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Design of a Mobile Phone-Based Artificial Intelligence (AI) Application to Assess Dietary Intake and Provide Nudges to Improve Healthy Eating Choices

Formative Research in Ghana and Vietnam

Bianca C. Braga
Noora-Lisa Aberman
Alejandra Arrieta
Boateng Bannerman
Adam Burns
Gloria Folson
Phuong Huynh
Bastien Koch
Pete McCloskey
Phuong Nguyen
Sawudatu Zakariah-Akoto
David Hughes
Aulo Gelli

Poverty, Health, and Nutrition Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

AUTHORS

Bianca C. Braga (Curi.Bianca@tufts.edu) is a PhD candidate at Tufts University and a consultant at the International Food Pollicy Institute (IFPRI), Washington, DC.

Noora-Lisa Aberman (naberman@gainhealth.org) is a senior technical specialist at GAIN and was an associate research fellow at IFPRI.

Alejandra Arrieta (arrie1aalejandra@gmail.com) is a PhD candidate at the University of Washington and was a research analyst at IFPRI.

Boateng Bannerman (bboray@gmail.com) is a PhD candidate at the Noguchi Memorial Institute for Medical Research, University of Ghana.

Adam Burns (burns@edgeresearch.com) is the Chief Operations Officer and Senior Research Analyst at Edge Research, Arlington, Virginia.

Gloria Folson (gfolson@noguchi.ug.edu.gh) is a research fellow at the Noguchi Memorial Institute for Medical Research, University of Ghana.

Phuong Huynh (hnphuong@gmail.com) is the Deputy Director of the Food and Nutrition Training Center National Institute of Nutrition, Vietnam.

Bastien Koch (B.Koch@cgiar.org) is a research analyst in IFPRI's Poverty, Nutrition, and Health Divison, Washington, DC.

Pete McCloskey (petermccloskey1@gmail.com) the lead AI engineer at Plant Village at Penn State University.

Phuong Nguyen (P.H.Nguyen@cgiar.org) is a senior research fellow in IFPRI's Poverty, Nutrition, and Health Divison, Washington, DC.

Sawudatu Zakariah-Akoto (SZakariah-Akoto@noguchi.ug.edu.gh) is a Research Fellow at the Noguchi Memorial Institute for Medical Research, University of Ghana.

David Hughes (dph14@psu.edu) is an Associate Professor of Entomology and Biology at Penn State University.

Aulo Gelli (a.gelli@cgiar.org) is a senior research fellow in IFPRI's Poverty, Nutrition, and Health Divison, Washington, DC.

Notices

Abstract

Background: Low quality diets are a public health problem affecting individuals of all ages worldwide. Nudging for Good (NFG) is a new research project aimed at developing, validating, and examining the feasibility of using artificial intelligence (AI)-based technology to improve adolescent girls' diets in urban Ghana and Vietnam.

Objectives: Provide evidence to support the design of a new mobile phone intervention including: a) identifying the demand for mobile app to improve diets in adolescent girls; b) defining the intervention objectives and activities to be delivered via a mobile app; and c) assessing the potential for nudging functionality to be incorporated in the mobile app.

Methods: This study used mixed methods including both literature and nutrition-related app reviews, as well as focus group discussions. A literature review was conducted using PubMed and Google Scholar databases, and intervention studies using technology to improve nutrition outcomes of adolescents were included. Nine focus group discussions (five in Ghana and four in Vietnam) were undertaken with 61 girls to gauge smartphone and internet access and use and to obtain feedback on the prototype of a mobile app.

Results: Nine studies met the selection criteria for the literature review, including seven randomized control trials (RCTs) and two systematic reviews. The evidence from the literature on how technology-based nutrition interventions should be conducted and what should be the best outcomes of success was mixed. Most of the 22 apps reviewed required manual entry of dietary information, and recommended diets based on motivation to change body weight. In the focus groups discussions, the adolescents suggested modifications on the prototype of the mobile app we presented, and indicated possibility to regularly take pictures of foods and beverages during meal time.

Conclusion: We did not find an app available in either the Ghana or Vietnam markets that could improve dietary quality of adolescents without focusing on weight. Most apps available only had manual features to log food intake, which is time consuming. Moreover, adolescents expressed interest in using a new, modified version of the app we presented. We aim at developing a new mobile phone application based on AI technology that gives personalized and reliable nutrition advice to improve adolescent girls' diets. However, the literature review was not conclusive on what should be the characteristics of an app and how interventions to measure an app's impact on dietary quality should be conducted.

Keywords: Diet, adolescents, artificial intelligence technology.

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Introduction

Adolescence is characterized by rapid physical and psychosocial growth and development (Das et al., 2017). Inadequate diets and disease during adolescence can contribute to deficiencies that affect brain structure and function across the lifespan (Das et al., 2017; Fall et al., 2015; Bryan et al., 2004). For example, undernutrition during adolescence has long-term consequences for development and health, and it can affect the survival and wellbeing of children of adolescent girls (Bryan et al., 2004; Gómez-Pinilla, 2008). However, undernutrition is but one of the nutrition challenges faced by adolescents. There has been an increase in overweight prevalence due to changes in dietary intake and physical activity levels through modifications in the food systems and transportation modes, and greater accessibility to activity-saving technologies (Popkin *et al.*, 2020; Jaacks *et al*., 2019). Shifts to unhealthy diets and reductions in physical activity contributed to the global increase in unhealthy weights: the proportion of children and adolescents with obesity rose from less than 1% in 1975 to 6% for girls and 8% for boys in 2016 (Gómez-Pinilla, 2008). Unhealthy weight during childhood and adolescence is associated with psychosocial problems, social stigmatization, poor self-image (John et al., 2017), non-communicable diseases in adulthood (NCD-RisC, 2017; Freedman et al., 1999 Must & Strauss, 1999; Must, 1996), and reduced life expectancy (Biro & Wien, 2010; Peeters et al., 2003; Virdis et al., 2009;).

One of the factors that affect weight is food choice. Food choices are mediated by individual and environmental factors including food availability, access, social influence and preferences (Herforth & Ahmed, 2015). Adolescence is a time when habits are formed, when youth start making their own decisions and are particularly sensitive and selective about information sources for decisions. Advertising, nutrition education, food vending and peers play a role in food choices (Herforth & Ahmed, 2015; Hawkes et al., 2015). Schools are an important food environment for adolescents in high-income countries (Kubik et al., 2003; Weschler et al., 2000). Although the double burden of malnutrition, or a high prevalence of both under and over nutrition in the same population, has been increasing faster in low- and middle-income countries (LMIC) than in high-income countries (Popkin *et al.*, 2020), less is known about food environments in LMIC (Hawkes et al., 2015; Kubik et al., 2003; Story et al., 2002; Weschler, 2000). However, interventions in the home, community and workplace can shape the food environment and influence diets (Bjørge et al., 2008; Engeland et al., 2004).

Moreover, interventions delivered via the internet, gadgets, and telehealth are potentially engaging and scalable (Australia Bureau of Statistics, 2011). The use of technology-based interventions such as apps, text messages, internet-based nutrition curricula, and others have been used to teach adolescents about nutrition and healthy eating (Kaakinen *et al.,* 2018). Wearable sensors that collect real-time behavior and physiological data may improve data collection reach and quality, thereby increasing the opportunities for interactive and adaptive interventions (Turner *et al.,* 2015). These personalized interventions can change behavior and help in clinical decision-making (Kumar *et al.*, 2013). Although screen time has been linked to sedentarism and obesity, mobile technology can be used as part of strategies to reduce risky behavior that typically emerges in adolescence, including unhealthy diets (Champion *et al.,* 2019; Stiglic & Vinner, 2019).

Nudging for Good (NFG) is an innovative project aimed at developing, validating, and examining the feasibility of using mobile Artificial Intelligence (AI)-based technology to improve adolescent girls' diets in urban Ghana and Vietnam. NFG involves a new interdisciplinary collaboration between the International Food Policy Research Institute (IFPRI), Penn State/FAO, the University of Ghana, the Thai Nguyen National Hospital, the Thai Nguyen University of Pharmacy and Medicine, and the National Institute of Nutrition (NIN) in Vietnam.

This paper summarizes the findings of formative research aimed at generating evidence to support the development of a new mobile phone application (the "app") and has the following objectives: a) identifying the demand for mobile app interventions to improve diets in adolescent girls; b) defining the intervention objectives and activities to be delivered via a mobile app; and c) assessing the potential for nudging functionality to be incorporated in the mobile app.

