with the Dietary Guidelines for Americans (DGA) 2015-2020.[40] The score for the individual components was also calculated.

- For the snack quality score, the output from ASA24 was used to identify the type, number, and serving size of snacks consumed. Then, the score was calculated using the scoring algorithm developed for the Snackability app,[36] which was based on the USDA Smart Snack Guideline.[41] Briefly, this score takes into account the first ingredient, the nutrition standard by portion size (calories, total fat, saturated fat, trans fat, sodium, and sugar), and the food processing for a score ranging from -1 to 11 points. The higher the score, the healthier the snack is and more compliant to the guideline. The snack scores were calculated as an average score for each participant.

4. <u>Snacking behaviors:</u> this was assessed as follows:
    - Timing of snack, this was obtained from the ASA24 output report, in which the time, type, and number of snacks consumed was recorded. Snacking time was categorized into four time periods: morning (5:00 AM to 11:59 AM), early afternoon (12:00 PM to 2:59 PM), late afternoon (3:00 PM to 5:59 PM), and evening (6:00 PM to 4:59 AM). For each time period, we calculated the snack score as described previously and compared the difference of the snack scores among these four time periods.

- Snacking frequency, reasons for snacking, type of snacks more accessible and available to them, and knowledge about how to choose a healthy snack was assessed using a questionnaire used in other studies.[30,36,42]

Statistical analyses

For descriptive statistics, mean and standard deviation (SD) were used for continuous variables and frequency and percentage for categorical variables. Analysis of variance was used to compare snack quality score, HEI-2015 total score, or BMI by snacking behavior, adjusted by age, gender, race/ethnicity, and income with Tukey post hoc analysis to assess significant difference between pairs of group means. Pearson correlation (controlled for age, gender, race/ethnicity, and income) was used to examine associations between snack quality score, HEI-2015 total score and component scores, and BMI. All reported P-values were two-tailed, and P-values < 0.05 were considered statistically significant. Statistical analysis was performed using SPSS Statistics software (version 28, IBM, New York).

Results

A total of 298 participants were recruited for the study but only 140 participants (18-24 years) completed all baseline questionnaires, including at least two 24-h dietary recalls. Mean (SD) for age was 21.1 (1.7) years and for BMI was 30.3 (5.6) kg/m^2 (Table 1). Most participants were female (86.4%), Hispanic (30.7%), and from colleges in Florida (80.7%) with a household income less than $50,000 (51.4%).

Table 1. Socio-demographic characteristics of college students participating in the Snackability trial at baseline (N =140)

Characteristics	**Mean (SD) or N (%)**
Age (years), mean (SD)	21.1 (1.7)
Gender, n (%)	
Female	121 (86.4)
Male	19 (13.6)
Race/ethnicity, n (%)	
White	41 (29.3)
Hispanic or Latino	43 (30.7)
Black or African American	15 (10.7)
Asian	16 (11.4)
Other/multiracial	25 (17.9)
States, n (%)	
FL	113 (80.7)
Others (KY, LS, SC, TX)	27 (19.3)
Household income, n (%)	
<$50,000	72 (51.4)
$50,000-$100,000	42 (30.0)
>$100,000	26 (18.6)
Body mass index (kg/m^2), mean (SD)	30.3 (5.6)
Overweight (<30.0 kg/m^2)	81 (57.9)
Obese (≥30.0 kg/m^2)	59 (42.1)

A total of 89% of participants reported consuming snacks, with a frequency of 2.4 (1.1) times per day (Table 2). Although the majority knew how to choose a healthy snack (86.4%), most reported that unhealthy snacks were more accessible and available to them (69.3%). The top three reasons for snacking were to stave off hunger (65%), because snacks were tasty/palatable (63.6%), and for pleasure (63.6%).

Table 2. Snacking behaviors of college students participating in the Snackability trial at baseline (N = 140)

Snacking behaviors	**Mean (SD) or N (%)**
Snacking frequency, mean (SD)	
Times of snacks consumed per day	2.4 (1.1)
Knowledge to choose a healthy snack, n (%)	
Yes	121 (86.4)
No	19 (13.6)
Type of snacks more accessible/available, n (%)	
Healthy snacks (i.e., fruits, vegetables, nuts, etc.)	43 (30.7)
Unhealthy snacks (i.e., chips, crackers, cookies, etc.)	97 (69.3)
Reasons for snacking, n (%)	
Snacks are tasty/palatable	89 (63.6)
To stave off hunger	91 (65.0)
Snacks are convenient	72 (51.4)
To fill the gap between meal	88 (62.9)
Snacks are affordable	22 (15.7)
Snacks are pleasure	89 (63.6)
Number of snacks consumed at different snacking time, n (%)	
Morning (5:00 AM to 11:59 AM)	55 (8.8)
Early afternoon (12:00 PM to 2:59 PM)	95 (15.3)
Late afternoon (3:00 PM to 5:59 PM)	184 (29.5)
Evening (6:00 PM to 4:59 AM)	289 (46.4)

Snacks represented 8.6% of total energy intake, 14.1% of total sugar intake, 5.1% of total sodium intake, and 10.2% of total saturated fat intake (Table 3). Mean (SD) of HEI-2015 total score was 54.8 (12.1) and snack quality score was 6.7 (2.0).

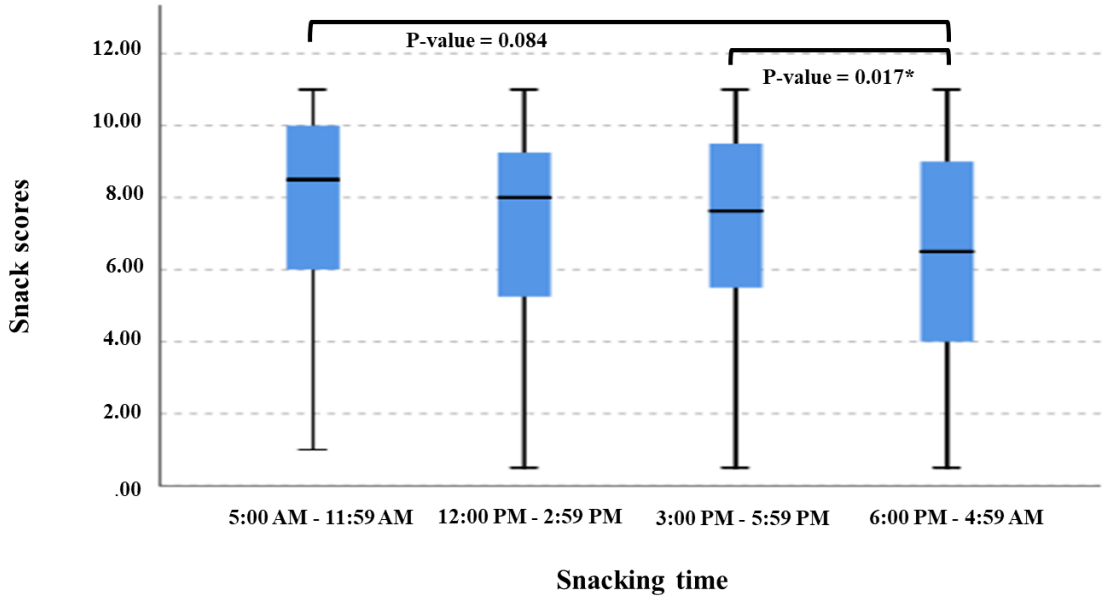
Table 3. Nutritional contents of the overall diet and snacks of college students participating in the Snackability trial at baseline (N = 140[a])

Nutritional contents	Overall diet[b]	Snacks	
	Mean (SD)	Mean (SD)	%
Energy (kcal/day)	1878 (722)	162 (167)	8.6[c]
Carbohydrate (g/day)	214 (95)	21 (22)	9.8[c]
Protein (g/day)	79.5 (38.6)	3.8 (5.8)	4.8[c]
Total Fats (g/day)	78.0 (37.1)	7.3 (10.8)	9.4[c]
Total sugars (g/day)	78 (55)	11 (13)	14.1[c]
Sodium (mg/day)	3188 (1342)	164 (279)	5.1[c]
Total saturated fats (g/day)	25.5 (15.7)	2.6 (5.3)	10.2[c]
Quality scores	54.8 (12.1)[d]	6.7 (2.0)[e]	

[a]A total of 96 participants only had two 24-hour dietary recalls.
[b]Nutritional contents of overall diet including snacks were reported without the inclusion of dietary supplements.
[c]Percentages are a ratio of nutritional contents from snacks to nutritional contents from overall diet.
[d]Quality scores for the overall diet were based on HEI-2015 total score.
[e]Quality scores for the snacks were based on snack score from the Snackability app

Snack quality scores were compared by timing of snacks consumed (Figure 1). Most participants consumed snacks in the evening (46.4%), which had a significantly lower snack quality score compared to afternoon snacks (P=0.017).

Figure 1. Snack quality score by snacking time from all snacks consumed by college students participating in the Snackability trial at baseline (N = 140)



*Significant value was considered at *P*-value < 0.05 by Tukey post hoc analysis.

After adjusting for potential confounders (Table 4), no significant differences in snack quality score, HEI-2015 total score, and BMI were detected by snacking frequency, knowledge about choosing healthy snacks, and reasons for snacking (except snacking for pleasure). However, participants with greater accessibility and availability to unhealthy snacks had significantly lower snack quality score (*P*=0.001), lower HEI-2015 total score (*P*=0.006), and higher BMI (*P*=0.019) than those with greater accessibility and availability to healthy snacks. Snacking for pleasure had significantly lower snack quality score than snacking for non-pleasure (*P*=0.037).

Table 5 presents the significant correlations between the HEI-2015 total score (r=0.459, *P*<0.001) and several component scores (total vegetables, greens and beans, fruits, whole grains, dairy, refined grains, and added sugars) with the snack quality score

after controlling for age, gender, race/ethnicity, and income. BMI had a significantly negative correlation with HEI-2015 total score (r=-0.219, *P*=0.016) but no significant correlation with snack quality score. Additionally, BMI was inversely correlated with HEI-2015 greens and beans and whole fruits.

Table 4. HEI-2015 total score, snack quality score, and BMI by snacking behaviors of college students participating in the Snackability trial at baseline (N = 140)

Variables	HEI-2015 total score		Snack quality score		BMI	
	Mean (SD)	***P*-value[a]**	**Mean (SD)**	***P*-value[a]**	**Mean (SD)**	***P*-value[a]**
Snacking frequency (times/day)						
0-1 time per day	56.9 (10.7)	0.380	7.2 (1.6)	0.154	30.7 (5.2)	0.815
≥2 times per day	54.2 (12.4)		6.6 (2.0)		30.2 (5.7)	
Knowledge to choose a healthy snack						
Yes	55.0 (12.4)	0.396	6.7 (2.0)	0.697	30.1 (5.5)	0.263
No	53.2 (9.9)		6.6 (1.5)		31.9 (6.4)	
Type of snacks more accessible/available						
Healthy snacks (i.e., fruits, vegetables, nuts, etc.)	58.2 (13.9)	0.006*	7.5 (1.9)	0.001*	28.5 (4.4)	0.019*
Unhealthy snacks (i.e., chips, crackers, cookies, etc.)	53.2 (11.0)		6.3 (1.9)		31.1 (5.9)	
Reason for snacking						
Snacks are tasty/palatable						
Yes	54.4 (12.7)	0.710	6.5 (2.1)	0.174	30.6 (6.1)	0.651
No	55.3 (11.8)		7.0 (1.8)		29.9 (4.7)	
To stave off hunger						
Yes	53.5 (11.6)	0.155	6.7 (2.0)	0.878	30.5 (5.9)	0.667
No	57.0 (12.7)		6.8 (2.0)		30.0 (5.1)	

Variables	HEI-2015 total score		Snack quality score		BMI	
	Mean (SD)	*P*-value[a]	Mean (SD)	*P*-value[a]	Mean (SD)	*P*-value[a]
Snacks are convenient						
Yes	53.6 (11.9)	0.225	6.7 (1.9)	0.888	31.1 (6.3)	0.116
No	56.0 (12.2)		6.7 (2.1)		29.5 (4.6)	
To fill the gap between meal						
Yes	54.8 (12.8)	0.721	6.8 (2.0)	0.645	30.0 (5.4)	0.336
No	54.7 (10.9)		6.6 (1.9)		30.9 (6.0)	
Snacks are affordable						
Yes	53.0 (9.4)	0.442	6.7 (2.2)	0.939	30.3 (6.0)	0.783
No	55.1 (12.5)		6.7 (1.9)		30.3 (5.5)	
Snacks are pleasure						
Yes	53.7 (12.3)	0.241	6.4 (2.1)	0.037*	30.7 (5.9)	0.311
No	56.6 (11.6)		7.2 (1.7)		29.7 (5.0)	

[a] Adjusted by age, gender, race/ethnicity, and income; **P*-value < 0.05 considered significant (2-tailed).

Table 5. Correlation between snack quality score or BMI with HEI-2015 total and component scores of college students participating in the Snackability trial at baseline (N = 140)

Variables	Snack quality score				BMI			
	Pearson correlation	**P-value**	**Adjusted Pearson correlation[a]**	**P-value**	**Pearson correlation**	**P-value**	**Adjusted Pearson correlation[a]**	**P-value**
HEI-2015 total score	0.464	<0.001*	0.459	<0.001*	-0.188	0.026*	-0.219	0.016*
HEI-2015 total vegetables	0.326	<0.001*	0.312	0.001*	-0.171	0.044*	-0.160	0.079
HEI-2015 greens and beans	0.205	0.022*	0.191	0.036*	-0.208	0.013*	-0.237	0.009*
HEI-2015 total fruits	0.365	<0.001*	0.343	<0.001*	-0.160	0.060	-0.175	0.055
HEI-2015 whole fruits	0.445	<0.001*	0.426	<0.001*	-0.237	0.005*	-0.269	0.003*
HEI-2015 whole grains	0.314	<0.001*	0.319	<0.001*	-0.143	0.092	-0.130	0.154
HEI-2015 dairy	0.259	0.003*	0.236	0.009*	-0.073	0.394	-0.041	0.654
HEI-2015 total protein foods	0.061	0.500	0.079	0.387	0.026	0.759	0.020	0.826
HEI-2015 seafood & plant proteins	0.030	0.742	0.043	0.643	-0.006	0.947	-0.004	0.966
HEI-2015 fatty acids	-0.043	0.636	-0.027	0.765	0.137	0.108	0.064	0.483
HEI-2015 refined grains	0.231	0.010*	0.223	0.014*	0.027	0.752	-0.021	0.820
HEI-2015 sodium	-0.063	0.488	-0.062	0.502	-0.101	0.237	-0.079	0.387
HEI-2015 saturated fats	0.000	0.996	-0.002	0.982	-0.025	0.773	-0.104	0.255
HEI-2015 added sugars	0.294	0.001*	0.316	<0.001*	-0.111	0.191	0.012	0.899
BMI	-0.115	0.202	-0.149	0.102				

[a] Adjusted by age, gender, race/ethnicity, and income; **P*-value < 0.05 considered significant (2-tailed).

Discussion

This study among a sample of college students with overweight and obesity showed that the quality of snacks differed by snacking time, with evening snacks having the lowest snack quality score. Also, those with more accessibility and availability to unhealthy snacks had lower diet and snack quality scores and higher BMI. Snacking for pleasure had lower snack quality score. Also, snack quality score was positively correlated with HEI-2015 total score and several component scores but not with BMI.

Snacking time had an impact on snack quality, in which there was a significantly lower snack quality score in the evening snacks compared to afternoon snacks. Other studies found that morning snacks were associated with a better diet quality or nutrient density while evening snacks were associated with a lower diet, nutrient density, or higher BMI.[29,43,44] Snacks consumed in the evening may be energy-dense and nutrient-poor snacks that may lead to lower diet quality and could be associated with weight gain. This could be explained in part by the circadian rhythm, as studies have found a peak in hunger sensation at around 8 pm (range 5 - 9 pm).[45,46] However, healthy snacks, such as high-protein soy snacks and hummus, consumed in the afternoon have also been found to significantly improve appetite, satiety, and overall diet quality.[28,47] Therefore, snacking time and quality of snacks may be important in the relation between hunger-satiety regulation.[28,47–49] This could also affect weight, as shown by a study using a representative sample of the Spanish population (1655 adults aged 18–64 years) in which snacks with greater than 15% of total energy intake consumed mid-morning or mid-afternoon were associated with a lower risk of obesity.[50]

Snacking frequency was not associated with snack quality, diet quality, or BMI in the present study. Other studies reported that snacking frequency was modestly associated with diet quality and/or BMI,[12–14,17,20] although not all studies showed this.[15,18,19] Several studies have shown that the type of snacks (healthy vs unhealthy) seems to be more important contributors to energy and nutrients of the daily diet, diet quality, and BMI rather than snack frequency.[14–16,18,24,51] Mechanistically, studies have shown the importance of the circadian clock related to the timing and quality of food and snack intake and their associations with body weight,[29,43,50,52] but frequency seems less important. However, the present study found a significantly lower snack quality score among those that reported snacking with pleasure compared to those that reported snacking without pleasure. A previous study reported that sweets, dessert, and sugary drinks were linked to pleasure.[53] Also, a study conducted during the pandemic found that pleasure was one of the food choice determinants more associated with eating behaviors among participants with overweight and obesity to cope with stress and psychological distress which was associated with higher intake of energy-dense snacks.[35,54]

The food environment is also an important factor related to the quality of snacks and overall diet. Several studies have noted that college students had greater availability and accessibility to unhealthy snacks than healthy snacks on campuses and they seemed to select unhealthy snacks rather than healthy snacks.[23,30,31,55] This also extended to the home during the COVID-19 pandemic when many colleges in the country were mainly teaching remotely. While restricted to home, the present study found that those with higher accessibility and availability to unhealthy snacks had lower diet and snack quality and higher BMI. Similarly, during the normal or pandemic situation, home food

availability and accessibility is a major factor of snack intake.[56,57] Studies among adolescents found that availability of unhealthy foods at home was positively associated with energy-dense, sweet, and savory snack intake ($P<0.05$).[58,59]

The quality of the snack was also an important determinant of overall diet quality, with a higher snack quality score significantly associated with higher intake of vegetables, fruits, whole grains, and dairy, and inversely associated with lower intake of refined grains and added sugars. Also, a higher overall diet quality was inversely associated with BMI. This result is consistent with other studies that have showed that a higher overall diet quality is modestly associated with higher snack quality and lower BMI.[14,18,21,22]

There are several strengths worth noting in this study. First, the diet quality was assessed using HEI-2015 from ASA24 dietary recalls, which allowed participants to enter snack occasions, time, and snacks consumed separate from meals. Second, the study included a diverse sample of students from different colleges in the US. One of the limitations is that the results cannot confirm the causal relationship due to the cross-sectional nature of the study. The data was collected during the COVID-19 pandemic which may have changed snacking behaviors. Under reporting in the 24-h recalls could have affected the results, as this is greater in individuals with overweight and obesity.[60,61] Also, self-report questionnaires and dietary recalls may lead to imprecise data report, but it would be difficult to evaluate snacking behavior and dietary recalls without self-report data. Finally, only a fraction of recruited participants completed the 24-h recalls limiting the sample size. Thus, future studies in a larger sample should evaluate the longitudinal

associations between snacking behavior on overall diet quality, snack quality, and body weight.

