Research Brief

Evaluating the Validity of the PortionSize Smartphone Application for Estimating Dietary Intake in Free-Living Conditions: A Pilot Study

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ABSTRACT

Objective: Evaluate the validity of the PortionSize application.

Methods: In this pilot study, 14 adults used PortionSize to record their free-living food intake over 3 consecutive days. Digital photography was the criterion measure, and the main outcomes were estimated intake of food (grams), energy (kilocalories), and food groups. Equivalence tests with ±25% equivalence bounds and Bland-Altman analysis were performed.

Results: Estimated gram intake from PortionSize was equivalent (P < 0.001) to digital photography estimates. PortionSize and digital photography estimated energy intake, however, were not equivalent (P = 0.08), with larger estimates from PortionSize. In addition, PortionSize and digital photography were equivalent for vegetable intake (P = 0.01), but PortionSize had larger estimates of fruits, grains, dairy, and protein intake (P > 0.07; error range 11% to 23%).

Conclusions and Implications: Compared with digital photography, PortionSize accurately estimated food intake and had reasonable error rates for other nutrients; however, it overestimated energy intake, indicating further application improvements are needed for free-living conditions.

Key Words: portion size, food intake, energy intake, food groups, mHealth

INTRODUCTION

Assessing food and nutrient intake accurately is essential for improving health and nutrition as well as reducing the risk of chronic diseases. Current food image-based methods allow capturing dietary data in real time1–5; however, these methods rely on human raters to estimate food intake, meaning they cannot provide real-time and detailed feedback about an individual’s diet. Given that food intake is strongly influenced by decisions made before eating begins,6,7 providing people with feedback on food selection (before food is eaten) can make it easier to modify their dietary behavior when the behavior occurs.8,9 Thus, the PortionSize application (app) was developed to provide users with real-time feedback on dietary selection, intake, and adherence to the US Department of Agriculture (USDA) MyPlate recommendations.10

PortionSize uses specific formulas to calculate the user’s energy and food group requirements on the basis of their sex, age, weight, and height.11,12 The app integrates food templates and other techniques that allow users to estimate their portions in real time on the basis of images they capture of their food with the app. As the user consumes meals throughout the day, the app provides immediate feedback on the energy, food group, and nutrient content before and after each eating occasion, as well as cumulative feedback on their intake for the entire day.11,12 The app dashboard is updated in real time and easily allows the user to see if they have achieved their energy, food group, and nutrient targets (Figure 1). These innovative features highlight the potential of PortionSize to advance the science of dietary assessment and nutrition counseling.
However, evaluation of its usability and validity is crucial to determine if it is useful in various settings.

Preliminary validity data from PortionSize has been reported by Saha et al., who tested the accuracy of the app in laboratory conditions in a small sample of 15 adults. The results showed that PortionSize overestimated energy intake by ~13% when compared with weighed intake. In addition, PortionSize produced equivalent estimates for consumption of food (grams), sugars, fruit, and dairy compared to weighed intake. The results from the study reported herein were obtained from the same sample of participants who subsequently used PortionSize over 3 days in free-living conditions. In this pilot study, PortionSize’s validity was tested against a criterion measure, the validated digital photography of foods method. Furthermore, we quantified ratings of participants’ satisfaction and usability of PortionSize. We hypothesized that food (grams), energy (kilocalories), and food groups (servings) intake estimates from PortionSize would be equivalent to the criterion measure and that the app’s bias would not differ over levels of intake. The results of this free-living pilot study will identify ways to improve PortionSize, which may eventually assist individuals in accurately managing their dietary intake.

**METHODS**

**Participants**

The study had 2 phases: Phase 1 consisted of a laboratory test meal, which has previously been published, whereas Phase 2 included a 3-day intake estimation in free-living conditions. Participants were recruited from August to November 2020 by distributing flyers in the community, advertisements on the Pennington Biomedical Research Center (PBRC) website, and social media platforms. All interested individuals completed a screening questionnaire by telephone, and preliminarily eligible participants were scheduled for an in-person screening visit. Adults aged between 18 and 65 years with a body mass index (BMI) of 18.5–45 kg/m² who had an iPhone 6 or above were eligible to participate. Participants were excluded from participation if they self-reported having an eating disorder or serious mental illness.