Country context

Ghana is a West-African country with a population of approximately 30 million people (Davies, 2021), while Vietnam is a Southeast Asian country with about 96 million people (Duiker, 2020). They are both lower-middle income countries undergoing a nutrition transition that includes decreasing undernutrition rates, coupled with increasing prevalence of overweight and non-communicable diseases (World Bank, 2020; Global Burden of Disease, 2020). Increasing incomes and urbanization have contributed to changing diets, including greater exposure to food marketing, access to healthy and unhealthy foods, and reliance on convenience foods (Popkin, 1994; Popkin *et al.,* 2012). However, micronutrient deficiencies are still widespread (Ritchie & Roser, 2017). The prevalence of anemia in women of reproductive age, for example, is 46% in Ghana and 24% in Vietnam (Ritchie & Roser, 2017).

Methods

A review of the literature on internet-based interventions aimed at improving the dietary quality of adolescents worldwide was undertaken to assess 1) tools that could be used to nudge teenagers to make healthy food choices; 2) the effectiveness of interventions and how success was measured for these types of interventions, and 3) how diet-related apps can be made attractive to users. To fully answer these questions, we complemented the literature review with an analysis of electronic nutrition-related interventions, and reviewed the most downloaded and best-rated nutrition apps from the Apple App Store and Google Play from Ghana and Vietnam. We then undertook focus group discussions with adolescent girls aged from 15 to 17 years in both countries to explore the use of mobile phones and social networks, and to provide insights for the development of the application user-interface. The focus groups also explored opportunities to 1) make the new tool age-appropriate, fun to use, and attractive to adolescents; and 2) identify appropriate nudging approaches for adolescent girls to avoid unintended adverse effects such as singling out underperformers, or online bullying.

Literature review

To determine the most effective online tools for nudging adolescents to make healthier food choices and the best measures of success of internet-based nutrition interventions, we searched for articles in PubMed and Google Scholar without year limits. We included articles if 1) individuals in the sample were adolescents (aged 10 to 25 years), 2) interventions used electronic devices or computers to improve nutrition outcomes, 3) studies were published in English, 4) studies were available electronically, 5) studies had treatment and control groups, and 6) studies were peer-reviewed. We also included articles that analyzed the feasibility and acceptability of the technology used to change food-related behaviors. No article analyzed usability (or features and functions of technology). We excluded articles about electronic interventions that had as the only goal to improve behavior related to dietary-related psychological problems such as anorexia and bulimia nervosa. A research assistant selected articles that were further screened by three independent researchers according to the inclusion and exclusion criteria. After the selection of studies, data about their characteristics (author, year, country, design, and sample), main features of the intervention, outcomes measures, adherence, and effects of the interventions were extracted and synthesized in Table 1 for intervention studies and Table 2 for systematic reviews. We used the Quality Assessment of Controlled Intervention Studies of the National Institutes of Health to assess the quality of the studies as summarized in Table 3 for intervention studies and Table 4 for systematic reviews (National Institutes of Health, 2020). Because the design, samples, settings, and outcomes of the studies were very different, it was not appropriate to combine them statistically for a meta-analysis.

Review of existing mobile phone applications

To learn what makes apps attractive to users we searched for all nutrition-related apps in the Apple App Store and Google Play available for download in Ghana and Vietnam. We screened the top 100 paid and top 100 unpaid apps in the Health and Fitness category and downloaded all relevant apps compatible with iOS or Android. The inclusion criteria were: 1) apps related to nutrition and diet, 2) apps that track dietary intake, 3) apps that do not only track fasting, 4) apps that had at least one user rating.

Focus group discussions

Participants

We conducted four focus group discussions (FGD) with 32 adolescent girls in Thai Nguyen, Vietnam, using semi-structured discussion guides. The girls were randomly selected and recruited from 10th and 11th grades of an urban high school. In Accra, Ghana, we used the same method to recruit 29 girls from high schools in five urban neighborhoods and conducted five focus group discussions. All adolescents were purposively selected on a voluntary basis and varied in socioeconomic and demographic backgrounds and school performance. The FGD pilots were conducted with six girls selected based on convenience from Hanoi City, Vietnam, and eight girls in Accra, Ghana; the information from the pilots was included in this analysis.

During the FGDs, adolescents were asked about their use of smartphones, social media preferences, and their understanding of healthy diets. They were then shown the prototype of the mobile app and asked for their opinion on feasibility, usability, and acceptability (Bowen et al., 2010). The interviews in Vietnam lasted from 90 to 120 minutes and were conducted in Vietnamese by two senior researchers from the National Institute of Nutrition in Hanoi. The interviews in Ghana lasted from 80 to 136 minutes and were led in English by two senior researchers from the Noguchi Memorial Institute for Medical Research at the University of Ghana. All interviews were recorded and transcribed as non-verbatim. Field notes and interviewers' observations were also incorporated into the transcripts.

The data were analyzed using the framework approach, which provides a systematic structure to manage and identify FGD themes (Smith & Firth, 2011). An outline of the data analysis plan was prepared during the initial stage of data collection. *A priori* codes were assigned based on interview guidelines, but the final code list was developed after primary coding. The data were then used to identify recurring themes and sub-themes such as smartphone and social media use, and feedback on the app prototype developed by our engineering team. Finally, data were systematically indexed, responses were summarized according to the guidelines previously developed and the most common ones were synthesized separately for each FGD.

Results

Literature Review

Characteristics of the studies

Seven independent randomized controlled trials (RCTs) studies and two systematic reviews met the inclusion criteria. The systematic reviews summarized the literature published until 2014, therefore we also included all independent RCT studies that were not included in these two reviews. We use the word "independent" for RCT studies that were not part of these systematic reviews. Of the independent RCT studies, two were conducted in the United States (Chen *et al.,* 2018; Jake-Schoffman *et al.,* 2018), two in Canada (Chamberland *et al.,* 2017; Goodman *et al.,* 2018), one in the Netherlands (Alblas *et al.,* 2018), one in Hong Kong (Abraham *et al.,* 2015), and one in Thailand (Rerksuppaphol & Rerksuppaphol, 2017). Of the 24 studies included in the two systematic reviews considered (Champion *et al.,* 2019; Ho *et al.,* 2018), 18 were conducted in the US, two in Belgium, one in Mexico and Spain, one in Malaysia, one in the Netherlands, and one in Portugal. The RCT studies met from 36% to 86% of the quality assessment criteria, while the systematic reviews met from 80% to 100% of the criteria (National Institutes of Health, 2020).

Considering all independent RCT studies and the ones that were part of the systematic reviews, the types of technology-based interventions included internet-based curriculum to improve nutrition knowledge, cell phone calls and texts, computer games, apps, emails, accelerometers, and pedometers. Besides technology, studies used in-person visits to clinics, in-school participation, mindfulness techniques, and parental participation (Abraham *et al.* 2015; Chamberlant *et al.,* 2017). Two of the seven independent RCTs and ten studies from the 24 evaluated in the systematic reviews had parental participation (Abraham *et al.* 2015; Champion *et al.,* 2019; Ho *et al.,* 2018; Jake-Schoffman *et al.,* 2018). Intervention periods varied from one ten-minute session to 12 months (Alblas *et al.,* 2017; Ho *et al.,* 2018). The follow-up period was also extremely heterogeneous, ranging from two weeks to 36 months (Champion *et al.,* 2019).

Outcomes

The primary outcomes of the studies included anthropometric indicators such as body mass index (BMI) and BMI z-score, waist and hip circumference, and dietary intake such as consumption of sugar-sweetened beverages, fats, fried foods, fast-foods, fruits and vegetables, milk and alternatives, vitamin D, as well as biomarkers of micronutrient status including the blood concentration of vitamin D. Other outcomes were physical activity, TV and computer screen time, and feasibility and acceptability of the technology used in the interventions, and implicit attitudes towards food and dietary intake (Abraham *et al.,* 2015; Jake-Schoffman *et al.,* 2018). The majority of studies used self-reported data to measure the impact of interventions on anthropometry, physical activity, dietary intake, and knowledge in nutrition and health (Abraham *et al.,* 2015; Alblas *et al*., 2017; Chamberlant *et al*., 2017, Champion *et al*., 2019, Chen *et al*., 2018, Goodman *et al*., 2018, Ho *et al*., 2018, Jake-Schoffman *et al.,* 2018). Outcomes measured by health professionals included BMI and blood concentrations of vitamin D (Chamberlant *et al.,* 2017; Goodman *et al.,* 2018; Rerksuppaphol & Rerksuppaphol, 2017). In one of the studies, weight, height, waist and hip circumference, and blood pressure was measured but it was not clear whether these outcomes were self-reported (Abraham *et al.,* 2015).