Conclusions

The quality of snacks differed by snacking time, with evening snacks having a lower snack quality score. Those with more accessibility and availability of unhealthy snacks had lower diet and snack quality and higher BMI. In addition, snacking can be a healthy behavior by choosing healthy snacks, such as vegetables, fruits, whole grains, and dairy, that can improve overall diet quality and body weight. This information could be used to design future interventions for college students related to the improvement of the environment to have healthy snacks more accessible and available together with improving the snacking time and types of snacks consumed.

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CHAPTER IV

EFFECT OF USING THE SNACKABILITY APP ON SNACK QUALITY, DIET QUALITY, AND WEIGHT IN US COLLEGE STUDNETS: A RANDOMIZED CONTROLLED TRIAL

Introduction

Snacking is entwined in American food culture. Americans age 20 years and over consume snacks on a daily basis (95%), contributing to 23% of their total energy intake, 36% of total sugar intake, 20% of total fat and saturated fat intake, and 13% of total sodium intake per day.[1] Snacking is higher among college students where 98% consume snacks daily, at a frequency of about 4 times per day.[2] College students spend many hours on campus and studying late at night, often consuming a variety of snacks.[3–5] Most snacks consumed by students are energy-dense and nutrient-poor (unhealthy snacks), which results in a lower diet quality and weight gain.[6–12] On the other hand, studies have found that consumption of healthy snacks, such as fruits, vegetables, whole grain, nuts, and yogurt, help improve the diet quality.[6,9,13,14]

To help select healthy snacks, the USDA developed the "Smart Snack Guideline".[15] According to this guideline, a healthy snack must have as a first ingredient a whole grain, fruit, vegetable, dairy, or protein food and meet the nutrient standards for calories, calories from fat, fats, sugar, and sodium. However, the recommendations from this guideline are often lost in translation when college students are faced with the decision to choose a snack. There is a need for a practical method to help individuals identify which snacks meet the USDA guidelines, and therefore, is a healthy option. A

smartphone application (app) could be an appealing and accessible tool to help translate the guideline for college students as this group has the highest percentage of smartphone ownership (94%)[16] and app usage (77%)[17] with 7.6 apps used on a daily basis.[18] In addition, about 59% of smartphone users have downloaded health mobile apps, particularly fitness and nutrition apps.[19]

The use of nutrition apps have been positively associated with healthier snack and beverage intake and body mass index (BMI) in adolescents.[20] A study testing the eBalance app in 85 healthy weight adults found significant improvements in weight, diet quality, knowledge, and maintaining healthy lifestyle after 14 weeks.[21] Another study tested the Vegethon mobile app in 135 overweight adults found a significant increase in vegetable intake after 5 and 8 weeks.[22] However, another study testing the Snack Track School app in 988 adolescents found no health effects after 4 weeks, but only 64% actually used the app and only 21% were still using it at week 4.[23]

Currently, there are no user-friendly apps to identify if a snack is healthy at the moment of choosing a snack. Also, there is limited research on interventions to improve snack intake among college students despite high snack intake and abundant app usage in this population. Despite a lack of research in these areas, studies show that app interventions using behavior change techniques, such as feedback, goal setting, self-monitoring, shaping knowledge (information), and social support showed positive nutrition and health outcomes.[24] Therefore, the Snackability app was developed to help students choose a healthy snack based on the USDA guidelines and in the social cognitive theory (SCT) for behavior change. This app was tested among overweight and obese college students to determine if its usage improves the quality of the snack intake,

the diet quality, and body weight in a two-arm, 12-week randomized controlled trial (RCT). Thus, it was hypothesized that when college students used the app over time, the app could be a nutrition tool to help facilitate snacking behavior change resulting in improving quality of snack intake, diet quality, and body weight.

Methods

Study design

The study was a two-arm, 12-week RCT to determine the effects of using the Snackability app for improving the quality of the snack intake, the diet quality, and body weight among overweight and obese college students (NCT05302830). Participants were recruited from various US colleges and the trial was conducted completely online from June 2020 to June 2021 due to the COVID-19 pandemic. The study was approved by the Institutional Review Board at Florida International University (FIU; approval number IRB-20-0275). Written informed consent was obtained from all participants prior to study commencement.

Participants and eligibility

Overweight or obese college students (BMI $\geq$ 25 kg/m^2) were eligible for participation if they were ages 18-24 years, owned a smartphone with Android or iOS platforms, had access to an internet connection to use the app, from non-nutrition majors, and were willing to participate in a clinical trial for 3 months. Participants were excluded if they were currently enrolled in a weight loss and/or nutrition program, were taking any medications known to influence weight, and were pregnant or breastfeeding.

Recruitment, screening process, and randomization

Participant recruitment was done by email, webpage, and social media and data was collected using Qualtrics, a secured web-based survey. The electronic flyer was sent to faculty and staff in several universities in US via email to ask them to distribute it to their students. Also, the flyer was posted on the Snackability webpage and social media. Interested students clicked on a link in the flyer that led them to the screening form. Each eligibility criteria were automatically assessed in a step-wise progression; if they met all the criteria, then they were automatically led to the online consent form. Once participants signed the informed consent, they automatically proceeded with the baseline questionnaires. Then, the researcher contacted participants via their university emails with information on how to complete and submit the three 24-h dietary recalls and weight before randomization. Using a simple computerized randomization scheme, participants were randomly assigned to either the control or app intervention using a 1:1 ratio. The researcher who collected and analyzed the data was blinded to the study allocation throughout the study period.

Participants randomized to the intervention group received an end-user license agreement (EULA), the instructions to download and register with the Snackability app, and the instruction on how to use the app every time they had a snack. Participants randomized to the control group received a 1-page healthy snack information document and access to the app after the 12-week study period.

Intervention

The Snackability smartphone app was developed based on the USDA Smart Snack Guidelines.[15] It allowed participants to search for a snack (scan barcode or type

snack name), added a portion size consumed based on a portion size guide, and then the app provided a snack score and the breakdown scores with a specific feedback message about the score.[25] The score ranges from -1 to 11 points, in which a higher score was more compliant to the USDA guideline and therefore a healthier snack. Participants could also specify if they had an allergy; if so, the app would alert the participants when they chose a snack that contained the selected allergic ingredient.

The app incorporated behavior change techniques related to the constructs of the SCT to facilitate snacking behavior change, such as observational learning, outcome expectation, self-efficacy, goal setting, feedback on performance, self-motivation through rewarding, self-monitoring, and self-regulation. The SCT focuses on individuals that play an active role in their health by translating motivation into action by using the app to help select healthier snack choices and reinforcing adherence to the app through self-efficacy, goal setting, self-monitoring, and self-regulation.[26–28] The SCT also emphasizes on the dynamic interplay between individuals and the environment which mutually influence each other. College students use the app to help identify and select healthy snacks. Then, if they have healthier snacks around them, they are more likely to eat these snacks. Thus, the app intervention was meant to change the snacking behavior resulting in improving the snack and diet quality as target outcome which may lead to the eventual outcome of weight loss.

The app was a trial version that was not accessible through the App store or Google Play; it was only accessible through the EXPO app (https://expo.dev), an open-source platform for testing any type of app (for Android or iOS). The link and the username for this app was shared privately with each participant randomized to the app

group only; therefore, no one else had access to this app. After participants were randomized to the app group, they started to receive automated text messages once a week to remind them to use the app during the study. The messages were alternated with tips of how to use the app and on how to search for the snacks. In addition, if participants were not using the app, a research staff would send them an email reminding them to use the app.

Outcome measures

The study assessments were done online for all participants at baseline, 4, 8, and 12 weeks as described below.

1. Socio-demographic questionnaire (completed at baseline via Qualtrics): it included questions about age (in years), gender (male or female), race/ethnicity (White, Hispanic or Latino, Black or African American, Asian, Other/multiracial), household income (<$50,000, $50,000-$75,000, $75,000-$100,000, or >$100,000), food security status (high, low, or very low) using the six-item short form of U.S household food security survey module,[29] and stress level using the validated stressometer (0; no stress to 10; extreme stress).[30]
2. Body weight measures (completed at baseline, 4, 8, and 12 weeks via Qualtrics): Body weight was reported by participants using a standardized protocol with written and video instructions to measure this at home. Participants were instructed to perform the measurements in the morning, after voiding and before eating or drinking, wearing only light underclothing and barefoot, and to place the scale on a hard and flat surface floor. Before weighing, participants were asked to calibrate the scale following the

instructions shown in the video. Participant reported their weight with 1 decimal in kg or pounds (lb) in duplicate and height was self-reported in inches.

3. Diet and snack quality: was assessed from three non-consecutive 24-h dietary recalls collected from each participant at baseline and 12 weeks and one 24-h dietary recall at 4 and 8 weeks. Dietary recalls were collected and analyzed by the Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool, version 2020, developed by the National Cancer Institute (NCI).[31] Participants received the ASA24 quick start guides for 24-h recalls via email to help them complete this. The first recall was done together with the researcher via phone or Zoom call; during this call, participants were instructed to enter the snacks, which was defined as foods consumed between meals. The mean of the 24-h recalls was used in all analyses. Participants with a reported mean energy intake below 600 (female) or 650 (male) kcal/d or above 4400 (female) or 5700 (male) kcal/d were excluded.[32] The diet and snack quality was assessed as described below:

    - Diet quality: it was assessed using the Healthy Eating Index (HEI)-2015 total score and component scores for each participant at baseline, 4, 8, and 12 weeks by using the simple HEI scoring algorithm method.[33,34] The HEI-2015 total score consists of the sum of 13 components: 9 adequacy components (total vegetables, greens and beans, total fruits, whole fruits, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and 4 moderation components (refined grains, sodium, saturated fats, and added sugars). The HEI-2015 total score ranges from 0 to 100, in which a higher score is a better diet quality and more consistent with the Dietary Guidelines for Americans (DGA) 2015-2020.[35]

- Quality of snack: it was assessed using the scoring algorithm developed for the Snackability app[25], which was based on the USDA Smart Snack Guideline.[15] Briefly, this score takes into account the first ingredient, the nutrient standard by portion size, and the processing of foods for a score ranging from -1 to 11 points. The higher the score, the healthier the snack is and more compliant to the guideline. To identify the snacks consumed at each time point, the output from the ASA24 was used; for each snack consumed, the type, number, and serving size was recorded. The snack scores were calculated as mean score for each participant at baseline, 4, 8, and 12 weeks.

4. App engagement: The frequency of app use was retrieved from the app Firebase database, which showed each time the app was used by participants during the study. It was recoded for each time point (week 4, 8, and 12).

Statistical analyses

For descriptive statistics, mean and standard deviation (SD) were used for continuous variables and frequency and percentage for categorical variables. The socio-demographic characteristics were compared between the two groups at baseline using independent samples t-test for continuous variables and chi-square test for categorical variables.

The intent-to-treat principle was used to compare mean changes in snack score, diet quality, and weight between groups. The comparison of the outcomes between two groups at 4, 8, and 12 weeks was computed by repeated measure ANOVA for equal difference of variance and mixed model repeated measure ANOVA for unequal difference of variance. Analyses were also done using simple imputation for missing

data. All reported P-values were two-tailed, and P-values < 0.05 were considered statistically significant. Statistical analysis was performed using SPSS Statistics software (version 28, IBM, New York).

Results

Of the 262 who agreed to participate in the study, 142 participants completed all baseline requirements and were randomized to the control or app intervention groups (Table 1 and Figure 1). Three participants (2 in the control group and 1 in the app group) were excluded based on reported energy intake outside the accepted range. Thus, the imputed analysis included 72 participants in the control group and 67 participants in the app group. In the control group, a total of 34 (47.2%) participants completed the follow-up at week 4, 28 (38.9%) at week 8, and 56 (77.8%) at week 12. In the app group, 32 (47.8%) participants completed the follow-up at week 4, 27 (40.3%) at week 8, and 45 (67.2%) at week 12. In both groups, the main reason for not completing the follow ups was that participants did not complete at least two 24-h dietary recalls.

There were no significant differences in baseline characteristics between the control and app groups (Table 1). Overall, mean (SD) age was 21.1 (1.7) years, 84.6% were females, 30.9% were Hispanic, 51.1% had household income less than $50,000, 71.2% reported having a high food security, stress level was considered “medium level”, and mean (SD) BMI was 30.4 (5.6) kg/m^2. The socio-demographics were similar between those completed the study (n=106) and those lost to follow-up (n=33) (data not shown).

Table 1. Baseline characteristics of the randomized participants (N = 139)

Characteristics	**All (N = 139)**	**Control (N = 72)**	**App (N = 67)**	***P*-value**
Age in years, mean (SD)	21.1 (1.7)	21.0 (1.6)	21.3 (1.8)	0.285
Female, n (%)	77 (84.6)	63 (87.5)	57 (85.1)	0.677
Race/Ethnicity, n (%)				
White	41 (29.5)	22 (30.6)	19 (28.4)	0.156
Hispanic or Latino	43 (30.9)	21 (29.2)	22 (32.8)	
Black or African American	15 (10.8)	8 (11.1)	7 (10.4)	
Asian	15 (10.8)	4 (5.6)	11 (16.4)	
Other/multiracial	25 (18.0)	17 (23.6)	8 (11.9)	
State, n (%)				
FL	113 (81.3)	60 (83.3)	53 (79.1)	
Others (KY, LS, SC, TX)	26 (18.7)	12 (16.7)	14 (20.9)	
Household income, n (%)				
<$50,000	71 (51.1)	36 (50)	35 (52.2)	0.570
$50,000-$75,000	25 (18)	16 (22.2)	9 (13.4)	
$75,000-$100,000	17 (12.2)	8 (11.1)	9 (13.4)	
>$100,000	26 (18.7)	12 (16.7)	14 (20.9)	
Food security, n (%)				
High	99 (71.2)	50 (69.4)	49 (73.1)	0.818
Low	28 (20.1)	16 (22.2)	12 (17.9)	
Very low	12 (8.6)	6 (8.3)	6 (9)	
Stress, mean (SD)	6.9 (1.7)	6.8 (1.7)	7.0 (1.7)	0.415
BMI (kg/m^2), mean (SD)	30.4 (5.6)	30.8 (5.6)	29.9 (5.7)	0.363

Figure 1. Consort flow diagram of participants through the Snackability trial

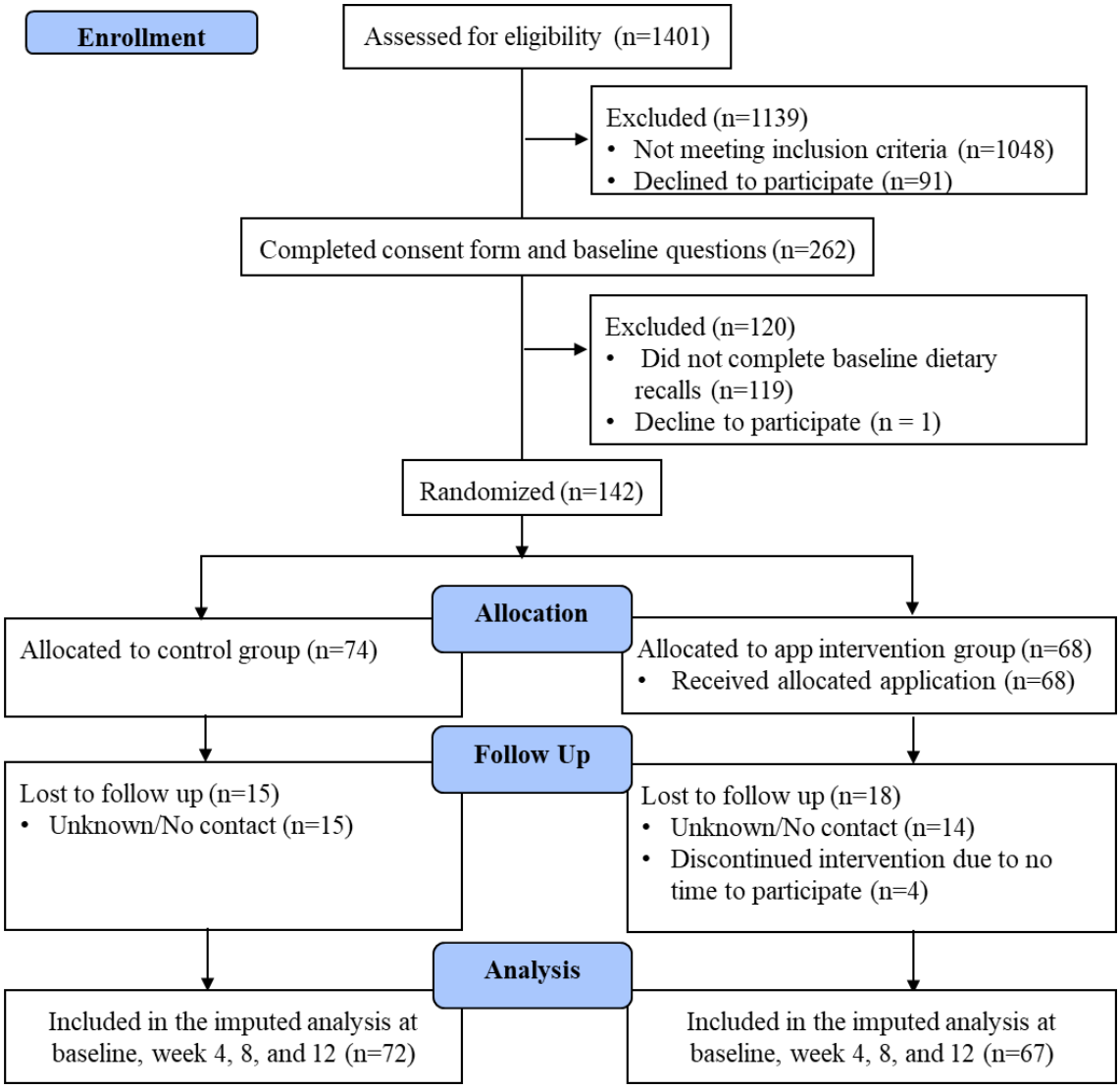

Table 2 shows the mean change in snack score, HEI-2015 total score, and weight at each time point using intent-to-treat analysis between groups. No significant changes were detected in any of the outcomes.

