Development of eHealth-Based Behavior Change Support for Young Adults Using the Nine Principles Framework

Anna Worthington, MHSc, RD; Nicola Gillies, PhD, RD; Rajshri Roy, PhD, RD; Andrea Braakhuis, PhD, RD

ABSTRACT
Implementing behavior strategies into nutrition research requires consideration. The Nine Principles framework was used to develop an eHealth behavior change support (BCS) program to enhance young adults’ adherence to (1) eating healthily and (2) recording dietary intake when participating in a randomized control trial. The Theory of Planned Behavior and qualitative focus group data informed a 10-week pilot of the BCS delivered on Facebook and texts. The BCS appeared to support optimal dietary recording and maintained dietary behaviors, suggesting using a framework underpinned by theory and user-centered design may be a promising avenue to enhance adherence in randomized control trials.

Key Words: dietary habits, health behavior, diet, healthy, behavior change techniques (J Nutr Educ Behav. 2023;55:38−47.)

INTRODUCTION
Nutrition-related randomized controlled trials (RCTs) frequently require free-living individuals to change their behaviors. For example, an RCT may require participants to change their dietary pattern, begin consuming provided food or establish a new behavior such as recording dietary intake.1,2 Adhering to these behaviors is often a study requirement, as they are intrinsically linked to biological markers used as primary outcomes but are not targeted as the main outcome themselves.3 Herein, we use behavior change support (BCS) to refer to strategies integrated into a study protocol and standardized across intervention groups to support adherence to behavior. This contrasts with a behavior change intervention that targets a behavior as the primary outcome and differs across groups within an RCT.

It is common for researchers to incorporate behavior change techniques (BCTs), or active ingredients,4 into BCS for RCTs, such as providing instruction on how to perform the behavior or material rewards.5 However, there is a lack of systematic implementation and reporting of BCS, such as a lack of clear descriptions of the BCTs used and the process through which they were selected, which hinders the identification, effectiveness, and replication of different components included.6,7 The incorporation of behavior change strategies into nutrition-related RCTs in which behavior change is not the primary outcome but is required by participants has received little attention in the literature, and integrated theory and practice research is needed.8

Over the last 2 decades, multiple frameworks based on behavioral models have been created to guide researchers in developing interventions to support behavior change.9−11 Using these frameworks can enhance adherence, improve research validity, and decrease resource waste,11 as understanding the mechanism of change using behavioral theory can enhance the effects of the intervention.6 Although commonly aimed at developing interventions, we propose these frameworks can also be used to develop BCS to enhance adherence to study requirements across groups in a nutrition-related RCT. One such framework is the Nine Principles, centralized around behavioral models and user-centered design.9 It seeks to integrate behavioral models (ie, those which identify underlying factors to understand behavior) with theories of change (ie, those which identify techniques effective at bringing about change) to guide the effective development of behavior change interventions.9

The PRotEin Diet Satisfaction (PREDITION) trial investigated the effects of moderate lean red meat consumption as part of a balanced diet. This trial was a 2-arm parallel RCT in which 80 young adults (aged 20−35 years) followed a diet containing pasture-fed red meat or plant-
based meat analogs for 10 weeks. The primary outcome for the PREDITION trial was a change in concentrations of polyunsaturated fatty acids in erythrocyte membranes, not a behavior change. However, to answer the research question, both arms were required to change from an omnivorous diet to a basal, healthy vegetarian diet, aside from their allocated intervention protein. Research suggests this heterogeneous population of young adults is among the hardest to generate positive dietary behavior change in.

As well as the change in dietary behavior, participants were required to establish the behavior of recording dietary intake on a smartphone application via a mix of manual and photograph entries every day for 10 weeks. This was essential for the validity of the study to (1) ensure adherence to respective dietary arms and (2) account for dietary factors that may modify or confound results. Although electronic recording is considered less burdensome for respondents than traditional paper-based methods, there is the risk of recording quality decreasing over time. Image-based dietary assessment has been reported to have improved participant interaction and provided an avenue for real-time analysis or assessment; however, the utility for nutrition assessment is currently limited. If participants failed to comply with recording requirements, they could be removed from the study, resulting in resource waste and data loss. Hence, there was a need to develop BCS within this RCT to enhance adherence to multiple required behaviors.