Dietary intake was self-reported in all studies (Abraham *et al.* 2015, Chamberlant *et al.,* 2017, Champion et al., 2019; Chen et al., 2018, Goodman et al., 2018, Ho et al., 2018, Jake-Schoffman *et al.,* 2018). Two of four independent RCT studies that analyzed the impact of interventions on the consumption of fruits and vegetables showed an increase in consumption during the intervention (Alblas *et al.,* 2017; Chamberland *et al.,* 2017; Chen *et al.,* 2018; Jake-Schoffman *et al.* 2018). In a school-based experiment, students in the intervention group consumed much higher fruits and vegetables compared to the control group (6.4 vs. 3.7 servings/day) (Chamberland *et al.,* 2017). In contrast, another study which parents and children dyads used a mobile app, accelerometers and pedometers did not find treatment effects for fruits and vegetables consumption, but found increase in fruit consumption (0.3 servings/day) in both groups over time (Jake-Schoffman *et al.,* 2018). The two studies that tried to change implicit attitudes towards the consumption of fruits and vegetables, via internet-based school curriculum (Chamberland *et al.,* 2017) and computer game interventions (Alblas *et al.,* 2017), were not successful. One study did not report results on dietary intake (Abraham *et al.,* 2015). Data from the nine studies included in one of the systematic reviews showed a small but significant increase in the mean servings per day of fruits and vegetables in the immediate post-intervention period, without significant heterogeneity between trials (Champion *et al.,* 2019). These effects were not sustained in the follow-ups, but there was heterogeneity on the number of mean servings per day of fruits and vegetables between the follow-up trials (Champion *et al.,* 2019).

The consumption of milk and milk alternatives, and intake of vitamin D was found to have increased post intervention in two RCTs (Chamberland *et al.,* 2017; Goodman *et al.,* 2016). A school curriculum-based intervention stimulated an increase in the consumption of milk and milk alternatives (Chamberland *et al.,* 2017). Post intervention, students in the intervention group consumed more milk and milk alternatives than the ones in the control group (3.5 vs 1.6 servings/day) (Chamberland *et al.,* 2017). In other study, participants in the intervention group received emails reminding them to complete records of vitamin D consumption through an app, and to watch videos, and read education slides with key points related to vitamin D and health (Goodman *et al.,* 2016). Mean vitamin D intake increased significantly from pre- to post-test (407 IU vs. M=619 IU) and more in the intervention than in the control group (F=4.09) (Goodman et al., 2016). Mean blood vitamin D3 increased significantly from pre- to post-test (M=28 vs. M=43nmol/L) but did not differ significantly between intervention and control groups (Goodman *et al.,* 2016). Vitamin D knowledge increased significantly only in the intervention group (Goodman *et al.,* 2016).

Out of all the independent RCT studies, only two involved interventions to decrease the consumption of sugar-sweetened beverages (Chen et al., 2018; Jake-Schoffman et al., 2018). Adolescents had a statistically significant reduction in sugar-sweetened drink consumption (z=-0.44, p=0.001) (Chen et al., 2018). Also, children had not had a significant decrease in daily serving consumption of sugar-sweetened beverages (− 0.1 servings, p = 0.05) (Jake-Schoffman et al., 2018). Four studies from the systematic reviews assessed the intake of sugar-sweetened beverages and high-energy snacks, but generally no change was seen immediately after the intervention, nor at follow-up (Champion et al., 2019). No difference was found in breakfast nor fast-food consumption between treatment groups (Chen et al., 2018).

Two out of three independent RCT that were not sufficiently powered to detect treatment effects of internet-based curriculum and knowledge interventions on BMI reported a decrease in this outcome (Chen et al., 2018; Rerksuppaphol & Rerksuppaphol, 2017). Another study designed an intervention in which adolescents in the intervention group had internet training about physical activity and nutrition, mindful training sessions and visited an obesity clinic, but had no impact on BMI, body fat nor on blood pressure (Abraham et al., 2017). Another study did not find significantly different body weight change between the intervention and control groups (1.3 ± 1.9 vs. 1.1 ± 1.9 kg), $p=0.37$ (Chamberland et al., 2017). A null result was also observed for changes in BMI z-scores between intervention and control groups (-0.09 ± 0.02 vs. -0.04 ± 0.03 kg), $p=0.12$ (Chamberland et al., 2017).

In an experiment in the US, adolescents in the intervention group had a statistically significant reduction in BMI ($z=-4.89$, $p<0.001$) and BMI z-score ($z=-4.72$, $p<0.001$) compared to adolescents in the control group (Chen et al., 2018). In Thailand, children and adolescents had significantly higher BMI, BMI z-score, weight z-score and waist-to-height ratio in the control group than in the intervention group (Rerksuppaphol & Rerksuppaphol, 2017). There was also a significantly higher percentage of overweight or obese individuals in the control group than in the intervention group (56.6% vs. 39.6%) ($p=0.009$) (Rerksuppaphol & Rerksuppaphol, 2017). Moreover, compared to baseline, children in the intervention group had no changes in weight z-score (-0.04, 95%, CI -0.16 to 0.07, $p=0.438$) and BMI z-score (-0.001, 95%, CI -0.19 to 0.18, $p=0.988$) at the end of the study (Rerksuppaphol & Rerksuppaphol, 2017). However, children in the control group had significant increases in weight z-score (0.25, 95%, CI 0.11 to 0.39, p-value<0.001) and BMI z-score (0.45, 95%, CI 0.27 to 0.63, p-value<0.001) at the end of the study (Rerksuppaphol & Rerksuppaphol, 2017). Both systematic reviews concluded that interventions that aimed at reducing BMI had small to null impact (Champion et al., 2019; Ho et al., 2018).

None of the three independent RCT studies that aimed at changing physical activity levels detected improvement in physical activity, although none of these studies were sufficiently powered to do so (Abraham et al., 2015; Chen et al., 2018; Jake-Schoffman et al., 2018). Two of them used pedometers and accelerometers to collect data (Chen et al., 2018; Jake-Schoffman et al., 2018). From the systematic reviews, one of the studies included used pedometers and three used accelerometers to measure physical activity (Champion et al., 2019; Ho et al., 2018). The intervention that used the pedometers relied on self-reported data collected by this device, though no effect was detected on physical activity (Patrick et al., 2013). All other interventions studies included in the systematic reviews relied on self-reported data based on questionnaires (Champion et al., 2019; Ho et al., 2018).

Two interventions aimed at lowering blood pressure (Abraham et al., 2015; Chen et al., 2018). One did not observe an impact of the internet curriculum, cell phone calls and reminders in blood pressure (Abraham et al., 2015), while the other did not report results on this outcome (Chen et al., 2018). Implicit attitudes concerning food were also generally found not to change post-intervention (Alblas et al., 2017). The two independent RCT studies that analyzed the feasibility and acceptability of interventions based on internet-based curriculum, cell app, email, as well as phone calls/texts, accelerometer, and pedometer, were successful in improving diet and health outcomes (Abraham et al. 2015; Jake-Schoffman et al. 2018). Feasibility and acceptability outcomes were measured according to the usage of intervention material (i.e., logins in intervention platform) and self-reported data collection (Abraham et al. 2015, Jake-Schoffman et al., 2018).

Table 1: Summary of the randomized-controlled studies about interventions with technology to improve food choice

Author, year, country	Study design, sample size and age	Length of the intervention, follow-up and description of intervention	Type of technology-based intervention	Food-choice related outcomes	Other outcomes	Principal findings: effect of the intervention	Adherence
Abraham et al. (2015). Hong-Kong.	RCT n=48. Mean age=14.4 y Age range=12 to 18 y	T1) Care visit at an obesity clinic + 12 week internet training, modified internet curriculum that consisted of twelve 15-minute interactive sessions with information about nutrition and physical activity. Relaxation mindful eating practices. Cell phone follow-up over 6 months. T2) Personalized dietary and exercise advice at each visit to the clinic conducted by dietitian/nutritionist. Parental participation. This was a 6-month intervention. C) Usual care visit at an obesity clinic.	Internet-based curriculum with cell phone calls/texts reminders	Primary: feasibility of adapting and using an existing internet curriculum and nutritional program with cell phone follow-up for obese teens. Secondary: dietary intake, and knowledge related to nutrition	Primary: none. Secondary: physical activity level, stress level, and knowledge related to physical activity, weight and blood pressure.	The high recruitment rate, high retention rate, high internet log-in rate, and reasonable compliance with completion of online curriculum sessions and use of cell phone reminders show that the curriculum is feasible. Patients also reported good satisfaction with the curriculum. No impact of the interventions on the BP, body fat, BMI, physical activity and stress. The impact on dietary intake was NR.	T1) 14 out of 16 subjects read the curriculum (87.5%). The majority of subjects (71%) completed all lessons. Only four parents read the curriculum. T2) A total of 400 messages were sent to 16 subjects. 15 subjects opted to receive the message by cell phone and one preferred email only. The response rate to dietary goals and exercise goals were 78.3% and 77.5%, respectively.
Alblas et al. (2017). The Netherlands.	RCT (2X2X2 mixed subject design) n=125 Mean age=20.17 y with SD=1.88. Age range ≥ 18 y	T) Play 10 minutes of computer game which goal is to supply a fictitious island with as much healthy foods as possible to avoid sinking. C) Similar to treatment but used clean and fossil fuel instead of foods. Experiment took 2 months.	Mobile app, accelerometers, pedometer, email with program materials and newsletter.	Primary: Implicit attitudes towards foods at baseline and after the health game or the control game. Foods used in the experiment were fruits and chocolate snacks.	None	Participants playing the control game had significant reduction ($p<0.001$) in healthy IAs from baseline (M=0.86, SE=0.05) to post-test (M=0.69, SE=0.05), while for participants playing the health game, the reduction from baseline (M=0.85, SE=0.05) to post-test (M=0.79, SE = 0.05) healthy IAs was significant ($p=0.021$).Health games reduced healthy implicit attitudes in control groups, but did not change implicit attitudes in treatment group. Baseline implicit attitudes did not moderate the effect of health game. Those with healthy implicit attitudes in baseline were more affected by the health game in virtual choice than those with less healthy implicit attitudes in baseline.	Not reported

RCT stands for randomized controlled trial; T) stands for treatment group (T1 is treatment group one, T2 is treatment group 2); C) stands for control group.