It has been suggested that a sample size of 10–15 participants is sufficient for a pilot study; thus, 15 participants were enrolled in the first phase of the study. After Phase 1, 1 participant did not complete Phase 2 (free-living phase); thus, this analysis included 14 participants. All participants provided written informed consent before enrollment. Participants received $75 on completion of both phases of the study. All study procedures were approved via expedited review by the Institutional Review Board at PBRC. The study is registered at ClinicalTrials.gov (NCT04494971).

**Procedures and Measurements**

In Phase 1 of the study, participants visited the laboratory, in which anthropometric measurements were taken by trained staff, and BMIs were calculated. The goal of this phase was to examine the validity of PortionSize under controlled conditions, which was previously published. During this first phase of the study,
participants received approximately half an hour of experiential training, which provided information and instructions on how to use PortionSize. A test meal that comprised plastic food models was provided during the training so participants could practice estimating food portions using the app. The training was completed once participants demonstrated mastery using the app. The training was followed by a lab-based meal that allowed participants to measure the simulated intake of test meals with PortionSize.

Within approximately 1 week of training, participants began the second phase of the study, which tested the usability and the validity of PortionSize in free-living conditions against a criterion measure, digital photography of foods. In Phase 2, participants were instructed to follow their regular eating routines but to use PortionSize to track their food selection and consumption on all eating occasions for 3 consecutive days (2 weekdays and 1 weekend day). This second phase also included an ecological momentary assessment (EMA) approach to prompt and remind participants to use the app throughout the observation period, with the goal of improving data quality and minimizing missing data (see the following section for the details of the EMA prompts). To obtain the criterion measure, participants captured their typical meals using the app, and the images were transferred to a secure web-based server, in which 2 trained raters quantified the amount of food in each image on the basis of the digital photography of foods method. After recording their typical 3-day dietary intake, participants completed a satisfaction survey to evaluate the usability of the app.

PortionSize App

Participants were instructed to use PortionSize to record all foods and beverages that they consumed in real time. Participants were instructed to follow their typical eating style and routines. When a participant selected their food for an eating occasion, they captured a before-meal image that included the amount selected for that eating occasion. To facilitate accurate estimation of portion sizes/food intake from food images, participants placed a reference card next to the food items when capturing images of their meals, which standardized the distance and angle of the image (Figure 2-A). When the participants took the image, they identified each meal item by selecting the item from the onboard database within PortionSize. This database includes a subset of the USDA Food and Nutrient Database for Dietary Studies (FNDDS) database (version 2017–2018). Therefore, PortionSize currently contains approximately 1,150 food items linked to food codes in the FNDDS database, allowing participants to identify items (or similar items) within meals. The participants identified meal items by tapping on a meal item on the screen to bring up a drop-down list of foods and beverages. Using the search function, they could also seek out specific foods (shown in Figure 2-B).

After finding the food item on the list, the user clicked select and was guided by the app to use the food templates (Figure 2-C). There were specific templates for each food item; for example, a deck of cards was appropriate for steak, and a poker
Each participant received 4 prompts, with a yes or no response, or they could type in more. The prompts included: (1) Did you eat or drink anything around individual participants’ mealtime, and (2) Can you take before and after images of your lunch? The participants captured with PortionSize were transmitted wirelessly and automatically to a server at PBRC. Using existing and validated visual comparison procedures, human raters analyzed these food images to estimate dietary intake. To determine the level of interrater reliability, we oversampled 20% of the images and used interclass correlation coefficients to compare the raters’ estimates of food selection, plate waste, and food intake. This evaluation revealed excellent interrater reliability among the 2 raters (intraclass correlation coefficient, > 0.95). Ratings were conducted using a computer program built at PBRC called the Food Photography Application. The raters received at least 15 hours of training by the designated master rater, in which they learned how to use the Food Photography app software. The tasks of learned raters were 3-fold: (1) to match each food item depicted in the before image to a proper food code in the FNDDS, (2) to search and select a food-specific image of standard portion size, and (3) visually compare participants’ images to the standard portion images to estimate the amounts of foods in the before- and after-meal images and enter those values into the software. The software then calculated dietary information on the basis of the entered amount and the FNDDS database (version 2017–2018), which includes 7,083 food and beverage items.