Table 2. Change in snack score, HEI-2015 total score, and weight between control and app groups at baseline, week 4, 8, and 12 follow-ups using intent-to-treat principles

	Change baseline to Week 4	Change baseline to Week 8	Change baseline to Week 12
Snack score[a], Mean (SD)			
Control	-0.5 (2.8) (n=23)	-0.5 (3.0) (n=10)	0.5 (2.8) (n=38)
App	0.1 (2.3) (n=26)	0 (2.7) (n=16)	0.2 (2.3) (n=28)
T-test (P-value)[b]	-0.794 (p=0.431)	-0.424 (p=0.675)	0.498 (p=0.620)
HEI total score, Mean (SD)			
Control	-3.3 (16.2) (n=34)	-1.9 (15.8) (n=28)	-0.7 (13.0) (n=56)
App	1.7 (13.4) (n=32)	-4.0 (15.9) (n=27)	-1.0 (15.6) (n=45)
T-test (P-value)[b]	-1.352 (p=0.181)	0.497 (p=0.621)	0.100 (p=0.921)
Weight, Mean (SD)			
Control	0.1 (1.9) (n=34)	0.5 (1.5) (n=21)	0.2 (3.0) (n=49)
App	-0.9 (2.4) (n=28)	-0.2 (2.0) (n=25)	0.2 (2.7) (n=44)
T-test (P-value)[b]	1.801 (p=0.077)	1.250 (p=.218)	0.005 (p=0.996)

[a] Not all participants consumed a snack
[b] Independent t-test with significant *P*-value < 0.05 (2-tailed)

Table 3 shows the repeated measures ANOVA using intent-to-treat principles with simple imputation to compare snack scores, HEI-2015 scores, and weight between control and app groups. Participants in the app group significantly increased snack score at week 4 ($P<0.001$) and week 8 ($P=0.015$) compared to the control group. Similarly, participants in the app group significantly increased HEI-2015 total score ($P<0.001$) at 4-week compared to the control group. There was no significant difference of weight between control and app groups during the 12-week study period, but the app group tended to decrease in weight at week 4 and week 12 more than the control group did.

Table 3. Comparison of snack score, HEI-2015 score, and weight between control and app groups at baseline, week 4, 8, and 12 using intent-to-treat principles with simple imputation (N = 139)

Variable	Time	Control (N = 72) Mean (SD)[b]	App (N = 67) Mean (SD)[b]	F	*P*-value
Snack score[a]	Baseline	6.7 (2.0)	6.6 (1.9)	0.045	0.832
	Week 4	5.9 (1.4)	7.3 (1.4)	17.127	<0.001*
	Week 8	6.0 (1.3)	6.7 (1.4)	6.192	0.015*
	Week 12	6.8 (2.0)	7.1 (1.7)	0.704	0.404
HEI-2015 total score	Baseline	53.8 (12.9)	55.9 (11.2)	1.122	0.291
	Week 4	51.8 (8.8)	59.2 (9.5)	22.312	<0.001*
	Week 8	50.2 (7.8)	51.3 (8.4)	0.659	0.418
	Week 12	52.9 (10.7)	55.5 (12.0)	1.833	0.178
Weight	Baseline	83.0 (1.6)	81.2 (1.6)	2.461	0.119
	Week 4	80.2 (1.6)	76.4 (1.6)		
	Week 8	77.5 (1.6)	75.9 (1.6)		
	Week 12	82.7 (1.6)	78.1 (1.6)		

[a]Not all participants consumed a snack so snack score was analyzed from 40 participants in the control group and 42 participants in the app group at baseline week 4, 8, and 12.
[b]Snack score and HEI-2015 total score used repeated measure ANOVA was reported by mean and standard deviation. Weight used mixed model repeated measure ANOVA was reported by mean and standard error.
[*]*P*-value < 0.05 considered significant (2-tailed).

Table 4 shows the repeated measures ANOVA using intent-to-treat principles with simple imputation to compare each HEI-2015 component score between control and app groups. Participants in the app group significantly increased component scores for total vegetables (*P*=0.001), fatty acids (*P*=0.003), refined grain (*P*=0.019), sodium (*P*=0.025), and saturated fats (*P*<0.001) at 4-week compared to the control group. When these analyses are done without imputation, no significant results are detected for any of the outcomes (data not shown).

Table 4. Comparison of HEI-2015 component scores between control and app groups at baseline, week 4, 8, and 12 using intent-to-treat principles with simple imputation (N = 139)

Variable	Time	Control (N = 72) Mean (SD)[a]	App (N = 67) Mean (SD)[a]	F	*P*-value
HEI-2015 total vegetables	Baseline	3.4 (1.6)	3.3 (1.4)	0.187	0.666
	Week 4	3.2 (1.3)	3.8 (0.9)	10.684	0.001*
	Week 8	2.8 (1.1)	3.3 (1.0)	5.936	0.016*
	Week 12	3.4 (1.2)	3.2 (1.3)	0.632	0.428
HEI-2015 greens and beans	Baseline	2.9 (0.3)	2.5 (0.3)	0.170	0.681
	Week 4	2.2 (0.2)	2.9 (0.2)		
	Week 8	1.9 (0.2)	1.5 (0.2)		
	Week 12	2.9 (0.2)	2.7 (0.2)		
HEI-2015 total fruits	Baseline	2.2 (0.2)	2.3 (0.2)	3.492	0.064
	Week 4	1.5 (0.2)	2.2 (0.2)		
	Week 8	1.7 (0.1)	1.8 (0.1)		
	Week 12	1.9 (0.2)	2.2 (0.2)		
HEI-2015 whole fruits	Baseline	2.5 (0.3)	2.8 (0.3)	2.662	0.105
	Week 4	1.8 (0.2)	2.2 (0.2)		
	Week 8	2.1 (0.2)	2.2 (0.2)		
	Week 12	2.1 (0.2)	2.5 (0.2)		
HEI-2015 whole grains	Baseline	3.1 (0.4)	3.2 (0.4)	1.592	0.209
	Week 4	2.9 (0.3)	3.0 (0.3)		
	Week 8	2.2 (0.2)	2.8 (0.2)		
	Week 12	2.7 (0.3)	3.3 (0.3)		
HEI-2015 dairy	Baseline	5.5 (0.3)	4.7 (0.3)	6.927	0.009*
	Week 4	4.9 (0.3)	4.7 (0.3)		
	Week 8	5.2 (0.2)	4.2 (0.2)		
	Week 12	5.5 (0.3)	5.0 (0.3)		
HEI-2015 total protein foods	Baseline	4.5 (0.1)	4.5 (0.1)	0.089	0.766
	Week 4	4.5 (0.1)	4.5 (0.1)		
	Week 8	4.2 (0.1)	4.2 (0.1)		
	Week 12	4.8 (0.1)	4.7 (0.1)		
HEI-2015 seafood & plant proteins	Baseline	3.1 (0.2)	3.4 (0.2)	3.181	0.077
	Week 4	2.7 (0.2)	3.5 (0.2)		
	Week 8	1.9 (0.2)	1.7 (0.2)		
	Week 12	3.2 (0.2)	3.5 (0.2)		
HEI-2015 fatty acids	Baseline	4.7 (0.4)	5.6 (0.4)	9.334	0.003*
	Week 4	4.9 (0.3)	6.0 (0.3)		
	Week 8	5.9 (0.3)	6.1 (0.3)		
	Week 12	5.0 (0.3)	5.8 (0.4)		
	Baseline	5.8 (3.6)	6.0 (3.0)	0.189	0.665

Variable	Time	Control (N = 72) Mean (SD)[a]	App (N = 67) Mean (SD)[a]	F	*P*-value
HEI-2015 refined grains	Week 4	6.2 (2.8)	7.3 (2.3)	5.666	0.019*
	Week 8	5.7 (2.4)	6.4 (2.3)	2.451	0.120
	Week 12	5.7 (3.2)	5.4 (3.2)	0.340	0.561
HEI-2015 sodium	Baseline	3.4 (0.4)	3.8 (0.4)	5.126	0.025*
	Week 4	3.5 (0.3)	4.5 (0.3)		
	Week 8	2.6 (0.3)	2.5 (0.3)		
	Week 12	2.0 (0.2)	3.1 (0.3)		
HEI-2015 saturated fats	Baseline	4.7 (0.4)	5.9 (0.4)	5.667	0.019*
	Week 4	5.4 (0.3)	5.9 (0.3)		
	Week 8	5.8 (0.3)	6.4 (0.3)		
	Week 12	4.9 (0.4)	5.2 (0.4)		
HEI-2015 added sugars	Baseline	8.2 (0.3)	8.1 (0.3)	0.668	0.415
	Week 4	8.2 (0.2)	8.8 (0.2)		
	Week 8	8.2 (0.2)	8.2 (0.2)		
	Week 12	8.9 (0.2)	8.9 (0.2)		

[a]HEI-2015 total vegetables, and refined grains used repeated measures ANOVA was reported by mean and standard deviation. HEI-2015 greens and beans, total fruits, whole fruits, whole grains, dairy, total protein foods, seafood & plant proteins, fatty acids, refined grains, sodium, saturated fats, and added sugars used mixed model repeated measures ANOVA was reported by mean and standard error.
[*]*P*-value < 0.05 considered significant (2-tailed).

Frequency of app use among participants randomized to the app group declined over time as shown in Figure 2. The mean (SD) app usage frequency was 11.5 (13.2) times at week 4, 6.3 (10.8) times at week 8, and 2.9 (4.8) times at week 12. A total of 65.7% of participants used the app during the first 4 weeks of the study and it significantly decreased to 38.8% at week 8 ($P<0.001$) and to 34.3% at week 12 ($P=0.008$). Of the 67 participants in the app group, only 21 participants (31.3%) used the app at least one time every 4 weeks from baseline until the end of the study.

Figure 2. Mean app usage frequency in participants randomized to the app group (N = 44)

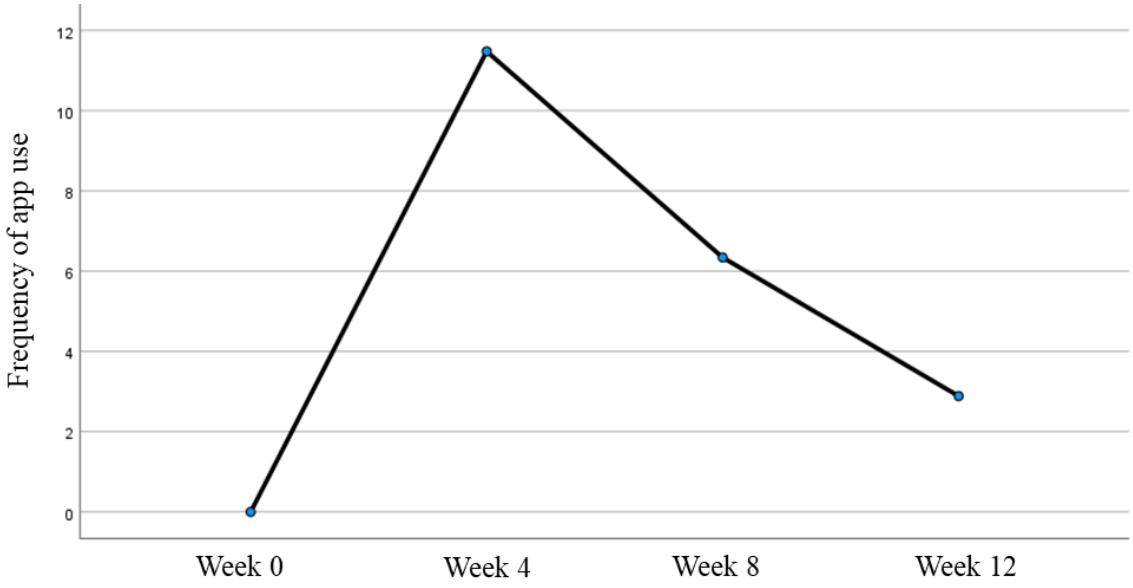

Table 5 shows the correlation between the app usage frequency with snack score, with HEI-2015 total score, and weight. No significant correlations were detected between app usage frequency and the outcomes.

In addition, durign the study, the Snackability app had technical issues due to technical issue of the Expo app for 3-4 weeks. These issues occurred when most participants were in the middle or towards the end of the study. Out of 44 participants who used the app during the 12-week study period, 63.6% (28 participants) experienced app broken while 36.4% (16 participants) experienced no app broken. The snack scores of participants that experienced app broken were not significantly different from participants that experienced no app broken at week 4 (P=0.631), week 8 (P=0.110), and week 12 (P=0.954).

Table 5. Correlations between frequency of app usage and snack score, with HEI-2015 total score, and weight[a]

	App usage (times) at week 4	App usage (times) at week 8	App usage (times) at week 12
Snack score	r =-0.149; p = 0.254	r = 0.099; p = 0.358	r = 0.050; p = 0.404
HEI-2015 total score	r = 0.157; p = 0.227	r = 0.198; p = 0.176	r = 0.003; p = 0.494
Weight	r = 0.170; p = 0.224	r = 0.048; p = 0.418	r =-0.035; p = 0.420

[a] Include participants that used the app at least one time (significance at 2 tailed *P*-value < 0.05)

Discussion

The present study showed that the quality of snack intake and the total diet quality significantly improved at week 4 among overweight and obese college students randomized to the app group compared to the control group in a RCT. The HEI-2015 component scores for total vegetables, fatty acids, saturated fats, refined grains, and sodium significantly increased in the app compared to the controls at week 4. At week 8 and week 12, the quality of snack intake and the diet quality were not significantly different between groups. This is also consistent with the app usage frequency, which significantly dropped after week 4.

Other studies using mobile applications have also seen improvements in diet. For example, the study testing the SCT-based Vegethon mobile app intervention found a significant increase of one serving of vegetable intake after 5 weeks using the app in overweight adults as compared to the control group.[22] However, the study testing the Snack Track School app, which incorporating reflective and rewarding strategies in the app, found that adolescents randomized to the app group for 4 weeks had no significant improvements in healthy snack ratio as compared to the control group.[23] They also

reported that only 20.5% were still using the app at the end of the study. Another app study called “Balance It” in overweight students ages 15-21 years found no significant improvements in diet or physical activity in the app group compared to the control group.[36] However, they found that those with very high app usage had a significant decrease in snack intake and significant increase in physical activity. Another study of web-based game called Creature 101 implemented within the school curriculum reported that intervention group significantly decreased intake of sugar-sweetened beverages and processed snacks as compared to the control group.[37] Unlike the Snackability app, these apps did not provide the snack score based on the guidelines for healthy snacks, score feedback, and self-monitoring with mean daily score graph and consumed snack history. The snack score and feedback message helped participants identify if a snack was healthy or not at the moment of choosing the snack. The Snackability app may influence participants to choose healthier snack choices. If participants decided to choose healthier snacks, the app also provided reporting features and gamification features which helped motivate and facilate participants to set goal and keep track of their snack intake over time and then improved the quality of snack intake resulting in better diet quality.

In the present study, we observed a significant decline in the app usage from week 4 (64%) to week 8 (39%) and week 12 (34%). This decline may explain the loss of significant effects of the app on the snack and diet quality beyond week 4. Several studies have also shown that health-related mobile apps have a 30-day threshold use,[38–40] similar to what was observed in the present study. Another study testing the Lose It! mobile app found that users (n = 1,011,008) were engaged with the app for 29 days.[39] Similarly, the popular smartphone app, MyFitnessPal, received high satisfaction with the app but the

logins dropped sharply after the first month.[40] The adherence rate in several studies testing mobile apps was about 50% and they all showed a gradual decline with time.[40–44] Despite this expected decline in app usage after 30 days, the Snackability app had technical issues due to technical issue of the Expo app for 3-4 weeks. These issues occurred when most participants were in the middle or towards the end of the study. However, within the app group, there was no significant effect of the app broken on the snack scores as compared to participants with no experience of the app broken at week 4, 8, and 12.

To increase app engagement, many apps have several behavior change techniques integrated. These include goal setting, feedback and self-monitoring, shaping knowledge (information), and social support, all of which have shown positive outcomes on individual and group-based interventions.[21,22,24,37,42,45–51] The Snackability app had some of these components integrated, such as the information on the total score for each snack and the breakdown score, the feedback about how healthy the snack is, the gamification features as self-motivation (level up and achievement gained), and reporting features as goal-setting and self-monitoring (mean daily score and consumed snack history). Furthermore, the app integrates types of snacks and portion size consumed contributing to different quantity of energy and nutrient, first ingredient, and level of food processing. All of these features may have had an impact on improving snack quality and total diet quality observed in the present study among those randomized to the app in the first 4 weeks of the study. In spite all these features, app engagement still declined after 4 weeks, similar to what has been documented in the other studies using mobile apps.