NR stands for not reported .Y stands for years-old; *Blood pressure was mentioned was one of the variables measured in the study, but results were not reported

Table 1: Summary of the randomized-controlled studies about interventions with technology to improve food choice (continuation)

Author, year, country	Study design, sample size and age	Length of the intervention, follow-up and description of intervention	Type of technology-based intervention	Food-choice related outcomes	Other outcomes	Principal findings: effect of the intervention	Adherence
Chamberland et al. (2017). Canada.	Clustered RCT (Randomization of school classes) n=282. Mean age=13.6 y. Age range = 13 to 14.	Classes were randomized to intervention (modified curriculum) and control (regular) for 6 weeks. Participants in the intervention were instructed to enter their consumption of fruits and vegetables 2x/day from 5x/week. Follow-ups in the 2nd, 4th and 6th weeks (intervention period), in which 2-week summary reports were analyzed by students with the help of teachers. Also follow-ups in the 9th and 17th (after intervention period).	Internet-based nutrition intervention	Primary: Consumption of fruits and vegetables, milk and alternatives	BMI z-scores and body weight change	Students in the intervention group consumed an average of 6.4 daily servings of fruits and vegetables and 3.5 daily servings of milk and alternatives, while the control group consumed an average of 3.7 servings of fruits and vegetables and 1.6 servings per day after at the intervention. These differences were statistically significant. Body weight change was not significantly different between the intervention and control groups (1.3 ± 1.9 kg vs 1.1 ± 1.9 kg, P = 0.37, respectively). The same was observed for changes in BMI z-scores (intervention: −0.09 ± 0.02 kg; control: −0.04 ± 0.03 kg, P = 0.12).	Attendance at school for entering data on the website influenced the success of the program. It was harder to complete data entry when students missed classes. Many students struggled to take responsibility outside of school hours to record their data.
Chen et al. (2018). USA.	RCT pilot. n=40. Mean age=14.9 with SD=1.67.	Usage of wearable sensor for 6 months, participation on 8 online education modules for three months (intervention length), and after completing the modules received tailored, biweekly text messages for three months. All assessments were conducted at baseline, three months and six months.	Wearable sensor (Fit-bit Flex), online education and text messages	Primary: None. Secondary: Sugar-sweetened beverage, breakfast, fast-food, fruits and vegetables, diet, self-efficacy	Primary: BMI and BMI z-scores. Secondary: screen time, physical activity, self-efficacy, physical health and psychosocial health	Adolescents in the intervention group had statistically significant reduction in BMI (z=-4.89, p<0.001) and BMI z-score (z=-4.72, p<0.001), sugar-sweetened drink consumption (z=-0.44, p=0.001), screen time (z=-0.51, p<0.001), and increased self-efficacy in nutrition (z=0.11, p=0.02) and physical activity (z=0.16, p=0.5). No difference was found in breakfast, fast-food consumption, vegetable and fruit consumption and physical activity time between intervention and control groups.	Not reported
Goodman et al. (2016). Canada	RCT. n=90. Intervention n=59 and control n=50. Mean age=22 with SD=2. Age range=18 to 25.	Intervention length was 12 weeks (36 recording days). On weeks 3, 6 and 9, intervention participants received an email that reminded them to complete their recordings, as well as a vitamin D newsletter. The mean study duration was 128 days with SD=31 days.	Vitamin D-calculator app, goal setting check-in email, and videos and education slides with 8 key points related to vitamin D.	Primary: Intake, knowledge, and/or perceptions of vitamin D among this sample of young adults. Blood concentrations of 25(OH)D3.	None	Mean vitamin D intake increased significantly from pre-test (M=407, SD=460 IU) to post-test (M=619, SD=655 IU), p<0.001. Mean intake increased more in the intervention than in the control group (F=4.09, p=0.046). Mean blood vitamin D3 increased significantly from pre-test (M=28, SD=16 nmol/L) to post-test (M=43, SD = 29 nmol/L), p<0.001, but did not differ significantly between groups. Vitamin D knowledge increased significantly only in the intervention group.	Over a third of participants submitted no app recordings. Among those who participated, the average rate of app submissions was 58% (M = 21 recordings).

Table 1: Summary of the randomized-controlled studies about interventions with technology to improve food choice (continuation)

Author, year, country	Study design, sample size and age	Length of the intervention, follow-up and description of intervention	Type of technology-based intervention	Food-choice related outcomes	Other outcomes	Principal findings: effect of the intervention	Adherence
Jake-Schoffman et al. (2018). USA.	RCT. Randomization of dyads (parents and adolescent). n=33. Intervention group 1 n=16. Intervention group 2 n=17. Mean age parents=43 with SD=5.8. Mean age adolescents=11 with SD=0.9. Age range=9 to 12 y.	Intervention length was of 12 weeks. At baseline and follow-up, dyads wore accelerometers for seven days. In the twelfth week, both intervention groups received study materials and correspondence.	Mobile app, accelerometer, pedometer, email with program materials and newsletter.	Primary: feasibility, acceptability and preliminary effectiveness of two family-based health promotion programs that had food choice related-goals (fruits and vegetables, sugar-sweetened beverage and fast-food)	Primary: Feasibility, acceptability and preliminary effectiveness of two family-based health promotion programs that also had non-food-choice related goals (physical activity)	The intervention was feasible and accepted. There were no group by time differences for physical activity or healthy eating. However, there was a significant increase in average daily steps (1397 steps, $p = 0.04$) and servings of fruit (0.3 servings, $p = 0.02$) and a marginally significant decrease in children's daily servings of sugar-sweetened beverages (− 0.1 servings, $p = 0.05$) when intervention groups of parents and children were combined.	The overall retention was of 94%. Parents: Kept step and food logs for an average of 9.4 weeks (SD=3.7) (median=12). Read an average of 8.5 weekly newsletters (SD=3) of the 12. Adolescents: kept step and food logs for an average of 9 weeks (SD=3.9) (median=11.5). Read an average of 5.2 weekly newsletters (SD=4.3) of the 12. Families: downloaded an average of 5.7 apps (SD=3.1) of the 12 apps sent with the weekly newsletter. 89% of families downloaded week 1 app, but rates declined throughout the weeks. Parents (97%) and children (86%) rated the program favorably.
Rerksuppaphol & Rerksuppaphol (2017). Thailand.	RCT. n=218. Control n=106. Intervention n=111. Age mean=10.7 with SD=3.	Intervention length was of 4 months. Anthropometric data were collected at baseline and every following month.	Internet-based program to collect data on nutrition, anthropometry and physical activity.	None	Primary: Changes in percentage of overweight and/or obese children at the end of the study. Secondary: Changes in BMI, waist and hip circumference.	Children and adolescents in the control group had significantly higher BMI, BMI z-score, weight z-score and waist-to-height ratio than children and adolescents in the intervention group. There was a significantly higher percentage of being overweight or obese in the control group (56.6%) than in the intervention group (39.6%) ($p=0.009$). Compared to their baseline, children in the intervention group had no changes in weight z-score (-0.04, 95%CI -0.16 to 0.07, $p=0.438$) and BMI z-score (-0.001, 95%CI -0.19 to 0.18, $p=0.988$) at the end of the study. Children in the control group had significant increases in weight z-score (0.25, 95%CI 0.11 to 0.39, p-value<0.001) and BMI z-score (0.45, 95%CI 0.27 to 0.63, p-value<0.001) at the end of the study, but children in the intervention group had not.	Not reported

Table 2: Summary of the review studies about interventions with technology to improve food choice