Electronic health (eHealth) has been identified as a promising avenue to reach young adults, with 91% of adults aged 18–34 years owning or having access to a smartphone, and it was determined to be the most feasible mode of delivery regarding study resources. The optimal design of eHealth programs likely involves a framework incorporating behavioral theory and user-centered design. Therefore, the Nine Principles framework was selected as an appropriate guide for developing the BCS in the PREDITION trial. As the PREDITION trial was an RCT, the dietary guidance, education, and support provided by this program were standardized. This report described the process of using the Nine Principles framework to develop acceptable BCS delivered via eHealth for implementation in the PREDITION trial that aims to increase young adults’ adherence to recording dietary intake and eating a healthy diet for 10 weeks. The efficacy of the BCS will be evaluated on completion of the PREDITION trial. The overarching aim is to advance our understanding and knowledge of health behavior change by integrating psychological theory and practice.

### NINE PRINCIPLES FRAMEWORK: PROCESS

The Nine Principles in Darnton’s framework (Table 1) were used to guide the development of a BCS program to maximize young adults’ adherence to (1) daily dietary recording on the smartphone application Easy Diet Diary (version 6.0.28, Xyris Software Pty Ltd, 2020), and (2) healthy dietary eating.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Tasks Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify target audience and behavior(s)</td>
<td>• Use population nutrition surveys to identify current dietary behaviors of young adults in NZ to target&lt;br&gt;• Define identified target behaviors</td>
</tr>
<tr>
<td>2. Identify relevant behavioral models and factors influencing the target behavior</td>
<td>• Conduct literature review on barriers and enablers of eating healthily for young adults&lt;br&gt;• Conduct preliminary survey of young NZ adults on barriers and enablers of target behaviors&lt;br&gt;• Integrate identified barriers and enablers with the Theory of Planned Behavior Model</td>
</tr>
<tr>
<td>3. Select key influencing factors and use them to create draft strategies for intervention</td>
<td>• Draft a BCS program that targets key barriers and enablers&lt;br&gt;• Conduct focus group for expert input on draft BCS&lt;br&gt;• Refine draft BCS according to experts</td>
</tr>
<tr>
<td>4. Identify effective intervention techniques</td>
<td>• Classify BCTs included according to the Behavior Change Technique Taxonomy (v1)</td>
</tr>
<tr>
<td>5. Engage the target audience for the intervention</td>
<td>• Conduct target audience focus groups for input on revised BCS&lt;br&gt;• Thematically analyze focus group responses&lt;br&gt;• Refine BCS as per target audience input&lt;br&gt;• Develop tangible BCS components for implementation</td>
</tr>
<tr>
<td>6. Develop prototype BCS</td>
<td>• Pilot BCS and conduct process evaluation at week 5&lt;br&gt;• Incorporate process evaluation feedback into BCS for main PREDITION trial&lt;br&gt;• Measure adherence to dietary recording and changes in healthy eating</td>
</tr>
<tr>
<td>7. Pilot and monitor continuously</td>
<td></td>
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<tr>
<td>8. Evaluate impacts and processes</td>
<td></td>
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<tr>
<td>9. Feedback learning from the evaluation</td>
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</table>