Interventions using mobile apps that have been incorporated within a multicomponent intervention have detected significant improvements in health outcomes.[47,52] For example, the study testing the FoodWiz2 app in 34 adolescents ages 16-19 years and study testing the TXT2BFiT app in 214 young adults with a high risk of weight gain were incorporated within multicomponent interventions, including personalized messages and coaching calls.[45,50] Participants using the FoodWiz2 app had a significant increase in the intake of fruits and a reduction in the intake of chocolates and fizzy drinks.[45] Participants using the TXT2BFiT app had a significant reduction in body weight, sugar-sweetened beverages intake, and energy-dense meals, and a significant increase in vegetable consumption at 12 weeks, particularly among those with high adherence.[50] The present study also incorporated automatic weekly text messages and personalize emails to remind participants to use the app, which could have also helped in the app engagement.

Body weight changes of participants in the app group were not significantly different compared to the control group. This stand-alone app may not be sufficient to result in a significant weight loss. Because there are several factors influencing body weight, such as genetic, eating habit, physical activity, sleep, and family habits and culture,[5,53] a multi-component intervention may be needed to have a significant impact on weight. Most studies using weight loss apps have in fact incorporated multicomponent interventions, such as including a prescribed diet, diet and exercise goals, and communication with a health care professional to result in significant weight loss.[54,55]

To the best of our knowledge, this is the first study to test the efficacy of a stand-alone mobile app for improving snack quality and diet quality. The Snackability app

significantly improved the snack quality probably by increasing the consumption of healthy snacks, such as vegetables and other snacks low in saturated fats, refined grains, and sodium as these components scores significantly improved at week 4, as well as the total score of diet quality. Other studies have also shown that increasing the consumption of fruits, vegetables, whole grains, nuts, and yogurt improves the diet quality.[6,9,13,14,56-62] Interventions focusing on the inherent benefits of the target behavior change, such as improving the quality of snack intake and diet quality may result in more sustained behavior change and improving health outcome in the long-term. Future studies for the app intervention should investigate and understand more about the factors and determinants of app intervention to improve the app engagement and retention rate.[39,47,63] Further exploration of the app database may be helpful to understand the app user's behavior. Also, studies suggested that personal support with the app and tailored or personalized incentives matched with user preference or social support should be considered to increase the adherence which would probably improve outcomes even more.[21,39,42,45,46,50,64] However, too many notifications, complexity of the app, or overwhelming the app users may be the reason for the low compliance for most apps.

Among the strengths of this study were that the app was developed based on the SCT and USDA guidelines and tested using a RCT design, the gold standard to test the effectiveness of interventions. The diet quality was assessed using HEI-2015 from at least two 24-h dietary recalls, which allowed participants to enter details of the snacks and meals consumed. Furthermore, the study included a diverse sample of students from different colleges in the US. One of the limitations was that the present study included only college students with overweight and obesity which cannot be generalize to other

groups. The study was conducted during the COVID-19 pandemic, which may had led to the low retention rate, especially at week 8 but researchers were able to contact existing participants back again to complete the study at week 12. Under reporting in the 24-h recalls could have affected the results, as this is greater in overweight and obese individuals.[65,66] Eventhough most participants encountered the interruption of the app for 3-4 weeks due to technical issues with the Expo app, there was no significant effect on the snack score. Future studies should consider changing from a regular mobile app to a web-based app to avoid issues with the platform in which apps are embedded. In general terms, a mobile app is built for a specific platform, whether iOS or Android, and requires downloading and installing on the phone to use even without an internet connection. Web-based apps require an internet connection when used but they do not require data to be downloaded or installed on the phone. It operates directly from the internet browser and are easier to update and maintain for researchers/developers.

Conclusions

The Snackability app can be a tool to help college students select healthy snack to improve the snack quality and the overall diet quality in short-term. However, future studies should consider increasing the app compliance by incorporating a multicomponent intervention, such as personal support, social support, and tailored or personalized incentives to match with the user preference of college students. Also, larger sample size and longer studies are needed to achieve more definitive conclusions.

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CHAPTER V

EFFECT OF USING THE SNACKABILITY APP TO PROMOTE HEALTHY SNACKING BEHAVIOR IN US COLLEGE STUDENTS: A RANDOMIZED CONTROLLED TRIAL

Introduction

The prevalence of overweight and obesity has become a major public health concern in the United States (US), particularly among college students, with more than one-third (~35%) considered overweight and obese in 2021.[1] College students are susceptible to weight gain and have difficulties in making healthy food choices, due to the increased independency, stress, expense, and time constraints of college life in addition to high availability of healthy foods and snacks on many college campuses.[2–4] At the same time, snack intake has increased recently.[5] According to National Health and Nutrition Examination Survey (NHANES) 2017-2018, 95% of Americans age 20 years and over consumed snacks on a daily basis,[6] and this is even higher among college students with 98% consuming snacks daily at a frequency of about 4 times per day.[7] In addition, it is well documented that most snacks consumed by college students are energy-dense and nutrient-poor leading to lower diet quality and weight gain.[8–12]

Among college students, it is important to understand motivators of and barriers to eating healthy foods and snacks. Motivators of eating healthy foods and snacks include nutrition knowledge, parental influence, campus environment, social media, health benefits, and weight management.[2,3,13–15] On the other hand, barriers include lack of nutrition knowledge and motivation, poor taste of healthy foods and snacks, time

management, peer and parental influence, unsupportive campus environment, limited finance, and high cost of healthy food options.[2,3,13–15] Therefore, interventions are needed to improve snacking behaviors resulting in healthier snack and diet quality and this could eventually lead to weight loss among college students with overweight and obesity.

Although there are several interventions developed for improving snacking behavior,[16–28] most have been developed to influence snack choice at the point of purchase in vending machines, such as reducing the price of healthier items, classifying all vending items with traffic light system, providing nutritional information of the snacks with various levels of success. However, to our knowledge, none have used a mobile app for improving snacking behavior. Mobile apps have been shown to be successful in improving dietary behaviors in various populations, including college students.[29–40]

The Snackability smartphone app was developed by researchers at Florida International University as a tool to help students choose healthy snacks.[41] It was developed based on the Social Cognitive Theory (SCT) for behavior change[42–44] and the USDA Smart Snack Guidelines[45] in which each snack was scored ranging from -1 to 11 points (the higher score the more compliant to the guidelines and therefore the healthier the snack is). The SCT focuses on individuals that play an active role in their health by translating motivation into action by using the app to help select healthier snack choices and reinforcing adherence to the app through self-efficacy, goal setting, self-monitoring, and self-regulation.[42–44] According to the literature, integration of constructs in the behavior change theory into intervention strategies could be an effective way to facilitate behavior changes and improve health outcomes.[29,30] In addition, few studies report on the app evaluation including feasibility, acceptability, usability, and satisfaction. The app

evaluation helps understand the effectiveness of the app intervention and possible underlying factors that might explain why the intervention succeeded or failed in effecting change in outcomes.[46,47]

This study aimed to determine whether the Snackability app facilitated behavior change by increasing the motivators and reducing the barriers to eat healthy foods and snacks among overweight and obese college students in a two-arm, 12-week randomized controlled trial (RCT). It was hypothesized that when college students used the app over time, the app would promote healthy snacking behaviors by increasing motivators and reducing barriers to eating healthy foods and snacks. The secondary purpose of this study was to evaluate the feasibility, usability, satisfaction, acceptability of the app intervention. It was hypothesized that the app would be considered feasible, usable, satisfactory, and acceptable by 50% or more of the participants.

Methods

Study design

The study was a two-arm, 12-week RCT to determine the effects of using the Snackability app for improving snack behaviors among overweight and obese college students (NCT05302830). Participants were recruited from various US colleges and the trial was conducted completely online from June 2020 to June 2021 due to the COVID-19 pandemic. The study was approved by the Institutional Review Board at Florida International University (FIU; approval number IRB-20-0275). Written informed consent was obtained from all participants prior to study commencement.

Participants and eligibility

Overweight or obese college students (BMI ≥ 25 kg/m^2) were eligible to participate if they were ages 18-24 years, owned a smartphone with Android or iOS platforms, had access to an internet connection to use the app, from non-nutrition majors, and were willing to participate in a clinical trial for 3 months. Participants were excluded if they were currently enrolled in a weight loss and/or nutrition program, were taking any medications known to influence weight, and were pregnant or breastfeeding.

Recruitment, screening process, and randomization

Participant recruitment was done by email, webpage, and social media. The electronic flyer was sent via email to faculty and staff in several universities for them to distribute it to their students. Also, the flyer was posted on the Snackability webpage and in social media (Facebook and Instagram). Interested students clicked on the link in the flyer that led them to the screening form. Each eligibility criteria were automatically assessed in a step-wise progression; if they met all the criteria, then they were automatically led to the online consent form. Once participants signed the informed consent, they automatically proceeded with the baseline questionnaires. Then, participants were randomized using a simple computerized randomization scheme assigned to either the control or app intervention using a 1:1 ratio. The researcher who collected and analyzed the data was blinded to the study allocation throughout the study period.

Participants who were randomized to the intervention group received an end-user license agreement (EULA), the instructions to download and register with the Snackability app, and the instruction on how to use the app every time they had a snack.

Participants who were randomized to the control group received a 1-page healthy snack information and access to the app at the end of the 12-week study period.

Intervention

The theory-based Snackability smartphone app[41] was developed by researchers at Florida International University. The details of the development have been published elsewhere[41]. Briefly, the development of the app was based on the USDA Smart Snack Guideline[45]. According to this guideline, a healthy snack must have the first ingredient as a whole grain, fruit, vegetable, dairy, or protein food and meet the nutrient standards for calories, calories from fat, fats, sugar, and sodium. The app allowed participants to search for a snack (scan barcode or type snack name), add a portion size, and then the app provided a snack score and the breakdown scores with a specific feedback message about the snack.[41] The scores ranged from -1 to 11 points, in which a higher score was more compliant to the USDA guideline and therefore a healthier snack. Participants could also specify if they had an allergy; if so, the app would alert the participants when they chose a snack that contained the selected allergic ingredient.

The app incorporated behavior change techniques related to the constructs of the SCT to facilitate snacking behavior change, such as observational learning, outcome expectation, self-efficacy, goal setting, feedback on performance, self-motivation through rewarding, self-monitoring, and self-regulation. The SCT focuses on individuals that play an active role in their health by translating motivation into action by using the app to help select healthier snack choices and reinforcing adherence to the app through self-efficacy, goal setting, self-monitoring, and self-regulation.[42–44] The SCT also emphasizes on the dynamic interplay between individuals and the environment which mutually influence

each other. College students use the app to help identify and select healthy snacks. Then, if they have healthier snacks around them, they are more likely to eat these snacks. When students select and consume healthy snacks more than unhealthy snacks (energy-dense and nutrient-poor snacks) over time, food environment including home, campus stores, snack bar, and vending machines will have healthy snack choices more available and accessible for them. The focus was that participants used the Snackability app to help increase the motivation of and decrease the barriers to selecting and eating healthier snack choices which resulted in improving snack and diet quality and eventual weight loss.

The app was a trial version that was not accessible through the App store or Google Play; it was only accessible through the EXPO app (https://expo.dev), an open-source platform for testing any type of app (for Android or iOS). The link and the username for this app was shared privately with each participant randomized to the app group only; therefore, no one else had access to this app. After participants were randomized to the app group, they started to receive automated text messages once a week to remind them to use the app during the study. The messages were alternated with tips of how to use the app and on how to search for the snacks. In addition, if participants were not using the app, a research staff would send them an email reminding them to use the app.

Outcome measures

The study assessments were done online for all participants as described below.

1. Socio-demographic questionnaire (completed at baseline via Qulatrics): included questions about age (in years), gender (male or female), race/ethnicity (White,

Hispanic or Latino, Black or African American, Asian, Other/multiracial), household income (<$50,000, $50,000-$75,000, $75,000-$100,000, or >$100,000), food security status (high, low, or very low) using the six-item short form of U.S household food security survey module,[48] and stress level using the validated stressometer (0; no stress to 10; extreme stress).[49]

2. Body weight measures (completed at baseline and 12 weeks): Body weight was reported by participants using a standardized protocol with written and video instructions to measure it at home. Participants were instructed to perform the measurements in the morning, after voiding and before eating or drinking, wearing only light underclothing and barefoot, and to place the scale on a hard and flat surface floor. Before weighing, participants were asked to calibrate the scale following the instructions shown in the video. Participant reported their weight with 1 decimal in kg or pounds (lb) in duplicate and height was self-reported in inches. Body mass index was calculated by transforming the weight from pounds to kg and the height to cm and using the following equation: BMI = kg/m^2.
3. Motivators of and Barriers to Healthy Foods and Snacks-Adult: This was a reliable and valid questionnaire using the Adult Form as part of the Motivators of and Barriers to Health Smart Behaviors Inventory (MB-HSBI).[50]. The motivators scale of the questionnaire consisted of 20 items categorized into 5 subscales including routine, availability, health benefits, medical issues, and convenience. The barriers scale consisted of 15 items categorized into 3 subscales including negative attitude, availability, and self-control. The rate level of agreement of each item listed was assessed with a 4-point Likert-type scale ranging from strongly disagree (1 point) to

strongly agree (4 points). All points were added; the higher the points, the higher the motivators of eating healthy foods and snacks. For the barriers, the higher the points, the higher the barriers to eating healthy foods and snacks.

4. App usability, feasibility, acceptability, and satisfaction (completed at 12 weeks): This questionnaire asked about the usability, feasibility, acceptability, and satisfaction with the app using a 5-point Likert scale, ranging from strongly disagree (1 point) to strongly agree (5 points) and Yes/No questions. This questionnaire also included the five questions about perceived changes in using the Snackability app using a 5-point Likert scale.
5. Frequency of app use: The frequency of app use was retrieved from the app Firebase website, which showed each time the app was used by participants throughout the study.
6. Diet and snack quality: This was assessed from three non-consecutive 24-h dietary recalls (two during weekdays and one during the weekend) collected and analyzed by the Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool, version 2020, developed by the National Cancer Institute (NCI).[20] Participants received the quick start guides for 24-hour recalls from ASA24 via email to help them complete this. The first recall was done together via phone or Zoom call; during this call, participants were instructed to enter snacks as referred to foods consumed between meals. Energy and nutrient (protein, total fat, carbohydrate, total sugars, sodium, and total saturated fatty acids) intake from overall diet and snacks was obtained from ASA24 output and the data was averaged from the three recalls.

- For the overall diet quality, the Healthy Eating Index (HEI)-2015 total score was calculated by the simple HEI scoring algorithm method.[21,22] The HEI-2015 total score consists of the sum of 13 components: 9 adequacy components (total vegetables, greens and beans, total fruits, whole fruits, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and 4 moderation components (refined grains, sodium, saturated fats, and added sugars). The HEI-2015 total score ranges from 0 to 100, in which a higher score is a better diet quality and more consistent with the Dietary Guidelines for Americans (DGA) 2015-2020.[23] The score for the individual components was also calculated.
- For the snack quality score, the output from ASA24 was used to identify the type, number, and serving size of snacks consumed. Then, the score was calculated using the algorithm developed for the Snackability app,[18] which was based on the USDA Smart Snack Guideline.[19] Briefly, this score takes into account the first ingredient, the nutrient standard by portion size, and the processing of foods for a score ranging from -1 to 11 points. The higher the score, the healthier the snack is and more compliant to the guideline. The snack scores were calculated as an average score for each participant.

Statistical analyses

For descriptive statistics, mean and standard deviation were used for continuous variables and frequency and percentage for categorical variables. The socio-demographic characteristics were compared between the two groups at baseline using two samples t-test for continuous variables and chi-square test for categorical variables.

The intent-to-treat principle was used to compare mean changes in the motivator and barrier subscales from baseline to 12 weeks between study groups. Analyses were also done using simple imputation for missing data. Comparison of mean change between the two groups was used two samples t-test. Stepwise regression analysis was used to determine if change in subscale scores of motivators and barriers impacted on change in outcomes within the app group.

For the app usability, feasibility, acceptability, and satisfaction questionnaire, the app was considered usable, feasible, satisfactory, and acceptable if 50% or more of the participants answered as 'strongly agreed'/'agreed' or 'Yes' using one-sample binomial tests. Spearman's rho correlation coefficient was used to correlate app feasibility, acceptability, and satisfaction and perceived changes in eating healthy snacks with frequency of app use. Stepwise regression analysis was used to determine if app feasibility, acceptability, satisfaction, frequency of app use, and perceived change in eating healthy snacks impacted on the outcomes. All reported P-values were two-tailed, and P-values < 0.05 were considered statistically significant. Statistical analysis was performed using SPSS Statistics software (version 28, IBM, New York).

Results

Of the 262 who agreed to participate in the study, 142 participants completed all baseline requirements and were randomized to the control or app intervention groups (Table 1 and Figure 1). Three participants (2 in the control group and 1 in the app group) were excluded based on reported energy intake outside the accepted range. Thus, the imputed analysis was 72 participants in the control group and 67 participants in the app

group. In the control group, a total of 34 (47.2%) participants completed the follow-up at week 4, 28 (38.9%) at week 8, and 56 (77.8%) at week 12. In the app group, 32 (47.8%) participants completed the follow-up at week 4, 27 (40.3%) at week 8, and 45 (67.2%) at week 12. In both groups, the main reason for not completing the follow ups was that participants did not complete at least two 24-h dietary recalls.

There were no significant differences in baseline characteristics between the control and app groups (Table 1). Overall, mean (SD) age was 21.1 (1.7) years with the majority of female (84.6%), Hispanic (30.9%), students from universities in Florida (81.3%), household income less than $50,000 (51.1%), having a high food security (71.2%). Mean (SD) stress level and BMI were 6.9 (1.7) considered "medium level" and 30.4 (5.6) kg/m^2. The socio-demographics were similar between those completed the study (n=106) and those lost to follow-up (n=33) (data not shown).