Author, year	Country	Study design, sample size and age	Length of the intervention and follow-up	Type of technology-based intervention	Outcomes	Principal findings: effects of the intervention	Adherence
Champion et al. (2019)	Systematic review with studies from the USA (n=10), the Netherlands (n=1), Belgium (n=2), and Mexico and Spain (n=1)*	14 publications. Sample sizes ranged from n=91 to n=4158. Total sample n=18,873 students. Mean age: 13·41 years (SD 1·52). Age range:11-18 years.	The duration of the interventions ranged from one 20-30-minute session to three years. 21 trials had follow-up sessions that ranged from 2 weeks to 36 months.	Internet, computers, tablets, mobile technology, or tele-health	Consumption of SSB, fats, fruits and vegetables, physical activity, screen time, smoking and alcohol consumption	Electronic-health school-based interventions significantly increased fruit and vegetable intake, but no effects were seen for fat or sugar-sweetened beverage or snack consumption. Interventions significantly increased accelerometer-measured and self-reported physical activity, and reduced screen time immediately after the intervention. However, effects were not sustained at follow-up when data were available.	Not reported
Ho et al. (2018)	Systematic review with studies from the USA (n = 8), Portugal (n = 1), and Malaysia (n = 1).	10 publications. Sample sizes ranged from n=57 to n=101 participants. Total sample size n=505. Mean age ranged: 13.1-15.2 years. Age range: 11-18 years.	The duration of the interventions ranged from 3 months to 12 months. Three trials had follow-up sessions, that ranged from 8 months to 24 months.	Internet-based interventions that used self-guided programme through a web-site with interactive components.	Primary: BMI and BMI z-score. Secondary: quality-of-life, psychosocial, physical activity and frequency of fried food consumption.	Internet-based self-monitoring interventions exerted a small effect size on the reduction of BMI.	It was unclear if intervention impacts were sustainable in the long term as only three trials presented follow-up data and one trial reporting follow-up beyond one year.

*We did not include the studies from Champion et al. which interventions were to exclusively reduce smoking and alcohol consumption

Table 3: Quality assessment of randomized-controlled intervention studies included

Questions to assess the quality of the studies included	Abraham et al. (2015)	Alblas et al. (2017)	Chamberland et al. (2017)	Chen et al. (2018)	Goodman et al. (2016)	Jake-Schoffman et al. (2018)	Rerksuppaphol & Rerksuppaphol (2017)
1. Was the study described as randomized, a randomized trial, or an RCT?	Yes	Yes	No, but randomized clustered intervention	No, but randomized clustered pilot	Yes	Yes	Yes
2. Was the method of randomization adequate (i.e., use of randomly generated assignment)?	Yes	Yes	NR	Yes	Yes	NR	Yes
3. Was the treatment allocation concealed (so that assignments could not be predicted)?	Yes	NR	NR	NR	Yes	Yes	Yes
4. Were study participants and providers blinded to treatment group assignment?	Yes	NR	No	Yes	Yes	Yes	NR
5. Were the people assessing the outcomes blinded to the participants' group assignments?	NR	NR	NR	Yes	Yes	NR	NR
6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?	Yes	Yes	Yes	Yes	Yes	No	Yes
7. Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?	Yes	Yes	No	Yes	Yes	Yes	Yes
8. Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?	Yes	Yes	No	Yes	No	Yes	Yes
9. Was there high adherence to the intervention protocols for each treatment group?	Yes	Yes	NR	NR	No	Yes	NR
10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)?	Yes	NR	NR	NR	NR	NR	NR
11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes	No
12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?	No	Yes	Yes	No	Yes	No	Yes
13. Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
14. Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?	Yes	Yes	Yes	Yes	NR	NR	NR
Percentage of "yes" answers from total questions excluding NR	86%	71%	36%	71%	79%	57%	57%

Table template extracted from the National Institutes of Health at https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools on 7/1/2021; NR stands for not reported

Table 4: Quality assessment of the review studies included

Author, year	Champion et al. (2019)	Ho et al. (2018)
1. Is the review based on a focused question that is adequately formulated and described?	Yes	Yes
2. Were eligibility criteria for included and excluded studies predefined and specified?	Yes	Yes
3. Did the literature search strategy use a comprehensive, systematic approach?	Yes	Yes
4. Were titles, abstracts, and full-text articles dually and independently reviewed for inclusion and exclusion to minimize bias?	No	Yes
5. Was the quality of each included study rated independently by two or more reviewers using a standard method to appraise its internal validity?	Yes	Yes
6. Were the included studies listed along with important characteristics and results of each study?	Yes	Yes
7. Was publication bias assessed?	No	Yes
8. Was heterogeneity assessed? (This question applies only to meta-analyses.)	Yes	Yes
Percentage of "yes" answers from total questions excluding NR	75	100

Table template extracted from the National Institutes of Health Website at https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools on 7/1/2021

Adherence

Out of the seven RCTs included, three gave precise, quantitative information on adherence rates, of which two reported high adherence (Abraham et al. 2015; Goodman et al., 2016; Jake-Schoffman et al. 2018). The systematic reviews did not report relevant information on adherence. Abraham and colleagues reported a high response rate, but there was no impact in diet and physical activity, possibly for lack of power (Abraham et al. 2015). Also, Jake-Schoffman and colleagues showed overall high retention rates, feasibility, acceptability, and an increase in self-monitoring steps, consumption of fruits, and a decrease in the consumption of sugar-sweetened beverage (SSB) (Jake-Schoffman et al. 2018). However, the study lacked power as well (Jake-Schoffman et al., 2018). Goodman and colleagues showed low adherence to the intervention protocol and no difference in blood concentration of vitamin D between control and treatment groups (Goodman et al., 2016). Still, there was an increase in self-reported vitamin D intake that may be explained by differential drop-out rates in the control and intervention groups (Goodman et al., 2018).

Review of existing mobile phone applications

To analyze the supply of smartphone apps in Ghana and Vietnam, we downloaded and used for one week all 22 apps available in the major app stores that tracked dietary intake. The majority of the apps focused on dietary intake and weight management. Logging dietary information mostly involved manually entering food and portion sizes which was time-consuming and would also affect the quality and quantity of the dietary data: Users had to manually search for items in 19 of the 22 apps, select them, and enter the portion size information. Only three apps had automated features that facilitated entering dietary information, including taking picture of foods and beverages, use barcodes, and provide information through nutrition facts panels.

Most apps available for download in Ghana (summarized in Table 5) and Vietnam (Table 6) tracked macronutrient intake in grams and total calories, water intake, and physical activity. They had features to calculate optimal caloric and nutritional intake when users entered information on food and beverage type and quantity consumed. We found seven apps that met our criteria in the Apple App Store and Google Play for Ghana. One had only an unpaid version, one had only a paid version, and five had paid upgraded versions. There was a vast disparity in the number of downloads of these apps. The most popular app, *MyFitness Pal*, had four million ratings summed from both stores, while the least popular, *Calorie Counter by GetFit*, had 79 ratings. The goal of all apps available in Ghana was to manage dietary intake and weight. Two of them offered meal plans, and one offered personalized meals. The *Carb Manager Keto* was the only app that managed the ratio between macronutrients to help users have a low carbohydrate diet. *Yazio* was the only app that had a smart adding feature that helps to log foods that are typically eaten together. *Calorie Counter by GetFit* was the only app that used a bar code and voice search functions. Only two apps developed interactions between users*: Calorie Counter by Easy Fit* through a Facebook community, and *MyFitness Pal* through *iMessage*. Most apps sent reminders to eat meals, drink water, and log dietary intake information. *Yazio* was the only one that sent reminders to log weight information, *Calorie Counter by GetFit* sent tips for healthy eating and to motivate the start and continuation of fasting, as did the *Lose It!* app.

For Vietnam, we found 15 apps that met our criteria in the Apple App Store and Google Play, of which eight were unpaid, and seven had unpaid and up-graded paid versions. The most popular was *Yazio* with about 315,000 ratings. *Meal Scanner* had zero-rating in the Apple App Store and was not available in Google Play. From the apps available in both stores, the sum of the number of ratings went from less than ten to more than 300,000. The majority of apps did not send notifications, but the most common notification from the apps that manage weight were reminders before mealtime. *Yazio* sent reminders for users not to forget to log weight and diet information; *Nutrition Plan and Menu to Reduce Weight* sent reminders to be physically active. Only four apps did not track weight or BMI, of which two use picture-taking as a tool to improve users' diets. For example, *Meal Scanner* could store pictures of meals in a photo gallery, while *Food Analysis –*

Nutrition and Health had a barcode scanner to track caloric intake. *Meal Tracker* could not be downloaded in the Apple App Store nor in Google Play, and *Food Analysis* did not send notifications during the period analyzed.

Focus group discussions

In this section, we present the results of the focus groups discussions with adolescents from Accra, Ghana and Thai Nguyen, Vietnam.