BCS indicates behavior change support; NZ, New Zealand; PREDITION, Protein Diet Satisfaction.
behaviors, such as those outlined in the Eating and Activity Guidelines for New Zealand (NZ) Adults during the PREDITION trial. The Easy Diet Diary smartphone application is a freely available food diary developed and owned by Xyris Software (Australia) Pty Ltd. The Easy Diet Diary application was chosen as a dietary assessment tool (ie, food diary or record) in a research setting, as it has undergone significant development and testing and has a high user rating. The methodology for the 10-week nutrition intervention trial that the BCS was integrated into can be reviewed elsewhere. A mixed methods approach was adopted for the current study. This involved triaging results from various sources, including a literature review, questionnaires, focus group interviews, and a pilot RCT (Table 1). All analyses used throughout the principles are described at the end of the methods section. Development of the BCS began in 2020 and the pilot was conducted at the end of 2021. Figure 2 gives an overview of the participants involved at the different time points. The trial was approved by the New Zealand Ministry of Health’s Health and Disability Ethics Committees, and appropriate consent procedures were followed. Ethical consideration was considered via an expedited review, and consent was required for all data. Those with chronic health conditions, obesity (body mass index [BMI] ≥ 30 kg/m²), history of anosmia and ageusia, use of medications (except for occasional nonsteroidal anti-inflammatory drugs and antihistamines), and children were excluded from participating.

Principle 1: Identify Target Audience and Behaviors

The target population included healthy young NZ adults aged 20–35 years. The target behaviors were eating healthily and recording dietary intake. To define eating healthily, the dietary habits section of the 2008/09 NZ Adult Nutrition Survey was used to explore the likely behaviors of adults aged 19–30 years, as this provided the most recent, comprehensive data by age group on multiple nutrition-related behaviors. For each habit, the optimal behavior to shift young adults toward was quantified using the Ministry of Health Eating and Activity guidelines and reviewed by an expert panel engaged in principle 3. Recording dietary intake was defined as documenting at least 1 full day of dietary intake (ie, 3 meal occasions entered either by manual or photograph entry) every 3–4 days on Easy Diet Diary.

Principle 2: Identify Relevant Behavioral Models

In principle 2, research data and behavioral models were integrated to identify key influencing factors of the target behaviors. A literature review was conducted to identify common barriers to and enablers of dietary behaviors in young adults. The databases Scopus and Google Scholar were searched using the following terms: barrier OR enabler AND young adult AND eating OR diet AND health∗.

Barriers may differ between populations, so a preliminary online survey was created on Survey Monkey (Momentive Inc) for young adults in NZ to further explore target behaviors. They were asked 8 questions, such as if they had previously used an application to record food intake; how long they would be willing to complete the food record; to identify barriers and enablers to recording dietary intake on an application; and identify enablers to adhere to dietary advice. A convenience sample of 47 responses from adults aged 18–35 years was collected through a shared link to the survey on the researcher’s Facebook group for 2 weeks until qualitative data saturation was reached. For each behavior, the perceived barriers and enablers were mapped onto Ajzen’s Theory of Planned Behavior to identify effective levers for change.

Principles 3 and 4: Designing a Draft Strategy and Identifying Program Techniques

A draft BCS program was designed on the basis of factors identified in principle 2 and pragmatic resource availability. Seven experts (3 registered dietitians, a psychologist, 2 food industry employees, and a student dietitian) were selected by purposive sampling for a focus group to provide practical and evidence-based feedback on the draft. The advice was sought on specific topics, including optimal use of text messages, definitions of behaviors, rewards for participants, and design issues. A successive focus group was held with the 3 dietitians for further input on structuring the program to promote eating healthily and how to effectively incentivize participants to enhance adherence.

The strategies included in the draft to address key barriers were compared and then aligned to BCTs named in the BCT taxonomy v1, an extensive taxonomy that defines 93 distinct BCTs. Using a taxonomy ensured the program was underpinned by psychological theories that link actions and outcomes, and enables later evaluation of these active components.

Principles 5 and 6: Engaging the Audience as Actors and Developing Prototype BCS

A recruitment email was sent to staff and students in the Faculty of Medical and Health Science at the University of Auckland, asking for volunteers to discuss the BCS. Volunteers were screened using the previously mentioned exclusions and similar eligibility criteria required for the main trial; they were eligible if they were aged between 20–35 years and were an omnivore who in the last 2 months had consumed at least 2–3 meals/wk containing meat or fish of any description. A convenience sample of the first 8 eligible volunteers was split across two 60-minute focus groups held via Zoom (Zoom Video Communications, Inc., version 5.0, 2020). The focus groups were asked to consider the following program attributes: Ability to adhere to dietary advice and dietary recording considering the proposed support; ideas on incentives to improve adherence, including peer or expert support options, text messaging, and type of preferred meal support. Feasible suggestions from the focus group were integrated into the BCS design. The BCS, including nutrition content, was then developed and reviewed by expert NZ registered
dietitians in the team, who have the knowledge and skills to ensure the quality of the information provided. The BCT taxonomy v1 was used again to identify the included BCTs.  