Table 1. Baseline characteristics of the randomized participants (N = 139)

Characteristics	**All (N = 139)**	**Control (N = 72)**	**App (N = 67)**	***P*-value**
Age in years, mean (SD)	21.1 (1.7)	21.0 (1.6)	21.3 (1.8)	0.285
Female, n (%)	77 (84.6)	63 (87.5)	57 (85.1)	0.677
Race/Ethnicity, n (%)				
White	41 (29.5)	22 (30.6)	19 (28.4)	0.156
Hispanic or Latino	43 (30.9)	21 (29.2)	22 (32.8)	
Black or African American	15 (10.8)	8 (11.1)	7 (10.4)	
Asian	15 (10.8)	4 (5.6)	11 (16.4)	
Other/multiracial	25 (18.0)	17 (23.6)	8 (11.9)	
State, n (%)				
FL	113 (81.3)	60 (83.3)	53 (79.1)	0.523
Others (KY, LS, SC, TX)	26 (18.7)	12 (16.7)	14 (20.9)	

Characteristics	All (N = 139)	Control (N = 72)	App (N = 67)	*P*-value
Household income, n (%)				
<$50,000	71 (51.1)	36 (50)	35 (52.2)	0.570
$50,000-$75,000	25 (18)	16 (22.2)	9 (13.4)	
$75,000-$100,000	17 (12.2)	8 (11.1)	9 (13.4)	
>$100,000	26 (18.7)	12 (16.7)	14 (20.9)	
Food security, n (%)				
High	99 (71.2)	50 (69.4)	49 (73.1)	0.818
Low	28 (20.1)	16 (22.2)	12 (17.9)	
Very low	12 (8.6)	6 (8.3)	6 (9)	
Stress, mean (SD)	6.9 (1.7)	6.8 (1.7)	7.0 (1.7)	0.415
BMI (kg/m^2), mean (SD)	30.4 (5.6)	30.8 (5.6)	29.9 (5.7)	0.363

Figure 1. Consort flow diagram of participants in the Snackability trial

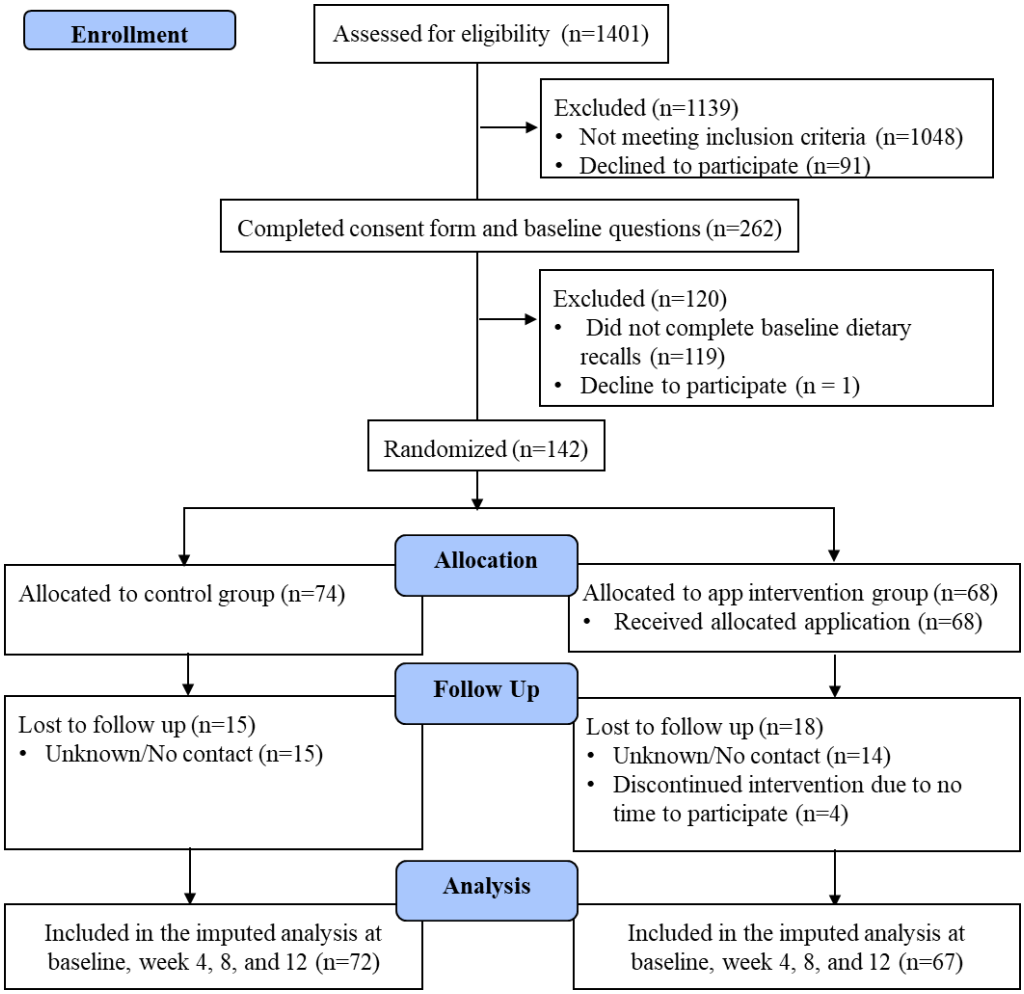

Table 2 shows the motivators to eating healthy foods and snacks at baseline and change from baseline to 12 weeks between groups. There were no significant differences in any of the motivators between the control and app groups at baseline. In the routine subscale, the app group significantly increased the personal goal of eating healthier snacks (P=0.028). In the availability subscale, the app group significantly increased the variety of new fruits and vegetables tried (P=0.056) and had more fruits and vegetables available at home (P=0.003). In the health benefit subscale, the app group significantly increased the motivation of eating healthy foods for maintaining their body in shape (P=0.010) and to be physically active (P=0.045).

Table 3 shows the barriers to healthy foods and snacks intake at baseline and change from baseline to 12-week follow-up between groups. At baseline, the app group had a significantly higher barrier for 1 item in the negative attitude subscale (not paying attention if the meal/food has fruits or vegetables) and for 2 items in the availability subscale (fresh healthy foods are not easily available or easy to find at restaurants) compared to the control group. However, after the 12-week intervention, participants in the app group significantly reduced the barriers in 2 items in the negative attitude subscale (not caring about eating fruits and vegetables every day; P=0.015 and not paying attention if the meal/food has fruits or vegetables; P=0.050) and 1 item in the availability subscale, in which the app group had fresh healthy foods significantly more easily available at home (P=0.007) as compared to the control group.

Table 2. Motivators of healthy foods and snacks intake at baseline and change from baseline to 12-week follow-up between groups using intent-to-treat principles with simple imputation (N = 139)

Item	Group	Baseline			Change from baseline to week 12		
		Mean	SD	*P*-value	Mean	SD	*P*-value
When I eat healthy foods (like fruits, vegetables, and lower-calorie snacks) it is because...							
Routine							
...eating healthy foods is part of my regular routine.	**App**	2.69	0.91	0.680	0.59	0.84	0.134
	Control	2.75	0.90		0.37	0.88	
...I have a personal goal of eating healthier snacks.	**App**	3.54	0.70	0.392	0.08	0.80	0.028*
	Control	3.63	0.49		-0.19	0.60	
...I eat healthy foods every day so that I can be healthy.	**App**	2.70	0.92	0.820	0.57	0.97	0.119
	Control	2.74	0.87		0.33	0.87	
...I have the discipline to eat healthy.	**App**	2.48	0.99	0.514	0.30	0.97	0.158
	Control	2.58	0.92		0.04	1.11	
Availability							
...fruits and vegetables can be easily eaten without being cooked.	**App**	3.16	0.86	0.332	-0.01	0.84	0.757
	Control	3.31	0.85		-0.05	0.88	
...I like the taste of most fruits and vegetables.	**App**	3.27	0.79	0.744	0.12	0.69	0.953
	Control	3.22	0.88		0.11	0.76	
...I like to add variety to what I eat by trying new fruits and vegetables.	**App**	2.88	0.95	0.444	0.44	1.04	0.056
	Control	3.00	0.89		0.12	0.90	
...fruits and vegetables (fresh or frozen) are usually available in my home.	**App**	2.90	0.87	0.075	0.47	0.92	0.003*
	Control	3.17	0.90		0.00	0.89	

Item	Group	Baseline			Change from baseline to week 12		
		Mean	SD	*P*-value	Mean	SD	*P*-value
***Health* Benefits**							
…eating healthy foods and snacks helps me look good.	**App**	3.30	0.74	0.526	0.29	0.83	0.097
	Control	3.38	0.68		0.08	0.69	
…eating healthy foods keeps my body in shape.	**App**	3.31	0.76	0.082	0.37	0.80	0.010*
	Control	3.51	0.58		0.04	0.68	
…someone has taught me why fruits and vegetables are healthy.	**App**	3.27	0.75	0.269	0.14	0.70	0.582
	Control	3.42	0.82		0.07	0.78	
…I think about what could happen if I eat too many unhealthy foods.	**App**	3.25	0.80	0.368	0.18	0.96	0.181
	Control	3.38	0.78		-0.03	0.88	
…eating healthy foods helps me to be physically active.	**App**	3.19	0.86	0.342	0.28	0.90	0.045*
	Control	3.32	0.69		0.00	0.77	
Medical issues							
...I am concerned about preventing high blood pressure.	**App**	2.93	1.08	0.359	0.28	0.96	0.970
	Control	3.08	0.95		0.29	0.92	
...I am concerned about preventing high cholesterol.	**App**	2.96	0.94	0.062	0.16	0.92	0.834
	Control	3.25	0.90		0.12	1.00	
...I am concerned about preventing diabetes.	**App**	3.19	0.99	0.805	0.01	0.93	0.097
	Control	3.15	0.97		0.28	0.96	
...I have a health or medical condition and need to eat healthy because of it.	**App**	1.94	1.11	0.533	0.36	1.18	0.909
	Control	2.06	1.06		0.33	1.17	

Item	Group	Baseline			Change from baseline to week 12		
		Mean	SD	*P*-value	Mean	SD	*P*-value
Convenience							
...I can find healthy snacks that come in handy, small packages.	**App**	2.78	0.90	0.559	0.16	0.98	0.873
	Control	2.86	0.81		0.18	0.85	
...there are healthy options at most restaurants that I go to.	**App**	2.30	0.94	0.079	0.36	0.97	0.971
	Control	2.57	0.87		0.37	1.03	
...healthy snacks come in little packages that help me to not eat too much.	**App**	2.49	0.91	0.437	0.21	1.05	0.469
	Control	2.61	0.88		0.34	1.01	

*P-value < 0.05 considered significant.

Table 3. Barriers to healthy foods and snacks intake at baseline and change from baseline to 12-week follow-up between groups using intent-to-treat principles with simple imputation (N = 139)

Item	Group	Baseline			Change from baseline to week 12		
		Mean	**SD**	***P*-value**	**Mean**	**SD**	***P*-value**
When I do not eat healthy foods (like fruits, vegetables, and low-calorie snacks), it is because...							
Negative Attitude							
...I just do not care about eating fruits and vegetables every day.	**App**	1.84	0.91	0.386	-0.13	0.89	0.015*
	Control	1.71	0.81		0.23	0.85	
...I do not like the taste of most vegetables.	**App**	1.94	0.98	0.764	-0.05	0.91	0.420
	Control	1.89	1.03		0.07	0.85	
...when I go to the grocery store, I do not specifically think about buying fruits or vegetables.	**App**	2.12	0.98	0.456	-0.19	0.90	0.483
	Control	2.00	0.90		-0.08	0.94	
...I just do not care about eating healthy every day.	**App**	1.91	0.95	0.366	-0.09	0.96	0.609
	Control	1.78	0.77		-0.02	0.79	
...when I make or buy a meal, I do not think about whether or not it has fruits or vegetables in it.	**App**	2.43	0.97	0.015*	-0.30	1.20	0.050*
	Control	2.06	0.83		0.08	1.05	
…I do not like to try new fruits or vegetables that I have never had before.	**App**	1.94	1.04	0.817	-0.10	0.97	0.505
	Control	1.90	0.86		0.00	0.79	
…when I think “healthy food,” I think “tastes bad.”	**App**	1.94	0.94	0.567	-0.12	0.84	0.305
	Control	1.85	0.97		0.04	0.96	

Item	Group	Baseline			Change from baseline to week 12		
		Mean	**SD**	***P*-value**	**Mean**	**SD**	***P*-value**
…I do not look or feel any different when I eat healthy.	**App**	1.90	0.86	0.249	0.01	1.05	0.653
	Control	1.74	0.77		0.08	0.78	
Availability							
…fresh healthy foods are not easily available.	**App**	2.58	0.94	0.019*	-0.38	0.90	0.007*
	Control	2.19	0.99		0.08	1.05	
…I cannot get healthy snacks in the snack machines.	**App**	2.87	1.04	0.619	-0.23	1.11	0.155
	Control	2.78	1.04		0.04	1.08	
…healthy foods are not easy to find at restaurants.	**App**	2.81	0.97	0.033*	-0.12	0.86	0.995
	Control	2.47	0.86		-0.12	0.88	
Self-control							
...I get cravings for unhealthy foods.	**App**	3.70	0.52	0.399	-0.18	0.69	0.100
	Control	3.63	0.54		-0.38	0.73	
...I crave sweets or junk food instead of fruit as a snack.	**App**	3.33	0.75	0.244	-0.12	0.80	0.557
	Control	3.17	0.87		-0.21	0.93	
...when someone cooks or gives me unhealthy food, I eat it.	**App**	3.42	0.72	0.893	-0.10	0.70	0.527
	Control	3.40	0.60		-0.18	0.70	
...when there are unhealthy foods at home, it is hard to choose healthy foods.	**App**	3.34	0.71	0.105	-0.21	0.83	0.075
	Control	3.13	0.86		0.06	0.94	

*P-value < 0.05 considered significant.

Table 4. Subscale scores of the motivators of and barriers to eating healthy foods and snacks at baseline and change from baseline to 12-week follow-up between groups using intent-to-treat principles with simple imputation (N = 139)

Subscale	Group	Baseline			Change from baseline to week 12		
		Mean	SD	*P*-value	Mean	SD	*P*-value
Motivators of eating healthy foods and snacks							
Routine	App	2.85	0.66	0.497	0.38	0.66	0.024*
	Control	2.92	0.60		0.14	0.58	
Health benefits	App	3.27	0.52	0.095	0.25	0.55	0.009*
	Control	3.40	0.42		0.04	0.42	
Medical issues	App	2.75	0.82	0.311	0.20	0.73	0.649
	Control	2.89	0.71		0.26	0.71	
Availability	App	3.05	0.56	0.246	0.25	0.54	0.048*
	Control	3.17	0.66		0.06	0.60	
Convenience	App	2.52	0.60	0.106	0.24	0.67	0.571
	Control	2.68	0.54		0.31	0.65	
Barriers to eating healthy foods and snacks							
Negative attitude	App	2.00	0.69	0.201	-0.12	0.65	0.091
	Control	1.86	0.56		0.05	0.55	
Availability	App	2.75	0.74	0.026*	-0.24	0.68	0.038*
	Control	2.48	0.68		0.00	0.70	
Self-control	App	3.45	0.49	0.176	-0.15	0.52	0.863
	Control	3.33	0.53		-0.17	0.55	

*P-value < 0.05 considered significant.

After the 12-week intervention, the app group significantly increased the routine, availability, and health benefits subscales as motivators of eating healthy foods and snacks as shown in table 4. In addition, the app group significantly decreased barriers by realizing that there were less healthy foods and snacks available around them as compared to the control group.

The results in table 5 shows that the availability subscale in barrier scale was a significant predictor for change in the snack score in the app group from baseline to week 12 while there was no significant predictor for change in the HEI-2015 total score as shown in table 6. In table 7, health benefit and medical issue subscales in motivator scale were significant predictors for change in body weight in the app group from baseline to week 12.

Table 5. Stepwise regression analysis results between change in subscale score of healthy food and snack motivators and barriers and change in snack score from baseline to 12-week follow-up within the app group using intent-to-treat principles with simple imputation (N = 67)

Variable	*B*	*SE B*	*β*	*t*	*P*-value[a]
Healthy food and snack motivators					
Routine			-0.008[b]	-0.057	0.955
Availability			0.084[b]	0.596	0.554
Health benefits			0.109[b]	0.779	0.440
Medical issues			-0.171[b]	-1.228	0.226
Convenience			0.010[b]	0.072	0.943
Healthy food and snack barriers					
Negative attitudes			0.065[b]	0.454	0.652
Availability	0.964	0.423	0.319	2.281	0.027*
Self-control			0.106[b]	0.727	0.471

Note: Snack score is dependent variable. **P*-value < 0.05 considered significant.
[a] Predictor in the model: (Constant), Barrier availability
[b] Beta In of excluded variables from the model

Table 6. Stepwise regression analysis results between change in subscale score of healthy food and snack motivators and barriers and change in HEI total score from baseline to 12-week follow-up within the app group using intent-to-treat principles with simple imputation (N = 67)

Variable	*B*	*SE B*	*β*	*t*	*P*-value
Healthy food and snack motivators					
Routine	-1.390	3.667	-0.063	-0.379	0.706
Availability	4.620	3.856	0.170	1.198	0.236
Health benefits	1.475	4.406	0.055	0.335	0.739
Medical issues	1.915	2.723	0.096	0.703	0.485
Convenience	0.725	2.970	0.033	0.244	0.808
Healthy food and snack barriers					
Negative attitudes	0.357	3.339	0.016	0.107	0.915
Availability	3.357	2.919	0.156	1.150	0.255
Self-control	-5.903	3.911	-0.210	-1.510	0.137

Note: HEI total score is dependent variable.