Smartphone ownership and social media use

Most adolescents reported having access to smartphones, but most in Ghana shared them with family members. Adolescents reported using smartphones to study, make new friends, take photos and entertain (listen to music, and watched movies and clips). Furthermore, they watched online classes, received school assignments, searched for material, used the online dictionary, found answers for homework, and read the news. In Vietnam, they made money selling clothes and cosmetics over social media, and ordered food and transportation. Some used smartphones to make social connections and relieve loneliness and boredom, while some used smartphones to avoid engaging with family members. Others used apps to track dietary intake, physical activity and manage weight. However, most reported having access only to slow smartphones with minimal memory.

Frequency of phone use in both countries varied with the day of the week, time of the day, parental permission, and phone access. They checked their phones from every minute to once a day, or every time they received a message. Weekend evenings were the peak time of use. In Ghana, some preferred using smartphones in the evening because friends are online and the network is faster. In Vietnam, most used their phones between classes, after lunch, at night after finishing homework, and on the weekends, although they carried smartphones all the time. Ghanaian adolescents did not use their phones during bedtime. They also did not use it at church, at work, or school because it is not allowed, but using phones during mealtime was not a problem. In Vietnam, girls were not allowed to use phones at home during meals, nor in class. They were concerned with disturbing other students and their parents at home with too many messages, so phones are often muted and in vibration mode. In Ghana, notifications were also seen as potentially informative yet disruptive. Ghanaian adolescents typically turned on notifications of people and channels they like in social media, but some never set notifications on because the phones are shared. All adolescents are concerned with availability of data, because they share a phone in Ghana and have limited money to charge pre-paid phones in Vietnam. Consequently, adolescents preferred to use phones connected to Wi-Fi rather than using the phone networks. Most Vietnamese participants never turned off their phones, but some switched on airplane mode when asleep.

Favorite online platforms

Most girls in both countries used *Facebook, Instagram, Tik Tok, Twitter and Youtube.* In Vietnam, they also used *Messenger, Zalo, Mocha,* and *Zoom*. In Ghana, *Snapchat, Whatsapp, Telegram, and Houseparty* were also among the favorite apps. Vietnamese girls did not share much information on their *Facebook* wall because of privacy and bullying concerns. Ghanaian girls made new friends, met old ones and posted comments on *Facebook*. On *Instagram*, they all watched education-related programs, followed celebrities' lives, and collaborated in the work of their internet role models. In *Snapchat*, adolescents liked taking pictures and using filters. They enjoy that Snapchat gives points for having likes and comments. *Youtube* was seen as a great searching tool, and was used to learn about cooking, exercising, nutrition, and diet. In *Whatsapp*, teenagers connected via messages and video calls – including with people they don't know –, watched others' statuses, and got school assignments. They used *Zoom* for distance learning, especially during the COVID-19 lockdown, and *Zalo* and *Mocha* for communicating with messages and calls because it is cheap. They turn off notifications of these platforms when they receive too many.

In Ghana, some participants used game and competition apps to avoid boredom and to feel challenged. They felt proud when they won. Competing in *Boomplay* gave coins to buy music, *Songpop* paid users an online currency to purchase game items, while *Magic Tiles, Subway Surf,* and *Temple Run* also paid currency to buy things online. *Cash Crate* sent money to share with friends. *Candy Crush* sent symbols when users won or lose, and because of its colors and sounds. In Vietnam, adolescents did not play online games often, but preferred the ones that require an invitation from friends on social media platforms. Others download specific game apps such as *Candy Crush, Talking Angela, PUBG,* and *COD* that could be linked to *Facebook,* which makes possible to share performance results and connect with friends. Some used online shopping apps like *Grab* and *Shoppee*, in which scores can be exchanged for goods and services. The features of games that were considered most attractive were the presence of teams, the possibility to talk to other players, competition, awards, and cumulative scores that they can exchange for real or virtual goods.

Practices related to healthy eating

In Ghana, adolescents learned about food groups from teachers, doctors, parents, church, and television, but looked for information on healthy eating on the internet. Parents and the school environment were seen as the major influences on their diet. Most ate what was available at home, but some parents did not have enough money to afford the diet they learned about in school. Salads, vegetables, and fruits were seen as healthy, and oil, salt, and sugar as unhealthy, but balanced diets were not a clear concept for the majority of respondents. Some adolescents talked about the energy-giving, protective, and bodybuilding food groups, which refer to a classification learned in primary schools formulated by the Ghana Health Service.

In Vietnam, girls learned about the concept of food groups and the food pyramid in school, but did not have a clear comprehension of the concept of food groups nor could name the different food groups. Although they could recall the main ideas behind food pyramids, they did not apply it in their daily food consumption because it lacks information on how much to eat from each food group. Parents taught them about food safety and healthy diets, and they ate what their families offered for meals. Foods were purchased and cooked mostly by their mothers or under their mothers' instructions.

Body image was adolescent's number one concern related to food and diet. Most Vietnamese thought they should lose weight. Those who tried to lose weight looked for information on *Google, Youtube,* and *Facebook* communities. They read websites on top of the *Google* search list and choose information from those with more comments and likes, mostly when easily understandable. Some followed fad diets like *Keto* or *Eat Clean*, and diets of internet influencers, others mentioned the concept of portions in the plate that they had seen on foreign websites, but that did not apply to the Vietnamese diet.

Food and technology

Ghanaian adolescents shared pictures of meals with friends, but Vietnamese only posted special meals to remember special occasions and recommend them to friends, and because they saw day-to-day meals as uninteresting. Some Ghanaians liked to brag on social media about the foods they ate in restaurants. In both countries, posts about food on social media made adolescents feel like eating the food posted: some felt happy, and others felt sad when they could not eat, for example, the birthday cake or the expensive meal in the picture.

Adolescents cared about healthy diets. Most wary about gaining weight since it has negative health and social implications. Very few have used apps to improve their health, but they would like to have an app that would calculate what they should eat. Most diet-related apps available in Vietnam were not adapted to the Vietnamese context – the foods recommended are foreign-based, so foods were unavailable and expensive. They also mentioned that nutrition-related apps were time-consuming because users have to look on a list for all foods and beverages consumed.

Possibility of taking pictures during mealtime

Adolescents from both countries could take pictures of their meals most of the time. In Ghana, respondents did not foresee problems in taking pictures of meals unless they were at parties or in school, because teachers would not let them take a picture of their meals. In Vietnam, when they were in a rush to get to school, they had to eat on the street or secretly eat in class, so they could not take a picture. It would also be strange to separate a portion of a dish to take a picture when the meal is shared with members of families. Nevertheless, this was acceptable when Vietnamese girls were trying to control the amount of food eaten. In Vietnam, taking pictures of foods when many people gather for special occasions, or when their families were eating with guests was seen as impolite. However, they shared pictures of common meals with their parents to report the quality of their diet when they were not together. Also, they have to take a picture before and after eating a dish when they shared or could not finish it. Finally, it is not possible to upload the picture of meals without internet or phone access.

Table 5: All apps that track dietary intake among the top 100 most popular apps in the health and fitness categories in the App Store and Google Play and App Store of Ghana

App	Paid or unpaid	Rating Google Play and App store	Number of ratings Google Play and App Store	Features	How do they track food intake?	Goal	Notifications
BetterMe	Paid for upgraded version	4 ; 4.5	81k ; 276	Tracks dietary intake, water intake and physical activity. Suggests personalized diet and fitness program, individual meal plans, workout for targeted body parts, articles, tips and tricks for positive body mindset	User enters the meal type (breakfast, lunch, dinner, snack); selects foods, meals, or recipes	Weight management; dietary intake management; muscle building	No notification
YAZIO	No	4.5 ; 4.8	303k ; 12	Tracks dietary intake (calories and macronutrient); tracks water intake; tracks anthropometry (weight); plans meals; suggests recipes; tracks physical activity; has smart adding feature (enters foods that users typically eat together)	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Send reminders of meals and water intake; reminder to log weight; incentive to log dietary intake
Calorie Counter by GetFit	Yes	NA ; 4.4	NA ; 78	Tracks dietary intake (calories and macronutrients); rates foods according to nutrient content; has barcode and voice search functions; plans meals and fastings	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Send reminders of meals and water intake; reminder to start fasting; send tips for healthy eating
Lose it!	Paid for upgraded version	4.6 ; 4.5	98k ; 28	Tracks dietary intake (calories and macronutrients); tracks water intake; tracks anthropometry (weight); tracks sleeping cycle; tracks physical activity	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Sends messages suggesting fasting; suggesting consistency; supporting to continued fasting
Calorie Counter by EasyFit	Paid for upgraded version	NA ; 4.6	NA ; 86k	Tracks dietary intake (calories and macronutrients); tracks weight; tracks physical activity; tracks water (in paid version); has a Facebook community about weight loss success; has tips to eat healthier	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weigh management; dietary intake management	No notification
MyFitness Pal	Paid for upgraded version	4.4 ; 4.4	2M ; 2.3M	Tracks dietary intake; tracks physical activity (steps); exports diet record files; has learning features; has copy and paste function for frequent foods; shares meals in iMessage; has nutrition facts panel; has diary that includes body pictures; suggests physical activity routine	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Send reminders to log meals
Carb Manager Keto	Paid for upgraded version	4.7 ; 4.8	62k ; 45	Tracks dietary intake (calories and macronutrients); tracks physical activity (counts steps)	User select type of meal (breakfast, lunch, snack or dinner); searches for and selects food or beverage; app shows how far user is from daily nutrient goal	Weight management; dietary intake management; muscle building; macronutrient intake ratio	Send reminders of meals and water intake