Principles 7–9: Piloting, Evaluation, and Feedback

The PREDITION trial organized participants into 8 groups of 5 pairs who co-habitatied in Auckland. Groups 1 to 8 in the PREDITION were randomly allocated to the red meat or plant-based analog arm. All groups received the same BCS. Twenty participants (10 pairs) were recruited for groups 1 and 2 of the PREDITION trial. Participants were provided an information sheet and signed a consent form before study enrolment. These groups acted as the pilot for the BCS and as the first 20 participants for the PREDITION trial. Final changes to the BCS based on process evaluation were made between weeks 5–8 of the pilot as it was necessary to start groups 3 onward at week 8. Process evaluation to measure the fidelity and sustainability of the BCS was conducted in week 5. This included 2 Qualtrics (Qualtrics, Inc., 4.21) questionnaires investigating engagement with the Facebook (Meta Platforms, Inc., 2021) group and barriers to recording dietary intake. Engagement with the Facebook group was monitored by researchers by quantifying likes and comments on posts. A Facebook poll in week 5 was administered to the expert focus groups (principle 7) and the transcripts of the expert focus groups (principle 3), were thematically analyzed using Microsoft Word (version 16.53). NVivo software (version 12 Pro, QRS International Pty Ltd, 2020) was used for the thematic analysis of more complex data scripts, such as the target audience focus group (principle 5) and responses to the pilot questionnaires (principle 7–9).

A general inductive approach was taken with all thematic analyses in this research. Steps involved initial familiarization by reading the data, then systematically creating codes by identifying recurrent or meaningful features of the data. Codes were then compared, and those linked were clustered into themes with supporting data. All data scripts were read at least 3 times and moderated by a second researcher.

A paired t test was conducted on SPSS (version 26.0, IBM, 2019) with a significance level set at $P < 0.05$ to compare the difference between the HDS at baseline and week 10 for all pilot participants. Because the end of the pilot overlapped with the start of the main study, these were not used to inform any change in the BCS. However, these measures are included here to illustrate the potential efficacy of the pilot BCS. Data are presented as mean and standard deviations unless otherwise specified.

Nine Principles Framework: Evaluation

Principle 1: Identify Target Audience and Behavior

The 2008/09 NZ Adult Nutrition Survey identified the following as

<table>
<thead>
<tr>
<th>Table 2. Definitions of Desirable Dietary Behaviors Targeted by the Behavior Change Support for Young New Zealand Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Dietary Behavior</strong></td>
</tr>
<tr>
<td>Sufficient fruit consumption</td>
</tr>
<tr>
<td>Sufficient vegetable consumption</td>
</tr>
<tr>
<td>Regularly choosing wholegrains options</td>
</tr>
<tr>
<td>Low consumption of sugar-sweetened beverages</td>
</tr>
<tr>
<td>Low consumption of fast food</td>
</tr>
</tbody>
</table>

<sup>a</sup>A serving of fruit is defined as 150 g; <sup>b</sup>A serving of vegetables is defined as 75 g; <sup>c</sup>A serving of whole grains is equivalent to 40 g of mixed grain bread; <sup>d</sup>Fast food is any foods high in fat or salt purchased from a fast-food place or takeaway shop (eg, fish and chips, burgers, fried chicken, pizza).
undesirable dietary behaviors of young NZ adults: inadequate intake of fruits, vegetables, and whole grains, overconsumption of sugar-sweetened beverages, and high consumption of food prepared outside the home. The quantifiable definitions for the desired behaviors to shift young adults toward can be found in Table 2.