Table 7. Stepwise regression analysis results between change in subscale score of healthy food and snack motivators and barriers and change in body weight from baseline to 12-week follow-up within the app group using intent-to-treat principles with simple imputation (N = 67)

Variable	*B*	*SE B*	*β*	*t*	*P*-value[a]
Healthy food and snack motivators					
Routine			-0.128[b]	-0.923	0.360
Availability			0.092[b]	0.716	0.477
Health benefits	-8.524	2.895	-0.373	-2.944	0.005*
Medical issues	4.868	2.160	0.285	2.254	0.028*
Convenience			0.141[b]	1.213	0.230
Healthy food and snack barriers					
Negative attitudes			0.003[b]	0.019	0.985
Availability			-0.006[b]	-0.055	0.956
Self-control			0.148[b]	1.254	0.214

Note: Body weight is dependent variable. **P*-value < 0.05 considered significant.
[a] Predictors in the model: (Constant), Health benefits, Medical issues
[b] Beta In of excluded variables from the model

Table 8 shows the responses to the feasibility, acceptability, satisfaction, and usability questionnaire for the app at the end of study. Out of 44 participants in the app group that answered the evaluation questionnaire, 19 participants (43.2%) continually used the app at least once every 4 weeks during 12-week study period. Among this group, the feasibility responses ranged from 33.3% (the app was quick) to 73.7% (the app was easy to learn). For acceptability, the responses ranged from 52.6% (felt comfortable using the app) to 94.7% (icon and font used were attractive and recognizable). For satisfaction, the responses ranged from 31.6% (would use the app again) to 42.1% (overall liked the app). For usability, the responses ranged from 36.8% (snack score improved in the past 4 weeks using the app) to 89.5% (snack score was ≥5 in the past 4 weeks).

Table 8. Feasibility, acceptability, satisfaction, and usability of the Snackability app in the app group at the end of study

Questions	All participants in the app group[a] (N=44) N (%)	Participants using the app at least one time every 4 weeks[b] (N=19) N (%)
Feasibility questions		
The app was easy to use	20 (45.5%)	11 (57.9%)
The app was easy to learn	27 (61.4%)	14 (73.7%)
It was easy to find snacks in the app	16 (36.4%)	8 (42.1%)
The app was very quick	11 (25.6%)	6 (33.3%)
The app had all the information I wanted	13 (29.5%)	7 (36.8%)
Acceptability questions		
The icon and font used were attractive and recognizable	32 (72.7%)	18 (94.7%)
I felt very comfortable using the app	20 (45.5%)	10 (52.6%)
I liked the layout of the app	25 (56.8%)	14 (73.7%)
I liked the screen of the app	28 (63.6%)	15 (78.9%)
Satisfaction questions		
I would use this app again	14 (31.8%)	6 (31.6%)
Overall, I liked the App	17 (38.6%)	8 (42.1%)
Usability questions		
Used the app when snacking in the past 4 weeks	20 (45.5%)[c]	13 (68.4%)
Snack score ≥5 in the past 4 weeks	28 (63.6%)	17 (89.5%)
Snack score improved in past 4 weeks with the app	11 (25.0%)	7 (36.8%)
App helped choose healthier snacks	14 (31.8%)	11 (57.9%)

[a]All participants in the app group who completed the app evaluation questionnaire at week 12

[b]Based on the app usage from the Firebase web analytics of the app

Table 9 shows the evaluation of feasibility, acceptability, satisfaction, and usability using the binomial test. Among all participants in the app group at the end of the study, only acceptability (70.5%) was significantly greater than 50% (P<0.05). When evaluating the app among participants that used the app at least one time in every 4

weeks, only acceptability (89.5%) and usability (94.7%) were significantly greater than 50% ($P<0.05$).

Table 9. Evaluation of feasibility, acceptability, satisfaction, and usability of the Snackability app in the app group at the end of trial

App evaluation	All participants in the app group (N=44)		Participants using the app at least one time in every 4 weeks (N=19)	
	N (%)	*P*-value	N (%)	*P*-value
Feasibility (≥50%)	18 (40.9%)	0.178	11 (57.9%)	0.293
Acceptability (≥50%)	31 (70.5%)	0.008*	17 (89.5%)	<0.001*
Satisfaction (≥50%)	18 (40.9%)	0.178	8 (42.1%)	0.356
Usability (≥50%)	26 (59.1%)	0.178	18 (94.7%)	<0.001*

One-sample binomial test was performed to test each hypothesis.
*P < 0.05 considered significant.

At week 12, the frequency of app use had no significant correlation with the app feasibility, acceptability, and satisfaction while the frequency of the app use significantly correlated with perceived changes in using the app, including increased knowledge (P=0.010), actual goal setting (P=0.038), and consistency (P=0.020) in eating healthy snacks (Table 10). In table 11, stepwise regression results present that the app acceptability and increased self-monitoring of eating healthy snacks from using the app over time significantly impacted on the snack score at week 12. However, the app evaluation, the frequency of app use, and perceived changes in using the app were not significant predictors on HEI-2015 total score and body weight at week 12.

Table 10. Correlation results between frequency of app use and app evaluation and perceived changes in using the Snackability app within the app group at week 12

Variables	Frequency of app use	
	Spearman correlation	P-value
App evaluation		
App feasibility	0.093	0.453
App acceptability	0.181	0.142
App satisfaction	-0.134	0.279
Perceived changes in using the Snackability app		
Increased knowledge of choosing and eating healthy snacks	0.313	0.010*
Increased actual goal setting to eat healthy snacks	0.254	0.038*
Increased consistency in eating healthy snacks	0.283	0.020*
Increased self-monitoring of eating healthy snacks	0.148	0.231
Improved snacking behavior change	0.179	0.147

*P-value < 0.05 considered significant.

Table 11. Stepwise regression results of app evaluation, frequency of app use, and perceived changes in using the Snackability app on snack score within the app group at week 12

Variable	B	SE B	β	t	P-value
App evaluation					
App feasibility			-0.419b	-1.632	0.112
App acceptability	0.684	0.308	0.361	2.221	0.033*
App satisfaction			-0.161b	-0.641	0.526
Frequency of app use			0.102b	0.616	0.542
Perceived changes in using the Snackability app					
Increased knowledge of choosing and eating healthy snacks			-0.234b	-0.508	0.617
Increased actual goal setting to eat healthy snacks			-0.788b	-1.926	0.067
Increased consistency in eating healthy snacks			-0.391b	-1.176	0.252

Variable	B	SE B	β	t	P-value
Increased self-monitoring of eating healthy snacks	0.723	0.309	0.431	2.34	0.028*
Improved snacking behavior change			-0.269b	-0.766	0.451

**P*-value < 0.05 considered significant

Discussion

The present study aimed to test if the theory-based Snackability app could increase the motivators and reducing the barriers to eating healthy foods and snacks as determinants of healthy snacking behavior. This study showed that having access to this app led to significant improvements in the motivators and significant reductions in the barriers to eating healthy foods and snacks as compared to controls during 12-week study period. This time frame is consistent with the time required to form or adopt a new behavior, which takes about 66 (18-254) days for most individuals.[51]

These changes may be related to the different features in the app, such as setting a goal of eating healthier snacks as a part of health action process, which may help in actively replacing an unhealthy routine with a new healthy one.[52] Setting a personal goal of eating healthy snacks may serve as an orienting function for being healthy. Other studies using nutrition/diet related mobile apps incorporated behavior change techniques (goal settings, feedback, self-monitoring, shaping knowledge, and self-reward found positive dietary behavior changes by increasing goal setting, frequency, and consistency of eating healthy foods and snacks.[31,53–55] Supported by the present study, the more frequency of the Snackability app use significantly correlated with the increased knowledge, goal settings, and consistency in eating healthy snacks.

Goal setting as part of self-efficacy and self-regulation in the SCT constructs is needed to overcome barriers and maintain healthy behavior.[42,44] This was evidenced by a significant improvement in negative attitude among participants in the app group, such as caring to eat fruits and vegetables every day and including fruits or vegetables when making or buying a meal. The Snackability app scores most fruits and vegetables with 9-11 points out of a total of 11, so this knowledge may have influenced a change in negative attitude.

In this study, routine, health benefits, and availability in the motivator scale and availability in the barrier scale in the app group significantly improved from baseline to week 12 as compared to controls. Furthermore, within the app group, health benefits and medical issues as motivators significantly effect on the change in body weight among this sample of college students with overweight and obesity. Supported by the literature, motivators of eating healthy foods and snacks among college students and young adults were to improve self-esteem, desire for improved health and attractiveness, assist with weight management, and exercise influencing on food choices.[2,3,13,15,56,57] Thus, the Snackability app was considered as a practical way that could motivate participants to use the app that helped increase motivators and reduce barriers to eating healthy foods and snacks. The app helped participants increase knowledge of choosing healthy snacks, set goals to have healthier snacks, and try to eat healthy foods and snacks as part of their regular routine to achieve the expected health benefits. Furthermore, the app also modestly increased the motivation to eating healthy foods to keep their body in shape and to be physically active, which is consistent with studies showing that college students are concerned for being physically active to keep their bodies in shape.[58] This may explain

that participants using the app perceived health benefits as a positive outcome expectation. Using the app may maximize the anticipated positive outcomes of eating healthy.

Obviously, the present study shows that the food environment has a huge impact on healthy food and snack intake among overweight and obese college students. It was surprising to observe significant improvements in the availability subscale for both the motivators and barriers to eating healthy foods and snacks and the availability in barrier scale significantly impacted on the change of snack score from baseline to week 12 among the app participants. In particular, the improvements were observed in the subscale of trying new fruits and vegetables and having more fruits and vegetables and fresh healthy foods available at home. As found in many studies, college campuses had greater availability and accessibility to unhealthy snacks than healthy snacks which significantly impacted college students' dietary behavior.[4,59–62] However, this study was conducted during the COVID-19 pandemic, when many US colleges were mainly teaching remotely and students were restricted to home. A recent study among college students conducted during the COVID-19 pandemic reported that the at-home-restrictions imposed the access to sufficient healthy foods among college students differently, with some students experiencing no change while others severely affected.[63] During the normal or pandemic situation, home food availability and accessibility is a major factor of snack intake.[64,65] Studies among adolescents found that availability of unhealthy foods at home was positively associated with energy-dense, sweet, and savory snack intake ($P<0.05$).[66,67] Thus, the app influenced and motivated students to have healthy foods and snacks available to them resulting in improving the quality of snack intake. Particularly in

college students with overweight and obesity, health benefits and weight loss may be the main driving factors for healthier snack intake, such as vegetables, fruits, nuts, seeds, dairy, and protein foods considered as healthy snack choices.

When evaluating the Snackability app, participants rated the feasibility and satisfaction lower than expected. For the development of the app, we used features that matched the target user preference, such as being simple, pleasant to use, requiring low effort, with goal-setting and self-monitoring, with feedback and advice on how to change behaviors, with tracking functions, showing how the snacks were scored, and developed by experts or academics.[41,68,69] However, incorporating multicomponent intervention, such as personal support, social support, and tailored or personalized incentives found to match with the user preference of college students and young adults.[32,36,70] These may help improve app engagement, feasibility, and satisfaction which would probably improve outcomes even more.

This study found that increased self-monitoring of eating healthy snacks significantly improved the snack score in the app group at 12 weeks. Another study compared diet and exercise monitoring using smartphone app (FoodWiz2) and paper diary among adolescents age 16-19 years.[38] Participants using the app significantly increased fruit intake and reduced intake of chocolate snacks and fizzy drinks. However, the study of dietary self-monitoring via a Calorie Counting app in undergraduate women found no significant effect on the dietary intake.[71] From the literature, self-monitoring of dietary intake is a valuable component to facilitate healthy dietary behavior change and behavioral weight loss.[55,72] Hence, the reporting features (average daily score shown as progress graph and consumed snack history) of the Snackability app helped facilitate self-

monitoring so that participants could keep tracking of their snack intake leading to improve the quality of snack intake. Future studies should evaluate the self-monitoring method that will work best for college students with overweight and obesity to increase adherence.

Among the strengths of this study were that the app was developed based on the SCT and the USDA guideline and it was tested using a RCT design, the gold standard to test the effectiveness of interventions. Furthermore, the study included a diverse sample of students from different colleges in the US. One of the limitations was that the present study was only college students with overweight and obesity which cannot be generalize to other groups. Also, the study was conducted during the COVID-19 pandemic which may have different results from normal situation. Lastly, self-report questionnaires and dietary recalls may lead to imprecise data report, but it would be difficult to evaluate motivators and barriers to eating healthy foods and snacks, the app evaluation, and dietary recalls without self-report data from the participants.

Conclusions

The present study showed that the theory-based Snackability app led to significant improvements in the motivators and significant reductions in the barriers to eat healthy foods and snacks with the expected health benefits among overweight and obese college students during 12-week study period. This app can be used as nutrition tool to help promote healthy snack intake through shaping knowledge, positive outcome expectation, goal-setting, and self-monitoring. When participants use the app over time, the app will facilitate snacking behavior change resulting in improving snack and diet quality.

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CHAPTER VI

CONCLUSIONS

In the present study, the theory-based Snackability app can be used as a tool to help increase the nutrition behavior of selecting and consuming healthier snacks. This sample of college students with overweight and obesity used the app to help identify if a snack was healthy or not. At the same, the app influenced participants to purchase and consume healthy snacks. When participants used the app over time, the app facilitated healthy snacking behavior change by increasing motivators of and reducing barriers to eating healthy snacks for their anticipated health benefits. Participants increased nutrition knowledge, goal setting, self-monitoring, frequency, and consistency of eating healthy foods and snacks from using the app over time. In addition, the app created awareness among participants to realize that there were greater availability of unhealthy snacks around them and participants tried to choose healthier snacks that are available around them and had more healthy snacks available at home. These findings demonstrate the effect of using the Snackability smartphone app to facilitate healthy snacking behavior change resulting in improving the quality of snack intake and diet quality. The university-related persons and policy makers should consider the implementation of theory-based smartphone apps to support healthy dietary behavor change together with the improvement of food environment for eventual weight loss among college students with overweight and obesity in order to prevent associated chronic diseases in their future.

CHAPTER VII

STRENGTHS AND LIMITATIONS

Among strengths of this study, the Snackability app was developed based on the SCT for behavior change and the Smart Snack Guidelines and tested using a RCT design which is the gold standard to test the effectiveness of interventions. Second, the diet quality was assessed using HEI-2015 from ASA24 dietary recalls, which allowed participants to enter snack occasions, time, type and amount of snacks consumed separating from meals. The data output of snack intake extracted from 24-h dietary recalls was able to use for the calculation of the snack scores. Last, the study included a diverse sample of students from different colleges in the US.

One of the limitations is that the present study included only college students with overweight and obesity which cannot be generalize to other groups of population. Also, the study was conducted during the COVID-19 pandemic, which may had led to the low retention rate, especially at week 8 but researchers were able to contact more participants back again to complete the study at week 12. Under reporting in the 24-h recalls could have affected the results, as this is greater in overweight and obese individuals. Additionally, self-report questionnaires and dietary recalls may lead to imprecise data report, but it would be difficult to evaluate snacking behavior and dietary recalls without self-report data from the participants. Lastly, the interruption of the app for 3-4 weeks due to technical issues with the Expo app but there was no significant difference of the snack scores between participants that experienced app broken and no app broken.

CHAPTER VIII

FUTURE RESEARCH

The future studies should evaluate how snacking behavior changes over time through a longitudinal study cause and effect relationships on overall diet quality, snack quality, and body weight in a larger sample. This information could be used in the future to design interventions to improve the environment to have healthy snacks more accessible and available for college students together with improving the snacking time and types of snacks consumed.

Future studies should also evaluate how to improve the compliance to the Snackability by incorporating a multicomponent intervention, such as personal support, social support, and tailored or personalized incentives to match with the user preference. In addition, the technical issue of the app is possible to happen during the study as the app needs to be maintained and updated consistently. Future studies should consider changing from a regular mobile app to a web-based app to avoid issues with the platform in which apps are embedded. As the present study was conducted during the COVID-19 pandemic, future studies should test the efficacy of the Snackability app in a normal setting, which may result in different intervention effects. Lastly, larger sample size and longer studies are needed to achieve more definitive conclusions.

APPENDICES

Appendix 1 – Recruitment Flyers

FIU FLORIDA INTERNATIONAL UNIVERSITY

Interested in trying out a new app to help identify healthy snacks?

We are looking for volunteers to help evaluate the smartphone app "Snackability"

This app identifies healthy snacks using a scoring system

Receive free healthy snacks and study tokens while learning how to make better, healthier food choices!

To participate you must:

1. Be an FIU Student
2. Have access to a smartphone
3. Be classified as over-weight
4. Be 18-24 years old
5. Be able to commit to a 3-month long trial

Please contact us at:

Email: snackability@fiu.edu

Website: www.snackability.fiu.edu

Scan this QR Code to see if you qualify!

Are you an FIU student?

Do you have a smartphone?

Are you interested in learning how to choose healthy snacks, while earning goodies, free snacks and a gift card?

Check out the Snackability study!

A completely online study that is recruiting individuals like you right now!

Scan this QR Code to see if you meet all of the requirements!


Interested in trying out a new app to help identify healthy snacks?
We are looking for volunteers to help evaluate the smartphone app "Snackability"
This app identifies healthy snacks using a scoring system.
Receive free healthy snacks and study tokens while learning how to make better, healthier food choices!
Please contact us at:
Email: snackability@fiu.edu
Website: http://snackability.fiu.edu/
Scan this code to see if you qualify!
To participate you must:
1. Be an FIU Student
2. Have access to a smartphone
3. Be classified as over-weight or obese
4. Be 18-24 years old
5. Be able to commit to a 3-month long trial
Snackability
FIU
FLORIDA INTERNATIONAL UNIVERSITY

Are you an FIU student?

Do you have a smartphone?

Are you interested in learning how to choose healthy snacks, while earning goodies, free snacks and a gift card?

Check out the Snackability study!

A completely online study that is recruiting individuals like you right now!

Scan the QR Code below to see if you meet all of the requirements!