Table 6: All apps that track dietary intake among the top 100 most popular apps in the health and fitness categories in the App Store and Google Play and App Store of Vietnam

App	Paid	Rating Google Play and App Store	Number of ratings Google Play and App Store	Features	How dietary intake is tracked	Goal	Notifications
Nudi Từ điển tra cứu dinh dưỡng (Nudi Nutrition Lookup Dictionary)	No	4 ; 4.6	22 ; 11	Tracks dietary intake (calories); provides nutrition information and dietary advise based on weight status, age and gender; suggests sample menus of 1-week foods for adults	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management; provide nutrition information of popular foods	Sends reminders before meal time every day
FitMode-kế hoạch dinh dưỡng (Nutrition Plan)	No	NA ; 5	NA ; 3	Tracks dietary intake (calories and macronutrients); tracks anthropometry (BMI and weight); provides nutrition and exercise plans; records food intake and body weight	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Sends notifications about menu; reminders about meal and physical activity time; warnings about caloric intake
GetFit-thực đơn giảm cân (Menu to Reduce Weight)	Paid for upgraded version	3.8 ; 4.8	12 ; 1.1k	Tracks dietary intake (calories), tracks anthropometry (BMI); plans meals; guides implementation of plans; shows recipes; suggests readings on nutrition and health	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; meal planning	Send notifications about menu, meal time, and exercise time. Warns about caloric intake.
Nubo-Cơ thể và dinh dưỡng (Body and Nutrition)	No	4.8 ; 4.9	39 ; 10	Tracks dietary intake; tracks alcohol consumption; tracks anthropometry (BMI and waist circumference); tracks health (symptoms of disease, menstruation, etc.); gives nutritional advise	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	No notifications
Tính calo (My Diet Coach)	Paid for upgraded version	4.5 ; 4.9	148k ; 9	Tracks dietary intake (calories and macronutrients); tracks anthropometry; tracks physical activity; suggests level of physical activity and diet according to weight loss goal; saves photos to track body change	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management; meal planning	No notifications

Table 6: All apps that track dietary intake among the top 100 most popular apps in the health and fitness categories in the App Store and Google Play and App Store of Vietnam (continuation)

App	Paid	Rating Google Play and App Store	Number of ratings Google Play and App Store	Features	How dietary intake is tracked	Goal	Notifications
Nhật ký ăn uống (Food Diary)	Paid for upgraded version	2.9 ; 4.8	417 ; 1k	Tracks dietary intake (calories and macronutrients); suggests personalized nutrition plan; tracks anthropometry (BMI); provides food diary; has frequently asked questions about nutrition and diet; provides information about nutrition, physical activity, recipes; has personal goal setting	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Sends reminders before meal time every day
Carb Manager	Paid for upgraded version	4.8 ; 4.7	64k ; 53	Tracks dietary intake (calories and macronutrients) based on weight loss goals; suggests type and intensity of physical activity; tracks anthropometry (body weight); tracks water intake	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Sends reminders before meal time every day
Lose It!	Paid for upgraded version	4.6 ; 4.8	99k ; 700	Tracks dietary intake (calories, macronutrients and water), anthropometry (body weight), sleeping cycle; plans meals; suggests recipes; suggests macronutrient and caloric intakes; has barcode, nutrition facts and food scanner	User searches for food or beverage; selects food or beverage; selects portion size; or take picture of food and beverage, barcode and nutrition facts. App calculates caloric intake.	Weight management; dietary intake management	Sends reminders before meal time every day
Meal Scanner	No	NA ; 0	NA ; 0	Tracks dietary intake (calories and macronutrients); can upload pictures of meals from personal photo gallery; has scanner for picture of meals	Information not found	Dietary intake management	No
Theo dõi dinh dưỡng (Track Nutrition)	No	4.1 ; NA	156 ; NA	Tracks dietary intake (calories and macronutrients); calculates caloric needs; provides nutritional information	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Dietary intake management	no notifications

Table 6: All apps that track dietary intake among the top 100 most popular apps in the health and fitness categories in the App Store and Google Play and App Store of Vietnam (continuation)

App	Paid	Rating Google Play and App Store	Number of ratings Google Play and App Store	Features	How dietary intake is tracked	Goal	Notifications
Nhật kí dinh dưỡng hàng ngày 2020 (Daily Nutrition Diary 2020)	No	5 ; NA	12 ; NA	Tracks dietary intake (calories and macronutrients); tracks anthropometry (BMI)	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	no notifications
Phân tích thực phẩm- Dinh dưỡng và sức khỏe (Food Analysis -- Nutrition and Health)	No	4.5 ; NA	879 ; NA	Tracks dietary intake (calories); has barcode scanner	Taking pictures of barcodes	Dietary intake management	no notifications
Tính khẩu phần ăn (Calculating the Ration of Foods)	No	4.5 ; NA	10 ; NA	Tracks dietary intake (calories and macronutrients)	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Dietary intake management	no notifications
Yazio (app in Engligh)	Paid for upgraded version	4.5 ; 4.7	298k ; 17.5k	Tracks dietary intake (calories and macronutrient); tracks water intake; tracks anthropometry (weight); plans meals; suggests recipes; tracks physical activity automatically; has smart adding feature (automatically enters foods that users typically eat together)	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management	Send reminders of meals and water intake; reminder to log weight; incentive to log dietary intake
Calorie, carb & fat counter (app in English)	Paid for upgraded version	4.5 ; 4.7	53k ; 1.6k	Tracks dietary intake (calories); tracks physical activity; tracks anthropometry (weight); suggests personalized nutrition plan	User searches for food or beverage; selects food or beverage; selects portion size; app calculates caloric intake	Weight management; dietary intake management; muscle building	Send reminders of meals

Discussion

This paper centers on formative research undertaken in the first phase of the NFG study to identify the most promising tools to nudge adolescents in online environments, the most appropriate outcomes to measure success for a nutrition intervention that uses mobile technology, map the nutrition-related apps available on the market, and discover how diet-related apps can be made attractive for use by adolescent girls. To achieve these objectives, we undertook a review of the literature and of the apps available on the market, as well as a series of focus group discussions with adolescents in Ghana and Vietnam.

Supply and demand issues relating to smartphone technology to improve diets

To better understand the implications of the study we broadly map the findings to a supply and demand framework relating to smartphone technology use to improve diets in adolescents. The review of the literature highlights that, to date, there is little evidence on the potential for technology-based nutrition-related interventions to improve health. In addition, it was unclear from the literature what the most appropriate choice of outcome is for an app-based nutrition intervention, and there were few apps that tracked dietary intake without also focusing on weight management.

Evidence from the FGDs suggested that most adolescent girls interviewed were interested in improving the quality of their diet and managing weight. They may be especially sensitive to weight-related feedback, though there are concerns about unintended effects including increased anxiety and the potential to increase the risk of eating disorders (Peterson & Fuller, 2019; Volpe *at al.,* 2016). To date, these adolescents did not have access to reliable sources of information on diets nor used nutrition-related apps. However, they were interested in using technologies that would allow them to improve their health, and most had access to smartphones and internet.

Participants of the FGD use *Facebook, Instagram, Snapchat, WhatsApp*, and other major social media. Most had access to and used these platforms on smartphones. Smartphones are used for entertainment, study and to avoid boredom or loneliness. They also reported turning on notifications for channels and profiles they enjoyed and checked their phones frequently. Although they did not play online games often, they reported enjoying team competition, winning awards, and cumulative scores that could be traded for goods. However, most have limited access to the internet, and some have limited access to phones, particularly in Ghana. Most schools do not allow phone use during school hours, nor do they provide Wi-Fi. In Vietnam, respondents reported that nutrition-related advice from apps was not tailored to their cultural and socioeconomic context. Respondents from both countries learned about healthy diets in school, but they did not apply these concepts to improve their diets. Girls preferred watching *Youtube* videos, looking for websites with positive reviews and "likes", and followed social media influencers' advice. Respondents found the apps available time-consuming but would like to have an app that tracks what they eat and gives nutritional advice that was user-friendly, helped them lose weight, and reduces fat mass. Adolescents reported that they could take pictures of meals most of the time when they had the phones with them, when they were not in school, when they were not in a rush in the morning, and, in Vietnam, when they were not sharing meals with older people. The majority of adolescents from Ghana shared pictures of meals with friends by text and on social media, but in Vietnam, most respondents only shared memorable meals.