Principle 2: Identify Relevant Behavioral Models

The online survey was completed by 46 eligible young adults (74% female) with a mean age of 22.2 ± 1.3 years. Of the respondents, 40% had previously used an application to record food intake. The average number of days participants reported being willing to fill out a food diary was 15 days (range, 2–31 days).

The modified Theory of Planned Behavior (TPB) model in Figure 1 depicts how the identified barriers and enablers may regulate the behavior of eating healthily in young adults. Key barriers included apathy toward eating healthily, lack of knowledge and culinary skills, perceived time and cost, and low motivation. Young NZ adults perceived the following to help them adhere to dietary advice: consistent support from peers and professionals; information on the benefits and practical advice such as meal ideas; BCTs such as reminders, tracking behavior, and rewards (Figure 1).

The TPB model was adapted a second time to depict the perceived barriers and enablers for the behavior of using an application to record dietary intake. Barriers included personal factors (eg, time and effort, difficulty quantifying food) and application design issues (eg, difficulty finding food or brand and inaccuracy of the application). Enablers to fill out a food diary application included reminders, peer support, goal setting, rewards such as money, and improved application features (eg, the ability to photograph food).

Principles 3 and 4: Designing a Draft Strategy and Identifying Program Techniques

Briefly, the proposed BCS program consisted of sending participants weekly emails with supporting resources to prompt participants to set a goal focusing on 1 prespecified dietary behavior, whereby a dietitian would monitor and provide standardized feedback, via text, at the end of the week. Four additional texts would be sent weekly: 3 reminders to record dietary intake and 1 healthy eating prompt.

A key suggestion from the expert focus group was to build rapport between the dietitian and participants through Zoom sessions. The second focus group resulted in the BCS being structured into an introduction week followed by 3-week blocks, each focusing on 1 overarching dietary behavior.

Components of the first iteration of this BCS aligned with 12 BCTs

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**Figure 1.** Modified TPB, based on Ajzen’s model, depicting key barriers and enablers young adults in New Zealand may experience regarding healthy eating. TPB indicates Theory of Planned Behavior.
defined in the BCT taxonomy v1, demonstrating that components that stem from target audience suggestions and experts also had a theoretical underpinning. For succinctness, the final BCTs employed have been summarized in Table 3 under principle 6.

**Principle 5: Engaging the Audience as Actors**

A total of 8 participants (62.5% females; mean age, 24 ± 3.1 years; mean BMI, 22.9 ± 2.3 kg/m²; mean intake of meat-containing meals, 7.6 ± 2.7 per week) participated in 2 focus groups. The themes identified in the analysis included diet support, social support, incentives, and text messages.

Meal provision was preferred by participants over cash or vouchers on completion of the study: “... rather than just giving me money, I would prefer the food...” (Participant 1). The provision of meal kits or ingredients for most nights of the week was also perceived as a big incentive to dietary adherence. One participant raised the issue of needing more support if they were randomized to the vegetarian group: “... as someone who’s just mostly eaten meat in almost every meal for pretty much all my life, I’d like to have a lot of support or at least like suggestions or ideas to be able to make the right kinds of vegetarian meals.” (Participant 2)

Participants liked the idea of “... meeting back with the same dietician... then you’re accountable, you get to know them” (Participant 3). Being put into support groups of ≤ 10 people, connected via an online social media platform, was also suggested by participants and seen as beneficial:

*I think the benefit to sort of just having an online platform like a text group or a Facebook group or messenger, whatever, is that yeah, it’s sort of asynchronous... you*

<table>
<thead>
<tr>
<th>No./Code of BCT</th>
<th>BCT Name</th>
<th>Recording Dietary Intake</th>
<th>Eating Healthily</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Social support (unspecified)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4.1</td>
<td>Instruction on how to perform a behavior</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6.1</td>
<td>Demonstration of the behavior</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7.1</td>
<td>Prompts/cues</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9.1</td>
<td>Credible source</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2.2</td>
<td>Feedback on behavior</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>8.1</td>
<td>Behavioral practice/rehearsal</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>14.3</td>
<td>Remove reward</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>1.1</td>
<td>Goal setting (behavior)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1.2</td>
<td>Problem-solving</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5.1</td>
<td>Information about health consequences</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5.3</td>
<td>Information about social and environmental consequences</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>12.5</td>
<td>Adding objects to the environment</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