Other Measurements

Body weight and height were assessed by trained researchers and used to calculate the participants’ BMI. Participants’ demographics were assessed using a survey, and their sex was self-reported by selecting male or female responses. Race or ethnicity was also self-reported by the participants from a list including non-Hispanic White, non-Hispanic Black, Hispanic, Asian or Pacific Islander, Native American (including Alaskan), biracial or multiracial (specify), or other (specify). Participants completed an 8-item survey that was adapted from prior studies to obtain overall satisfaction with PortionSize, satisfaction with embedded food templates and app training, and ease of use. All items were rated on a scale ranging from 1 to 6, with 1 indicating extremely dissatisfied or not at all and 6 indicating extremely satisfied or very much.

Statistical Analysis

The primary outcomes of this study were estimations of intake of food, energy, and food groups (ounce equivalent and cup equivalent) using PortionSize compared with the criterion method (digital photography of foods) across 3 consecutive days in free-living conditions. The secondary outcomes of the study were macronutrients (carbohydrates, fat, and protein), selected nutrients (saturated fat, cholesterol, dietary fiber, sugars, and added sugars), and selected micronutrients (sodium, calcium, iron, potassium, and vitamin D). The rationale for selecting these specific nutrients was to include the nutrients that are available for consumers in nutrition fact panels. Influence diagnostics were used to identify data points exhibiting high leverage on model parameters for estimations of food and energy intake. The influential data points were excluded from all analyses and reported with residuals and Cook’s D values.

A series of analyses were conducted to test the validity of PortionSize. First, all outcomes were analyzed by assessing the equivalence between PortionSize and the digital photography of foods method by using the Two One-Sided T-Test (TOST) method. These analyses relied on data from the mean outcome across the 3 days of measurement. Based on a previous validation study, the equivalence bounds were set at ±25%, with significance indicating evidence that the measures are equivalent and their difference falls within the 25% equivalence bounds. We also estimated the mean percent error (ie, [(PortionSize – digital photography)/digital photography] × 100) at the group level to quantify measurement error between PortionSize and digital photography. Second, Bland-Altman analyses were used to evaluate the level of agreement between the 2 methods for estimations of all outcomes. Differences or bias between the 2 methods on the y-axis was plotted against the mean of the 2 methods on the x-axis. The zero-bias line, 95% upper or lower confidence limits, and 95% limits of agreement were calculated.
limits (mean difference ± 2 SD of the differences), and the regression trend line were included on the same plot. For primary outcomes, the significance level was set at 0.05; however, for secondary outcomes, we set a P value of 0.01 to control the error rate.28

A linear mixed model with repeated measures was used to determine whether estimations for food and energy intake outcomes differed between the weekdays and the weekend days or across the 3 days.29 These analyses relied on data from daily intakes of food and energy. Standardized effect sizes (Cohen’s $d$) are reported for the primary and secondary outcomes. Based on Lakens et al,30 the hypothesized effect sizes were small because equivalence between PortionSize and the criterion measure was expected. Results from linear mixed models were reported as adjusted means ± SEM; all other results were reported as mean ± SD. All analyses were performed using SAS software (version 9.4, SAS Institute, Inc, 2013).

RESULTS
Subject Characteristics
A total of 14 participants were included in this analysis. Demographic characteristics of participants are shown in Table 1. Participants were White (100%) and predominantly female (71%). Mean ± SD age and BMI were 26.4 ± 11.0 years and 22.9 ± 4.6 kg/m², respectively. Half of the participants reported some college (50%) as their highest level of education, and the majority reported a household income ≤ $50,000.

Dietary Estimations
Participants recorded 147 eating occasions across 3 days in free-living conditions. Examination of the influence diagnostics for the model of dietary intake estimates identified 6 meals reported by 5 different participants as influential. These meal entries had extremely high residuals, leverage, and Cook’s distance ($D_i > 0.05$).31 It was evident that the estimations from these meal entries were extremely high because of overestimation caused by the misuse of portion templates in PortionSize. Thus, we excluded the 6 influential meal entries from both methods, resulting in a total of 141 eating occasions recorded by both methods across 3 days, 2.4 ± 0.6 occasions were entered as main meals per day, and 1.0 ± 0.7 were entered as snacks per day, in which 88% included food items and 12% were beverages (10% of beverages were alcoholic beverages). Participants responded to 181 (85%) of the 213 EMA prompts (with a range of 12–20 per participant) that were delivered around their mealtimes. Users recorded 7% of eating occasions using the forgot meal tab of PortionSize.