Appendix 2 – IRB Approved Consent Form

FIU IRB Approval:	03/25/2020
FIU IRB Expiration:	03/25/2021
FIU IRB Number:	IRB-20-0275

FIU | FLORIDA INTERNATIONAL UNIVERSITY

ADULT CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Effectiveness of the Snackability smartphone application to improve quality of the snack intake, general diet quality, and weight among college students

SUMMARY INFORMATION

Things you should know about this study:

- **Purpose**: To determine the effects of the Snackability app on quality of snack intake, general diet quality and weight in college students.
- **Procedures**: If you choose to participate, you will be assigned at random. The intervention group will be asked to use the app when consuming snacks during the study. You will respond several questionnaires online and measure your weight at home at baseline, 4, 8, and 12 weeks.
- **Duration**: 12 weeks.
- **Risks**: There is minimal risk in this study; you may feel discomfort when taking your weight at home and there is a risk of disclosure of personal information.
- **Benefits**: Learning about healthy snacks and receiving the information on your dietary intake
- **Alternatives**: There are no known alternatives available to you other than not taking part in this study.
- **Participation**: Taking part in this research project is voluntary.

Please carefully read the entire document before agreeing to participate.

PURPOSE OF THE STUDY

To determine the effects of the Snackability smartphone application (app) for 12 weeks on quality of snacks and the general diet and weight in college students as compared to control.

NUMBER OF STUDY PARTICIPANTS

If you decide to be in this study, you will be one of 192 overweight FIU students (aged 18-24 years) in this research study. To participate, you should be an owner of a smartphone with access to internet, not enrolled in a weight loss and/or nutrition program, not taking any medications to lose weight and not pregnant or breastfeeding.

DURATION OF THE STUDY

Your participation will require to complete online questionnaires and measure your weight at home at baseline, 4, 8, and 12 weeks.

PROCEDURES

If you agree to be in the study, you will be randomly assigned to one of two groups:

FIU IRB Approval:	03/25/2020
FIU IRB Expiration:	03/25/2021
FIU IRB Number:	IRB-20-0275

1. **Intervention group**: you will have access to the Snackability app from baseline. We will send you an email with the instructions on how to download and to use the app every time you have a snack for the next 12 weeks. To register in the app, we will ask you to use a non-FIU email, which could be your personal email, or a new email created just to get access to the app. Your email registered in the app will be used to track the information of the app in the Firebase website. This app will not have access to the information in your phone; only the information on snack search, snacks consumed, portion size defined for each snack, score of each snack, date and time of the snacks consumed, points gained per snack and per day, and allergies. Also, the app will request access to the camera to be able to scan the barcode of the snacks to easily find the snacks. You will be provided with an end-user license agreement (EULA) to review before downloading the app.

2. **Control group**: you will receive a 1-page information on healthy snacks and will also have access to the Snackability app at the end of the study.

During the study, we will ask you to complete several questions online using Qualtrics, a secure web-based survey, as follows:

Pre-screening: You will complete a short pre-screening checklist via Qualtrics to assess if you qualify for the study. If you have questions about the study, we will provide our email and phone number to contact us before signing the consent form.

Baseline online tasks (30 – 40 minutes or less): If you qualify and decide to participate in the study, you will review, sign, and date the informed consent using Qualtrics. Then, you will have access to the following online questionnaires:

- Contact and socio-demographic questionnaire: You will provide your phone number, email address, age, gender, race/ethnicity, information about your major at FIU, income of your parents, food situation, and the level of your stress.
- Perception of food and snack consumption questionnaire: You will complete questions about your perception of why you consume healthy foods and snacks.
- Intake of snack questionnaire: You will complete questions about your frequency of snack intake, snacking time, favorite snacks, availability of snacks, and reasons for snacking.
- Disordered Eating Attitude Scale: You will complete questions about your beliefs, thoughts, feelings, behavior and relationship with food.
- 24-hour food recalls: This will be completed in another website, the Automated Self-Administered 24-hour Dietary Recall (ASA24-2020). We will send you an email with the link, your username and a strong password; these were created specifically for you. The ASA24 system has no access to any contact information or personally identifiable information. In the ASA24 website, you will record all the foods and beverages consumed in the past 24 hours. This will be done for 2 days during the weekdays and 1 day during the weekend. You can contact us for assistance by phone or email.
- Weight and height: You will measure your weight at home by using any scale you have. If you do not have one, we will try to send you one by mail. We will send you detailed instructions on how to do this at home and a link to report your weight and height.
- Group assignment: When you have completed all tasks, then we will inform you of your randomly assigned group by email.

4 and 8-week online tasks (20 minutes or less):

- Perception of food and snack consumption questionnaire: You will complete questions about your perception of why you consume healthy foods and snacks.
- App usability and snacking behavior: You will complete questions about app usage and snacking behavior.
- 24-hour food recall: You will complete one 24-h recall as you did at baseline.
- Weight: You will measure your weight at home as you did at baseline.

12-week online tasks (30 – 40 minutes or less): You will complete all the tasks done at baseline except for the contact form. You will also complete questions about the usability, feasibility, satisfaction, and acceptability with the app.

Reminders throughout the study: We will remind you to complete the tasks of the study by text messages or by email using your FIU email. For those in the intervention group, we will also send you daily notifications to remind you to use the app by automated text messages and also friendly reminders by email using your FIU email.

RISKS AND/OR DISCOMFORTS

There is minimal risk in this study. You may feel discomfort when taking self-weight measurements and there is a risk of disclosure of personal information.

BENEFITS

You will receive information on how identify healthy snacks based on the USDA guidelines and healthy snacks. You will also receive information of your dietary intake. The results of the study will help us know if the Snackability app helps improve on quality of snacks and on your general diet and on weight. This can be used in the future by all college students.

ALTERNATIVES

There are no known alternatives available to you other than not taking part in this study. Any significant new findings developed during the study which may relate to your willingness to continue participation will be provided to you.

CONFIDENTIALITY

The records of this study will be kept private and will be protected to the fullest extent provided by law. In any sort of report, we might publish, we will not include any information that will make it possible to identify you. Research records will be stored securely, and only the researcher team will have access to them. However, your records may be inspected by authorized University or other agents who will also keep the information confidential. If we learn about serious harm to you or someone else, we will take steps to protect the person endangered even if it requires telling the authorities without your permission.

USE OF YOUR INFORMATION

Identifiers about you might be removed from the identifiable private information and that, after such removal, the information could be used for future research studies or distributed to another

FIU IRB Approval:	03/25/2020
FIU IRB Expiration:	03/25/2021
FIU IRB Number:	IRB-20-0273

investigator for future research studies without additional informed consent from you or your legally authorized representative.

COMPENSATION & COSTS

You will receive a snack bag with healthy snacks and a water bottle at the end of the study. You will also receive a $10 gift card at the end of the study. There are no costs to you for participating in this study.

RIGHT TO DECLINE OR WITHDRAW

Your participation in this study is voluntary. You are free to participate in the study or withdraw your consent at any time during the study. You will not lose any benefits if you decide not to participate or if you quit the study early. The investigator reserves the right to remove you without your consent at such time that he/she feels it is in the best interest.

RESEARCHER CONTACT INFORMATION

If you have any questions about the research study, you may contact the principal investigator Cristina Palacios at the Department of Dietetics and Nutrition, FIU, (305) 348-3235 or cristina.palacios@fiu.edu.

IRB CONTACT INFORMATION

If you would like to talk with someone about your rights of being a subject in this research study or about ethical issues with this research study, you may contact the FIU Office of Research Integrity by phone at 305-348-2494 or by email at ori@fiu.edu.

PARTICIPANT AGREEMENT

I have read the information in this consent form and agree to participate in this study. I have had a chance to ask any questions I have about this study, and they have been answered for me. I understand that I will be given a copy of this form for my records.

_____ _____

Signature of Participant Date

_____

Printed Name of Participant

_____ _____

Signature of Person Obtaining Consent Date

Appendix 3 – Renewal IRB Consent Form

FIU IRB Approval:	03/31/2021
FIU IRB Expiration:	03/25/2022
FIU IRB Number:	IRB-20-0275

FIU | FLORIDA INTERNATIONAL UNIVERSITY

ADULT CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Effectiveness of the Snackability smartphone application to improve quality of the snack intake, general diet quality, and weight among college students

SUMMARY INFORMATION

Things you should know about this study:

- Purpose: To determine the effects of the Snackability app on quality of snack intake, general diet quality and weight in college students.
- Procedures: If you choose to participate, you will be assigned at random. The intervention group will be asked to use the app when consuming snacks during the study. You will respond several questionnaires online and measure your weight at home at baseline, 4, 8, and 12 weeks.
- Duration: 12 weeks.
- Risks: There is minimal risk in this study; you may feel discomfort when taking your weight at home and there is a risk of disclosure of personal information.
- Benefits: Learning about healthy snacks and receiving the information on your dietary intake
- Alternatives: There are no known alternatives available to you other than not taking part in this study.
- Participation: Taking part in this research project is voluntary.

Please carefully read the entire document before agreeing to participate.

PURPOSE OF THE STUDY

To determine the effects of the Snackability smartphone application (app) for 12 weeks on quality of snacks and the general diet and weight in college students as compared to control.

NUMBER OF STUDY PARTICIPANTS

If you decide to be in this study, you will be one of 272 overweight college students (aged 18-24 years) in this research study. To participate, you should be an owner of a smartphone with access to internet, not enrolled in a weight loss and/or nutrition program, not taking any medications to lose weight and not pregnant or breastfeeding.

DURATION OF THE STUDY

Your participation will require to complete online questionnaires and measure your weight at home at baseline, 4, 8, and 12 weeks.

PROCEDURES

If you agree to be in the study, you will be randomly assigned to one of two groups:

1. **Intervention group**: you will have access to the Snackability app from baseline. We will send you an email with the instructions on how to download and to use the app every time you have a snack for the next 12 weeks. To register in the app, we will ask you to use a non-university email, which could be your personal email, or a new email created just to get access to the app. Your email registered in the app will be used to track the information of the app in the Firebase website. This app will not have access to the information in your phone; only the information on snack search, snacks consumed, portion size defined for each snack, score of each snack, date and time of the snacks consumed, points gained per snack and per day, and allergies. Also, the app will request access to the camera to be able to scan the barcode of the snacks to easily find the snacks. You will be provided with an end-user license agreement (EULA) to review before downloading the app.

2. **Control group**: you will receive a 1-page information on healthy snacks and will also have access to the Snackability app at the end of the study.

During the study, we will ask you to complete several questions online using Qualtrics, a secure web-based survey, as follows:

Pre-screening: You will complete a short pre-screening checklist via Qualtrics to assess if you qualify for the study. If you have questions about the study, we will provide our email and phone number to contact us before signing the consent form.

Baseline online tasks (30 – 40 minutes or less): If you qualify and decide to participate in the study, you will review, sign, and date the informed consent using Qualtrics. Then, you will have access to the following online questionnaires:

- Contact and socio-demographic questionnaire: You will provide your phone number, email address, age, gender, race/ethnicity, information about your major, income of your parents, food situation, and the level of your stress.
- Perception of food and snack consumption questionnaire: You will complete questions about your perception of why you consume healthy foods and snacks.
- Intake of snack questionnaire: You will complete questions about your frequency of snack intake, snacking time, favorite snacks, availability of snacks, and reasons for snacking.
- Disordered Eating Attitude Scale: You will complete questions about your beliefs, thoughts, feelings, behavior and relationship with food.
- 24-hour food recalls: This will be completed in another website, the Automated Self-Administered 24-hour Dietary Recall (ASA24-2020). We will send you an email with the link, your username and a strong password; these were created specifically for you. The ASA24 system has no access to any contact information or personally identifiable information. In the ASA24 website, you will record all the foods and beverages consumed in the past 24 hours. This will be done for 2 days during the weekdays and 1 day during the weekend. You can contact us for assistance by phone or email.
- Weight and height: You will measure your weight at home by using any scale you have. If you do not have one, we will try to send you one by mail. We will send you detailed instructions on how to do this at home and a link to report your weight and height.
- Group assignment: When you have completed all tasks, then we will inform you of your randomly assigned group by email.

FIU IRB Approval:	03/31/2021
FIU IRB Expiration:	03/25/2022
FIU IRB Number:	IRB-20-0275

4 and 8-week online tasks (20 minutes or less):

- Perception of food and snack consumption questionnaire: You will complete questions about your perception of why you consume healthy foods and snacks.
- App usability and snacking behavior: You will complete questions about app usage and snacking behavior.
- 24-hour food recall: You will complete one 24-h recall as you did at baseline.
- Weight: You will measure your weight at home as you did at baseline.

12-week online tasks (30 – 40 minutes or less): You will complete all the tasks done at baseline except for the contact form. You will also complete questions about the usability, feasibility, satisfaction, and acceptability with the app.

Reminders throughout the study: We will remind you to complete the tasks of the study by text messages or by email using your university email. For those in the intervention group, we will also send you daily notifications to remind you to use the app by automated text messages and also friendly reminders by email using your university email.

RISKS AND/OR DISCOMFORTS

There is minimal risk in this study. You may feel discomfort when taking self-weight measurements and there is a risk of disclosure of personal information.

BENEFITS

You will receive information on how identify healthy snacks based on the USDA guidelines and healthy snacks. You will also receive information of your dietary intake. The results of the study will help us know if the Snackability app helps improve on quality of snacks and on your general diet and on weight. This can be used in the future by all college students.

ALTERNATIVES

There are no known alternatives available to you other than not taking part in this study. Any significant new findings developed during the study which may relate to your willingness to continue participation will be provided to you.

CONFIDENTIALITY

The records of this study will be kept private and will be protected to the fullest extent provided by law. In any sort of report, we might publish, we will not include any information that will make it possible to identify you. Research records will be stored securely, and only the researcher team will have access to them. However, your records may be inspected by authorized University or other agents who will also keep the information confidential. If we learn about serious harm to you or someone else, we will take steps to protect the person endangered even if it requires telling the authorities without your permission.

USE OF YOUR INFORMATION

FIU IRB Approval:	03/31/2021
FIU IRB Expiration:	03/25/2022
FIU IRB Number:	IRB-20-0275

Identifiers about you might be removed from the identifiable private information and that, after such removal, the information could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from you or your legally authorized representative.

COMPENSATION & COSTS

You will receive a snack bag with healthy snacks and a water bottle after we assign you to a randomized group. You will receive a $5 gift card at week 4, a $5 gift card at week 8, and a $10 gift card at the end of the study. There are no costs to you for participating in this study.

RIGHT TO DECLINE OR WITHDRAW

Your participation in this study is voluntary. You are free to participate in the study or withdraw your consent at any time during the study. You will not lose any benefits if you decide not to participate or if you quit the study early. The investigator reserves the right to remove you without your consent at such time that he/she feels it is in the best interest.

RESEARCHER CONTACT INFORMATION

If you have any questions about the research study, you may contact the principal investigator Cristina Palacios at the Department of Dietetics and Nutrition, FIU, (305) 348-3235 or cristina.palacios@fiu.edu.

IRB CONTACT INFORMATION

If you would like to talk with someone about your rights of being a subject in this research study or about ethical issues with this research study, you may contact the FIU Office of Research Integrity by phone at 305-348-2494 or by email at ori@fiu.edu.

PARTICIPANT AGREEMENT

I have read the information in this consent form and agree to participate in this study. I have had a chance to ask any questions I have about this study, and they have been answered for me. I understand that I will be given a copy of this form for my records.

_____ _____

Signature of Participant Date

_____

Printed Name of Participant

_____ _____

Signature of Person Obtaining Consent Date

Appendix 4 – IRB Letter of Approval

FIU | FLORIDA INTERNATIONAL UNIVERSITY

Office of Research Integrity
Research Compliance, MARC 414

MEMORANDUM

To: Dr. Cristina Palacios

CC: Lukkamol Prapkree

From: Maria Melendez-Vargas, MIBA, IRB Coordinator

Date: June 10, 2020

Protocol Title: "Effectiveness of the Snackability smartphone application to improve quality of the snack intake, general diet quality, and weight among college students"

The Health Sciences Institutional Review Board of Florida International University has approved your study for the use of human subjects via the **Full Board Review** process. Your study was found to be in compliance with this institution's Federal Wide Assurance (00000060).

IRB Protocol Approval #:	IRB-20-0275	**IRB Approval Date:**	03/25/20
TOPAZ Reference #:	108729	**IRB Expiration Date:**	03/25/21

As a requirement of IRB Approval you are required to:

1) Submit an IRB Amendment Form for all proposed additions or changes in the procedures involving human subjects. All additions and changes must be reviewed and approved by the IRB prior to implementation.
2) Promptly submit an IRB Event Report Form for every serious or unusual or unanticipated adverse event, problems with the rights or welfare of the human subjects, and/or deviations from the approved protocol.
3) Utilize copies of the date stamped consent document(s) for obtaining consent from subjects (unless waived by the IRB). Signed consent documents must be retained for at least three years after the completion of the study.
4) **Obtain continuing review and re-approval of the study prior to the IRB expiration date.** Submit the IRB Renewal Form at least 30 days in advance of the study's expiration date.
5) Submit an IRB Project Completion Report Form when the study is finished or discontinued.

HIPAA Privacy Rule: N/A

Special Conditions: N/A

For further information, you may visit the IRB website at http://research.fiu.edu/irb.

MMV/em

Appendix 5 – Renewal IRB Letter of Approval

FIU | FLORIDA INTERNATIONAL UNIVERSITY

Office of Research Integrity
Research Compliance, MARC 414

MEMORANDUM

To:	Dr. Cristina Palacios
CC:	Lukkamol Prapkree
From:	Maria Melendez-Vargas, MIBA, IRB Coordinator
Date:	April 5, 2021
Protocol Title:	"Effectiveness of the Snackability smartphone application to improve quality of the snack intake, general diet quality, and weight among college students"

The Health Sciences Institutional Review Board of Florida International University has re-approved your study for the use of human subjects via the **Full Board Review** process. Your study was found to be in compliance with this institution's Federal Wide Assurance (00000060).