BCT indicates Behaviour Change Technique; PREDITION, Protein Diet Satisfaction.
Many participants felt they would be motivated by seeing an improvement in their health data: “I think they’ll notice like the health benefits over the course of the 10 weeks...personally that will keep me going” (Participant 4). A weekly competition within these groups was also suggested, in which participants could “...win like a week supply of groceries...” (Participant 5), but this lottery-style incentive was less appealing to them compared with consistent meal support: “I wouldn’t really like a sort of lottery at the end. The idea that you’re doing it and then you just got nothing as well” (Participant 6).

Participants felt the program included too many text messages, resulting in them ignoring the texts. A compromise suggested by the young adults was to use “more assertive” (Participant 2) text messages to remind participants about recording data in the application, whereas all “feedback and tips should be emailed” (Participant 7).

**Principle 6: Developing Prototype BCS**

The previous steps enabled the development of the following BCS program to be piloted in principles 7–9. The BCS was delivered by 2 NZ registered dietitians. During the 2-week lead-in period of the RCT, participants were sent a link to sign up for the dietary recording application, written instructions on how to use it, and were instructed to enter at least 1 item manually and by taking a photograph. During their first clinic visit, participants were reminded how to use the application through demonstration. They were also informed that their entries would be checked frequently, and they would be sent a text if their recording was insufficient. They were also informed this reward of free food was contingent on adhering to their intervention arm and sufficient dietary recording. Text reminders to record dietary intake were sent twice weekly at 8 AM Sunday and 8 PM Monday.

At baseline, participants received a healthy eating cookbook tailored to the intervention/control arm they had been randomized. The eHealth component consisted of a private Facebook group for each group of 5 pairs on the same intervention arm and was moderated by the dietitians. The Facebook group aimed to create a support network in which participants could ask questions, share ideas or recipes, encourage each other to eat healthily, and record food intake. The Facebook group was used to deliver written prompts and supporting resources such as a meal planning template, vegetarian cooking videos, and links to helpful websites to support eating healthily. A schedule was used to standardize the content and timing of posts across groups.

During the PREDITION trial, 3 clinic visits were scheduled to develop rapport with the dietitians, but minimal BCS could be implemented because of limited time. Instead, the dietitians prerecorded key information and support in 4 Zoom sessions (9–10 minute duration) posted on the Facebook groups at baseline and at the start of each 3-week block (ie, the end of weeks 1, 4, and 7). The themes for the blocks were (1) establishing a regular meal pattern, (2) eating fruits and vegetables, and (3) establishing healthy habits. The baseline introduction Zoom covered the rationale for the study, principles and benefits of healthy eating, instruction on how to set SMART goals, and outlined the BCS week block structure. For each subsequent Zoom recording, the dietary behaviors related to the theme were defined, information on the social and health consequences of performing them was provided, and participants were prompted to consider the barriers they may experience to performing it and provided ideas on how to overcome these. Common misinformation associated with each topic was addressed. At the end of each session, participants were encouraged to set a SMART goal, followed by a post prompting them to write their goal in the comments. Thirteen of the 93 BCTs in the BCT taxonomy version 1 were present in the BCS in the PREDITION trial pilot (Table 3).

**Principle 7–9: Piloting, Evaluation, and Feedback**

Twenty participants (60% female; mean age, 26.9 ± 3.8 years; mean BMI, 24.4 ± 2.7 kg/m²) were sequentially randomized to control arms and began 1 week apart. Group 1 was randomized to red meat and group 2 to plant-based analog, with both receiving the BCS.