The respondents from Ghana seemed more open to use the app prototype we presented, but adolescents from both countries would like the app to make recommendations based on personal anthropometry-related data. They also reported that seeing pictures of food increased appetite, therefore we should not build a feature to share pictures in our app. Finally, taking advantage of their taste for internet social interactions and competition, there is an opportunity for including game elements such as point scoring and team-based activities to foster healthy eating.

In summary, these results suggest that there is a considerable demand for a nutrition-related app to improve the diets of adolescents in Ghana and Vietnam. However, the supply of user-friendly apps providing reliable, accurate information on how to improve diets was limited in both countries.

Design features of the mobile, Artificial Intelligence(AI)-based app

Several important considerations on the development of a mobile AI-app can be drawn from the findings of this study. Currently, there is a technology gap between the supply and demand of adolescent girls in Ghana and Vietnam to provide appropriate nutrition advice. Existing apps are not practical enough and focus on weight management rather than on improving food choices and diet quality. The NFG project is aiming at developing a new app that uses AI technology to automatically recognize foods and beverages with the ultimate goal of improving adolescents' diets (Figure 1). This new technology, called Food Recognition Algorithm + Nudging Insights (FRANI), is aimed at improving data collection on food consumption and potentially provide high-frequency, precise estimates of dietary intake. Similar to other behavior change interventions focusing on food-based strategies (Tontisirin *et al.,* 2002), FRANI would also focus on improving knowledge on healthy and unhealthy foods, which in turn would improve food consumption behaviors and lead to healthy eating habit formation. The novel feature that FRANI would leverage is the ability to provide individualized feedback based on actual food intake patterns as identified by the AI model integrated in the app.

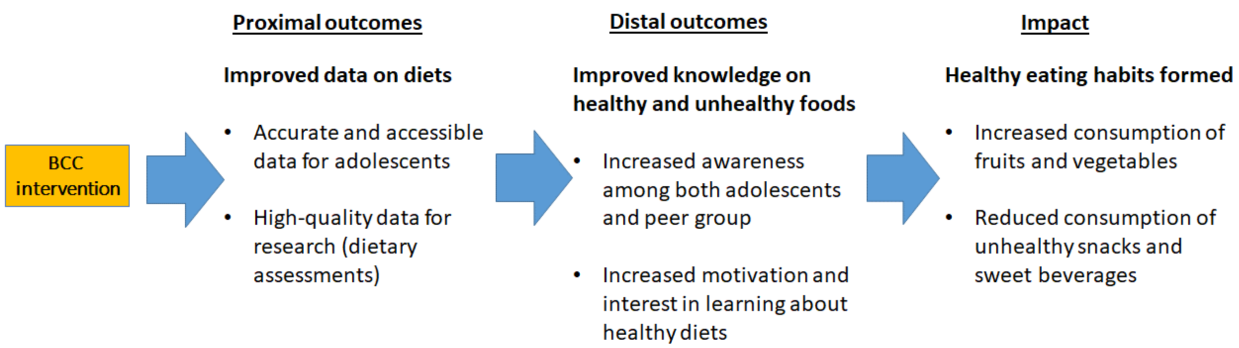

Figure 1: High-level impact theory for the new mobile app

The evidence generated from this study can be used to further develop the details of the program impact pathways for the FRANI app (Figure 2). The FRANI app can be designed to nudge adolescents towards eating higher-quality diets to improve health, while not focusing on weight management because of the potential harm to mental health. The FRANI app makes dietary management easier by means of AI technology that recognizes food groups and weights in the photos that users take of their meals. The two main activities that require user input include 1) setting daily objectives and 2) take pictures of food and beverages being consumed. For 1), FRANI asks users to choose their daily dietary goals based on food groups, and include simple options such as "eat some whole grain today," "have dark green leafy vegetables today,". These goals help to increase salience and motivation of consuming healthy foods and diversifying diets, whilst crowding out the consumption of energy-dense foods. Striving for these healthy behaviors may also help adolescents lose weight without feeling anxious about weight management. When users meet dietary goals, they receive medals that can be shared on a feed page and be "liked" by friends in the app. Pictures of meals cannot be posted in the app for others to see because, as discussed above, pictures of foods tend to trigger negative responses by making others feel hungry. Similarly, some adolescents only post pictures of special meals on social media, which can harm how other users perceive their own diet. There will be no comment feature in the app either to avoid online trolling and bullying. Users can also join teams of which members chose the same dietary goals.

To avoid excessive peer pressure, users do not see other team members' individual performance. Rather, they have information on the team's progress as a whole.

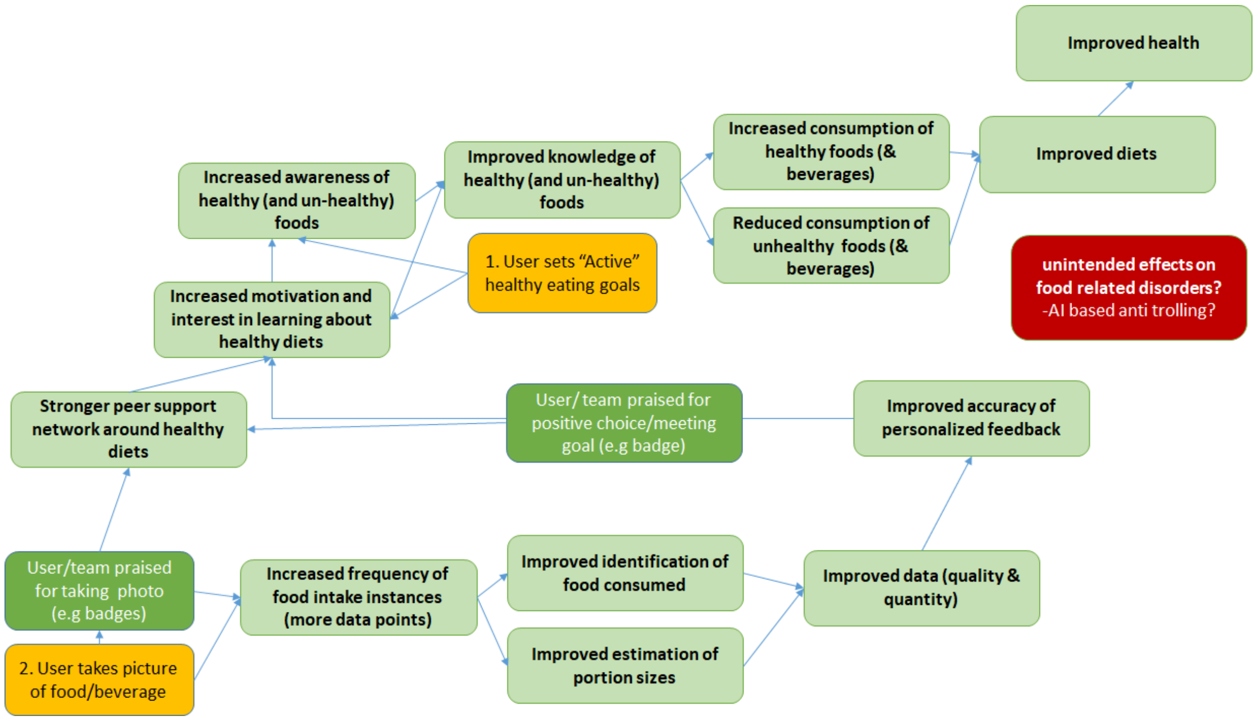

Figure 2: The stylized program impact pathways for FRANI

Conclusion

The design and implementation of food recognition app including AI technology is a complex research and development endeavor involving AI engineers, nutritionists, and public health scientists. The second phase of the project involves an acceptability and feasibility study of a prototype of the mobile application with more rounds of focus groups discussions. The third phase of the project includes a validation study comparing the accuracy of the AI-based dietary assessment to weighed records and standard 24-hr recall, as well as a pilot experiment on the feasibility of using the FRANI app to nudge users towards improving their diets. If successful, FRANI may provide important advances in dietary data collection methods, including high-quality, high-frequency data on as well as a tool to promote healthy diets through personalized diet-based nudges, increasing awareness among adolescents, interest in nutrition, and motivate them to make healthier food choices. Healthier eating habits may then form, increasing the consumption of fruits and vegetables and reducing the consumption of unhealthy snacks and sweetened beverages.

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Fax: +1-202-862-5606
Email: ifpri@cgiar.org