IRB Protocol Approval #:	IRB-20-0275-CR01	**IRB Approval Date:**	03/31/21
TOPAZ Reference #:	108729	**IRB Expiration Date:**	03/25/22

As a requirement of IRB Approval you are required to:

1) Submit an IRB Amendment Form for all proposed additions or changes in the procedures involving human subjects. All additions and changes must be reviewed and approved by the IRB prior to implementation.
2) Promptly submit an IRB Event Report Form for every serious or unusual or unanticipated adverse event, problems with the rights or welfare of the human subjects, and/or deviations from the approved protocol.
3) Utilize copies of the date stamped consent document(s) for obtaining consent from subjects (unless waived by the IRB). Signed consent documents must be retained for at least three years after the completion of the study.
4) **Receive annual review and re-approval of your study prior to your IRB expiration date.** Submit the IRB Renewal Form at least 30 days in advance of the study's expiration date.
5) Submit an IRB Project Completion Report Form when the study is finished or discontinued.

HIPAA Privacy Rule: **N/A**

Special Conditions: **N/A**

For further information, you may visit the IRB website at http://research.fiu.edu/irb.

MMV/em

Appendix 6 – Research Questionnaires

Date_____

Screening checklist to participate in the study

1. Are you 18 – 24 years old?	No___ Yes___
2. Are you a non-nutrition college student at Florida International University?	No___ Yes___
3. What is your weight?	___ lb or ___ kg
4. What is your height?	____in or ___ cm
5. BMI calculation (25.0 – 39.9 kg/m^2) – *THIS WILL BE AUTOMATICALLY DONE BY QUALTRICS WITH THE WEIGHT AND HEIGHT*	No___ Yes___
6. Do you own a smartphone with access to internet connection to use the app?	No___ Yes___
7. Are you willing to be randomized into the intervention group (access to the Snackability app now) or control group (access to the Snackability app later)?	No___ Yes___
8. Can you participate in the study for 3 months and complete assessments every 4 weeks from home (online questionnaires and self-weight)? *NOTE: we will provide one if you do not have one*	No___ Yes___
9. Are you enrolled in a weight loss and/or nutrition program?	No___ Yes___
10. Do you take medications for weight loss?	No___ Yes___
11. Are you currently pregnant or breastfeeding?	No___ Yes___

Contact and Socio-Demographic Form

Name and last name: _____

Cellphone: _____

FIU Email: _____

Personal email: _____

Age____ years

Gender: ___Female ___Male

Race/Ethnicity:

__White __Hispanic/Latino __Afro Caribbean
__African American __Asian __Other _____

Full time student: __Yes __No

Year of study (i.e. 1st, 2nd, 3rd…..year at FIU): ____ year

Field of study: _____

College: _____ Department: _____

Household income:

___ <$50,000 ___ $50,000-$75,000
___$75,000-$100,000 ___>$100,000

Food situation questions

1. The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more in the past 12 months.
   __ Often true
   __ Sometimes true
   __ Never true
   __ Don't know or refuse to answer

2. (I/we) couldn't afford to eat balanced meals in the last 12 months
   __ Often true
   __ Sometimes true
   __ Never true
   __ Don't know or refuse to answer

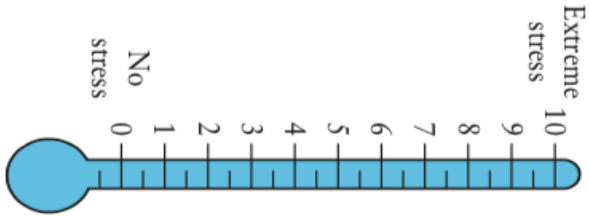
3. In the last 12 months, did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?
   __ Yes. If yes, how often did this happen?
      __ Almost every month
      __ Some months but not every month
      __ Only 1 or 2 months
   __ No
   __ Don't know or refuse to answer

4. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?
   __ Yes
   __ No
   __ Don't know or refuse to answer

5. In the last 12 months, were you every hungry but didn't eat because there wasn't enough money for food?
   __ Yes
   __ No
   __ Don't know or refuse to answer

Stressometer

Please circle the number (0-10) that best describes your stress level over the past week



Intake of snacks

1. In a typical day, how often do you eat snacks?

   ____times/day ____days/week

2. In a typical day, when do you usually consume snacks? (select all that applies)

   ____ Breakfast time
   ____ Mid-morning
   ____ Lunch time
   ____ Mid-afternoon
   ____ Dinner time
   ____ After dinner

3. What are the reasons for snacking? (select all that applies)

   ____ Snacks are tasty/palatable.
   ____ To stave off hunger
   ____ Snacks are convenient
   ____ To fill the gap between meal
   ____ Snacks are affordable
   ____ Snacks are pleasure

4. What kinds of snacks do you usually consume?

   _____ _____ _____

5. Do you know how to choose a healthy snack? ___No ____Yes

   If YES, how do you know if a snack is healthy?_____

   If NO, why?_____

6. Which type of snack is more accessible and available to you?

   ___Unhealthy snacks (i.e. chips, crackers, cookies, candies, chocolate, etc.)

   ___Healthy snacks (i.e. fruits, vegetables, nuts, seeds, whole grain low sugary bars/cookies/crackers, etc.)

ID_____

HEALTHY FOODS AND SNACKS

Think about when you eat healthy foods and healthy snacks. Healthy foods and snacks are <u>low</u> in fat, calories, and sugar. There are many healthy foods and snacks. These are just <u>some</u> examples of healthy foods and snacks:

- A turkey or chicken sandwich instead of a hamburger
- Salad with vinaigrette instead of ranch/blue cheese dressing
- Eating baked or grilled fish instead of meats higher in fat (like beef, lamb, or pork)
- A meal with vegetables instead of a meal with no vegetables
- A bean burrito instead of a beef burrito
- Pretzels, nuts, or popcorn (without butter and salt) instead of chips
- Low-fat frozen yogurt instead of ice cream
- Steamed brown rice instead of fried rice
- A piece of fruit as a snack instead of cookies
- Baked chicken or fish instead of fried chicken or fish

When I eat healthy foods (like fruits, vegetables, and lower-calorie snacks), it is because…	**Strongly Disagree**	**Somewhat Disagree**	**Somewhat Agree**	**Strongly Agree**
1. …I can find healthy snacks that come in handy, small packages.	O	O	O	O
2. …fruits and vegetables can be easily eaten without being cooked.	O	O	O	O
3. …there are healthy options at most restaurants that I go to.	O	O	O	O
4. …someone has taught me why fruits and vegetables are healthy.	O	O	O	O
5. …eating healthy foods is part of my regular routine.	O	O	O	O
6. …eating healthy foods keeps my body in shape.	O	O	O	O
7. …I am concerned about preventing high blood pressure.	O	O	O	O
8. …I have a personal goal of eating healthier snacks.	O	O	O	O
9. …eating healthy foods helps me to be physically active.	O	O	O	O
10. …I have a health or medical condition and need to eat healthy because of it.	O	O	O	O
11. …I eat healthy foods every day so that I can be healthy.	O	O	O	O
12. …I am concerned about preventing high cholesterol.	O	O	O	O
13. …healthy snacks come in little packages that help me to not eat too much.	O	O	O	O
14. …I like the taste of most fruits and vegetables.	O	O	O	O
15. …I am concerned about preventing diabetes.	O	O	O	O
16. …I like to add variety to what I eat by trying new fruits and vegetables.	O	O	O	O
17. …eating healthy foods and snacks helps me look good.	O	O	O	O
18. …fruits and vegetables (fresh or frozen) are usually available in my home.	O	O	O	O
19. …I have the discipline to eat healthy.	O	O	O	O
20. …I think about what could happen if I eat too many unhealthy foods.	O	O	O	O

HEALTHY FOODS AND SNACKS

When I do <u>not</u> eat healthy foods (like fruits, vegetables, and lower-calorie snacks), it is because…	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
1. …when there are unhealthy foods at home, it is hard to choose healthy foods	O	O	O	O
2. …when I think "healthy food," I think "tastes bad."	O	O	O	O
3. …fresh healthy foods are not easily available.	O	O	O	O
4. …when I go to the grocery store, I do not specifically think about buying fruits or vegetables	O	O	O	O
5. …I get cravings for unhealthy foods.	O	O	O	O
6. …I do not like the taste of most vegetables.	O	O	O	O
7. …I cannot get healthy snacks in the snack machines.	O	O	O	O
8. …I do not like to try new fruits or vegetables that I have never had before	O	O	O	O
9. …when someone cooks or gives me unhealthy food, I eat it.	O	O	O	O
10. …I do not look or feel any different when I eat healthy	O	O	O	O
11. …I crave sweets or junk food instead of fruit as a snack	O	O	O	O
12. …I just do not care about eating fruits and vegetables every day.	O	O	O	O
13. …when I make or buy a meal, I do not think about whether or not it has fruits or vegetables in it.	O	O	O	O
14. …healthy foods are not easy to find at restaurants.	O	O	O	O
15. …I just do not care about eating healthy every day	O	O	O	O

Please put an (X) mark in the box underneath the response that most closely corresponds with how you feel about the questions on the left.

	Eating this food often is healthy and necessary	Eating this food occasionally is healthy and necessary	Not eating this food is healthy and necessary
Sugar			
French Fries			
Oil			
Breads			
Rice			
Beans			
Pasta			
Red Meat			
Whole Milk			
Cheese			
Vegetables			
Fruits			
White Meat			

	Yes	No
Do you feel pleasure when you eat?		
Does eating ever feel unnatural to you?		
Have you ever spent one or more days without eating or having only liquids because you believed you could lose weight?		
Do you count the calories of everything you eat?		
Do you enjoy the feeling of an empty stomach?		
Do you "skip" meals to avoid putting on weight?		
Does eating make you feel "dirty"?		
Do you have good memories related to food?		
Would you like to not need to eat?		
Do you believe that it is normal to eat sometimes just because you are sad, upset or bored?		

Please select one answer from the options on the right	
When you eat more than usual, what is your behavior afterwards?	☐ Restart eating as usual. ☐ Assume you have lost control and keep eating even more. ☐ Decide to go on a diet to compensate. ☐ Use some kind of compensation, such as physical activity, vomiting, laxatives and diuretics

Please put an (X) mark in the box underneath the response that most closely corresponds with how you feel about the questions on the left.

	Always	Usually	Often	Sometimes	Rarely/ Never
I feel guilty when I eat something that I thought I should not eat for some reason.					
I quit eating a kind of food if I find out it has more calories than I thought.					
I worry all the time about what I am going to eat, how much to eat, how to prepare food and whether I should eat or not.					
I worry about how much a certain kind of food or meal will make me gain weight.					
I am angry when I feel hungry.					
It is hard to choose what to eat, because I always think I should eat less or choose the option with fewer calories.					
When I desire a specific kind of food, I know I won't stop eating until I have finished with it.					
I would like to have my appetite and eating behavior under total control.					
I try eating less in front of others in order to overeat when I am alone.					
I am afraid to start eating and not be able to stop.					
I dream of a *pill* that would replace food.					
I get nervous and/or lose my self-control at parties and buffets, due to a great amount of foods available.					
My relationship with food messes up my life as a whole.					

Body weight Recording FORM
Baseline

Participant ID: _____
Date: ___/___/_____
Time: _____
Type of scale used: _____
Brand of scale used: _____
Are you using kg or lb? _____

Scale calibration

- What item did you use to calibrate the scale? _____
- What is the regular weight of that item? _____
- What was the weight displayed on your scale for that item? ____

Body weight measurement

- Weight 1 ____*
- Weight 2 ____
- Were you wearing ONLY undergarments? Yes____ No_____
    - If not, what were you wearing? _____
- Were you bare feet? Yes____ No_____

Height

- What is your regular height in inches? ____

Usability of Snackability app and snacking behavior

1. How often did you use the app when snacking in the past 4 weeks?

___Every time
___Most times
___Sometimes
___Almost never
___Never

2. Estimate how many times did you use the App during the past 4 weeks?

_____times/day _____days/week

3. In the past 4 weeks, how often did you eat snacks?

_____times/day _____days/week

4. Did your score improve during the past 4 weeks that you used the App?

___No ____Yes

Explain_____

5. Did the app help you choose healthier snacks?

___No ____Yes

Explain_____

6. In the past 4 weeks, using the Snackability app has…

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Increased knowledge of choosing and eating healthy snacks					
Increased my actual goal setting to eat healthy snacks					
Increased my consistency in eating healthy snacks					
Increase self-monitoring of eating healthy snacks					
Improved my snacking behavior change					

Evaluation of acceptability, feasibility, satisfaction, and usability of the Snackability smartphone app

Questions	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Feasibility questions					
1. The App is easy to use.					
2. The App is easy to learn.					
3. It was easy to find the snack I wanted to eat in the app.					
4. The App is very quick.					
5. The App provided me all the information I wanted.					
Acceptability questions					
1. The icon and font used are attractive and recognizable.					
2. I felt very comfortable using the application.					
3. I liked the layout of the App.					
4. I liked the screen of the App.					
Satisfaction questions					
5. I would use this App again.					
6. Overall, I liked the App.					

Usability questions

1. How often did you use the app when snacking in the past 4 weeks?

___Every time
___Most times
___Sometimes
___Almost never
___Never

2. Estimate how many times did you use the App during the past 4 weeks?

_____times/day _____days/week

3. In the past 4 weeks, how often did you eat snacks?

_____times/day _____days/week

4. Did your score improve during the past 4 weeks that you used the App?

___No ____Yes

Explain_____

5. Did the app help you choose healthier snacks?

___No ____Yes

Explain_____

6. In the past 4 weeks, using the Snackability app has…

Questions	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Increased knowledge of choosing and eating healthy snacks					
Increased my actual goal setting to eat healthy snacks					
Increased my consistency in eating healthy snacks					
Increase self-monitoring of eating healthy snacks					
Improved my snacking behavior change					

7. Were there foods not found in the app? _____No _____Yes
   If yes, which ones:_____

8. Would you pay for this app? ___No ____Yes ___Maybe

9. What is your overall star rating of the app? _____ (from 1 to 5, being 5 the highest)

Appendix 7 – Information provided for the control group

Smart Snacks in a Nutshell

Nutrition Standards for All Foods Sold In Schools Final Rule

The Smart Snacks Final Rule finalizes science-based nutrition guidelines for competitive foods sold on the school campus during the school day. Foods and beverages sold in schools must meet both the general standards and the nutrient standards outlined in the final rule if they do not qualify for an exemption.

Foods

General Standards

Entrées, snacks, and sides must meet one of the following criteria:

- Be a whole grain-rich product
- Have a fruit, vegetable, dairy product, or protein food (meat, beans, poultry, etc.) as the first ingredient
- Be a combination food with at least ¼ cup fruit and/or vegetable

Nutrient Standards

Nutrient standards should be assessed for the serving size available for purchase and include all accompaniments. Entrées, snacks, and sides must meet all of the following standards:

Table 1 Allowable limit per nutrient

Nutrient	Allowable limit
Calories, entrée	≤350 calories
Calories, snack or side	≤200 calories
Fat	≤35% of total calories from fat Exemptions: reduced-fat cheese, part-skim mozzarella, nuts, seeds, nut/seed butters, dried fruit with nuts or seeds (with no added nutritive sweeteners or fat), seafood with no added fat, eggs
Saturated fat	<10% of total calories from saturated fat Exemptions: reduced-fat cheese, part-skim mozzarella, nuts, seeds, nut/seed butters, dried fruit with nuts or seeds (with no added nutritive sweeteners or fat), seafood with no added fat, eggs
Trans fat	0 g of trans fat (<0.5 g)
Sodium, entrée	≤480 mg
Sodium, snack or side	≤200 mg
Sugar	≤35% of weight from total sugar Exemptions: dried/dehydrated fruits or vegetables without added nutritive sweeteners, dried fruits with nutritive sweeteners for processing and/or palatability, dried fruit with only nuts/seeds (no added nutritive sweeteners or fat)

Exemptions from General and Nutrient Standards

The following items are exempt from all of the general and nutrient standards:

- An entrée the day of and the day after it is served as part of a reimbursable meal
- Fresh and frozen fruits and vegetables with no added ingredients except water
- Canned fruits with no added ingredients except water, which are packed in 100% juice, extra light syrup, or light syrup
- Low sodium and no-salt added canned vegetables with no added fat

Entrées

An entrée is defined as the main course of a meal that meets one of the following definitions:

- A combination food of meat/meat alternate and whole grain-rich grain
- A combination food of meat/meat alternate and vegetable or fruit
- A meat/meat alternate alone (excludes yogurt, cheese, nuts, seeds, nut/seed butters, and meat snacks [e.g., beef jerky])
- A breakfast entrée defined by the menu planner and served as part of the School Breakfast Program

If a product does not meet any of the qualifications for an entrée, it must be evaluated against the nutrient standards for a snack/side.

VITA

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2002-2006	B.S., Food Science and Technology Kasetsart University, Bangkok, Thailand
2008-2010	Quality assurance section manager The Union Frozen Products Co., Ltd., Samut Sakhon, Thailand
2011-2015	M.S., Nutrition and Dietetics Mahidol University, Bangkok, Thailand
2014	Mahidol University Global Education Scholarships for Postgraduate Student Exchange Program Jumonji University, Saitama, Japan
2013-2015	Dietitian (Part time) at CKD-CAPD Clinic, HRH Princess Maha Chakri Sirindhorn Medical Center Nakhon Nayok, Thailand
2015-2017	Assistant Instructor in Nutrition and Dietetic Program Institute of Nutrition, Mahidol University, Bangkok, Thailand
2015	Regional Training on “Nutritional Status Assessment” Universitas Indonesia, Jakarta, Indonesia
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2017-2022	PhD Student and PhD Candidate Florida International University, Miami, Florida
2019-2021	Teaching Assistant Florida International University, Miami, Florida
2020	Stempel Publication Award Florida International University, Miami, Florida
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2021 Dietetic Internship
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PUBLICATIONS AND PRESENTATIONS

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