From weeks 1–5, 31 posts were shared by researchers over the group 1 and 2 Facebook groups. On average, a post was seen by 7 out of 9 (n = 78%) group members. Of these, 6 posts (19%) were actively engaged via likes by a maximum of 2 participants, and 1 post received a comment. Two questions were posted by participants, each receiving 3 or 4 comments.

Seventeen out of 20 participants completed the week 5 survey regarding the effectiveness of the Facebook group. Two people did not accept the Facebook group invite, so they could not answer questions, and 1 person was on the Facebook group but did not respond to the survey. Of participants that responded, 10 (59%) reported engaging with the Facebook group once every 2 weeks or less, 4 (23%) engaged once a week, and 3 (18%) engaged 2–3 times a week. Most participants disagreed (47%, n = 8) or strongly disagreed (24%, n = 4) that the Facebook group content helped them stick to a healthy diet, whereas 5 (29%) agreed that the Facebook group helped (Table 4).

When asked what would enhance their engagement with the Facebook group, themes that arose included: using Facebook Messenger or emails and increasing Facebook notifications, such as tagging participants in comments. Two themes arose when participants did not use Facebook or were not interested in nutrition support. This was supported by the results of the Facebook poll, in which the biggest barriers to engagement for group 1 were not liking to use Facebook (n = 4) and forgetting the page existed (n = 3), whereas the biggest barrier for group 2 was that others were not commenting or...
The mean baseline HDS was 66.3 ± 15, whereas the week 10 HDS was 66.8 ± 13. There was no significant difference between the HDS at baseline and week 10 for participants (P = 0.861). A baseline HDS of 66 indicates that participants demonstrated relatively healthy eating behaviors according to the behaviors targeted, and the lack of significant change in HDS indicates these dietary habits were maintained.

**LESSONS LEARNED**

Engagement with an eHealth intervention is central to its ability to effectively bring about behavior change. It has been conceptualized as “(1) the extent (eg, amount, frequency, duration, depth) of usage and (2) a subjective experience characterized by attention, interest and affect” and can be influenced by many factors such as features of the intervention itself or within the context it is delivered. The Facebook group content was primarily aimed at improving healthy eating. Hence, the lack of engagement with the Facebook group may explain the nonsignificant change in the HDS over 10 weeks for the pilot participants. To combat this in the main trial, a prompt was sent to participants to turn on Facebook notifications during the first week. This message required participants to actively engage with it by thumbs-up reacting when they did it.

The HDS provides a proxy of diet quality, but caution should be taken, especially in this small sample, as it is not a validated tool and does not account for dietary changes outside the target dietary behaviors (Table 2). For example, it does not reflect adherence to the basal vegetarian diet, which was also indirectly targeted by the content of the Facebook group. A limitation of the study was not specifying acceptable HDS participants had to reach and maintain throughout the study. No quantitative cutoffs or benchmarks to define a healthy diet were specified for the HDHI from which the HDS was based.

Lack of engagement could be related to an unacceptable mode of delivery. Using and linking through social media, such as Facebook, was suggested by the target audience in principle 5 and has also been identified as a promising feature to include in nutrition interventions aimed at young adults. However, this focus group finding did not align with the needs of the pilot population. Piloting enabled researchers to add a secondary social media tool, Facebook Messenger, which the study participants deemed a more acceptable mode of delivery. The effect of introducing Messenger to increase engagement and overall compliance to the dietary arm will be reviewed following the completion of the PREDITION trial.

Another factor contributing to the lack of engagement is low motivation. This was a perceived barrier to eating healthily and decreased one’s intention to perform the behavior. The social support of the Facebook group and BCTs within the Facebook content was designed to increase motivation (Figure 1). However, participants may not have started with sufficient motivation to engage with the Facebook group in the first instance, reinforced by qualitative evaluation identifying a lack of interest in nutrition support as a theme for nonengagement. Young adults may not prioritize changing dietary behaviors because of competing time demands and perceive the consequences as distant. Incorporating a more proximal consequence as a BCT for altering their dietary habits, as was done for dietary recording, may have increased motivation to engage and improve

### Table 4. Summary of Quantitative Findings From Process Evaluation Questionnaires at Week 5

<table>
<thead>
<tr>
<th>Question</th>
<th>Score (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Facebook page content helps me to stick to a healthy diet</td>
<td>2.06 ± 0.75</td>
</tr>
<tr>
<td>I find the Easy Diet Diary mobile application difficult to use</td>
<td>2.37 ± 0.68</td>
</tr>
<tr>
<td>The difficulties with the application prevent me from recording</td>
<td>1.79 ± 0.71</td>
</tr>
<tr>
<td>I find it helpful to record with a pair/partner undergoing the study</td>
<td>3.37 ± 0.68</td>
</tr>
<tr>
<td>I find the text messages helpful for remembering to record</td>
<td>3.42 ± 0.61</td>
</tr>
<tr>
<td>I would like to receive more text messages to remind me</td>
<td>2.11 ± 0.74</td>
</tr>
<tr>
<td>I think that my current eating habits are unhealthy, so I don’t record</td>
<td>1.58 ± 0.51</td>
</tr>
<tr>
<td>I am well supported by the research team to record sufficiently on the</td>
<td>3.53 ± 0.51</td>
</tr>
<tr>
<td>application and meet study requirements</td>
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Note: Values are mean ± SD (1, strongly disagree; 2, disagree; 3, agree; 4, strongly agree).
dietary behaviors, but it was not feasible to implement within the context of the main PREDITION trial.

Preliminary results suggest the BCS successfully established the behavior of dietary recording, which has been demonstrated to decrease over time. Text messages were an acceptable and effective mode of delivery and have been previously identified as a promising strategy to use within interventions for young adults. However, participants still reported wanting an additional text reminder, which was therefore added to the main PREDITION trial. Of note, the BCT removal reward may have sufficiently motivated participants to adhere to recording requirements, as failure to do so would have resulted in the cessation of free food secondary to being withdrawn from the RCT. A thorough evaluation of the effectiveness of included BCTs will be conducted on completion of the PREDITION trial.

A key limitation of using the Nine Principles framework is the practicality of applying it to different contexts and behaviors. For instance, piloting may not always be feasible, especially if implemented within a small-scale RCT, limiting researchers’ ability to carry out steps 7-9. The BCS developed for the PREDITION trial could not be piloted for 10 weeks. Had impact evaluation been conducted, further improvements may have been made to enhance effectiveness, such as setting a benchmark HDS for participants to remain in the study.

The Nine Principles require researchers to select the most relevant model to explain the target behavior. The TPB was selected as it is a widely used model, has been previously shown to increase the efficacy of dietary interventions aimed at adolescents and young adults, and is designed to change individual action at an intrapersonal level. However, conceptual models such as this do not account for all factors that influence a person’s behavior, especially those as complex as food choices, and extrapolating theory into practice does not always equate. For instance, habit, emotion, and sociodemographic characteristics are not considered in the TPB but have been previously demonstrated to play a role in dietary behaviours.

Alternative models, such as the capability, opportunity, and motivation behavioral model, may provide a more holistic view of the factors needed to change behavior while being more user-friendly.

**IMPLICATIONS FOR RESEARCH AND PRACTICE**

Here we demonstrate how the Nine Principles framework could guide the developing BCS within an RCT to enhance adherence to desired behaviors. However, this framework does not account for underexplored behaviors. This shortfall could be addressed by further adaption of the framework as conducted previously for the behavior of scaling up individual upcycling. The intercept of theory and practice is important for any successful integration of a BCS program. Rather than view the framework as rigid steps, we recommend the underlying principles be used to guide the development of BCS. Documentation of the framework and process followed, specific BCTs incorporated, and tools used to evaluate the BCS are important for furthering our understanding of how to effectively develop BCS. The need to adapt frameworks and make decisions regarding appropriate behavioral model use in a time-pressured environment is a barrier that may prevent researchers from using them in nutrition-related RCTs, even with the prospect of enhancing adherence. Further practical support is warranted to guide researchers through this development process.

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