When looking into dietary estimations for each method, estimations of food intake (grams per day) were not significantly different on weekdays compared to weekend days for PortionSize (1,081 ± 123 vs 1,155 ± 153 g/d, respectively; P = 0.64) and digital photography (1,073 ± 121 vs 1,112 ± 121 g/d, respectively; P = 0.82). The results were similar for energy intake estimates when comparing weekdays to weekends for PortionSize (1,452 ± 136 vs 1,778 ± 176 kcal/d, respectively; P = 0.11) and digital photography (1,317 ± 116 vs 1,415 ± 145 kcal/d, respectively; P = 0.53). Similarly, reported food and energy intake did not differ significantly across 3-days for both methods (P > 0.29).

Based on PortionSize and digital photography data, participants consumed 97% ± 3% of the amount of food they selected. PortionSize estimates indicated that participants consumed 44% of their daily energy as carbohydrates, 17% as protein, and 39% as fat. Digital photography estimates were similar: participants consumed 44% of their daily energy as carbohydrates, 18% as protein, and 38% as fat. Supplementary Table 2 shows the food group estimations compared with daily nutritional goals.

Differences Between PortionSize and Digital Photography
The results of the equivalence test indicated that estimated food intake by PortionSize (mean ± SD, 1,105 ± 418 g/d) was equivalent to digital photography estimates (1,086 ± 396 g/d; $P < 0.001$). The mean food intake difference between the 2 methods
was 19 ± 189 g, and the mean percent error for the estimation of food intake was 1.8% (Table 2). PortionSize and digital photography estimates of energy intake (1,561 ± 447 vs 1,350 ± 389 kcal/d) were not equivalent (P = 0.08), with higher estimates from PortionSize (211 ± 318 kcal/d; mean percent error, 15.6%) compared with digital photography (Table 2). As shown in Figure 3-A, the Bland-Altman plot for total intake showed a mean difference of 19 g, and the 95% confidence limit of agreement located above and below the mean difference was 389 g and 351 g, respectively. The measurement error of PortionSize in estimating food intake was consistent over different levels of food intake (P = 0.68). A similar pattern of error over different levels of energy intake was observed for total energy intake (Figure 3-B), and the regression indicated that bias did not differ over levels of intake (P = 0.50).

PortionSize and digital photography were equivalent for vegetables (P = 0.008), but PortionSize had larger estimates of fruits, grains, dairy, and protein intake (all P > 0.07). Although the magnitude of food group error was relatively low for fruits (0.13 cup Eq) and dairy (0.23 cup Eq), the errors were more meaningful for grains (0.49 oz Eq) and protein (1 oz Eq). Among the 5 food groups (Table 2), estimations of vegetables had the lowest mean percent error (−1.4%), with those for protein having the highest (22.7%). Bland-Altman analysis for all food groups had wide limits of agreement, and no significant trends were found (r² < 0.22; P > 0.09) except for protein. The regression line was significant (r² = 0.42; P = 0.01), with PortionSize underestimated protein intake at lower levels of intake, but overestimation occurred and increased with higher levels of intake.

The estimates for protein were equivalent (P = 0.004); however, the estimates of fat (P = 0.19) and carbohydrates (P = 0.25) were not equivalent between PortionSize and digital photography (Table 2). All other nutrient intake estimates were not equivalent between the 2 methods (P > 0.02). Among all nutrients, the estimations of calcium had the lowest mean percent error (5.9%), with those for iron having the highest (116.1%). Bland-Altman analysis for all nutrients had wide limits of agreement, and no significant trends were found (r² < 0.42; P > 0.01) except for cholesterol and iron. The regression line was significant for cholesterol (r² = 0.44; P < 0.01) and iron intake (r² = 0.98, P < 0.001); PortionSize underestimated intake of cholesterol and iron at lower levels of intake, but overestimation occurred and increased with higher levels of intake.

### Table 2. Comparison of Portion Size, Energy, and Nutrient Intake Estimates Between PortionSize and Digital Photography (n = 14)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>PortionSize</th>
<th>Digital Photography</th>
<th>Difference</th>
<th>Equivalence at ±25%</th>
<th>Effect Sizea</th>
<th>Mean Percent Errorb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portion size (g)</td>
<td>1,105.2 ± 418.4</td>
<td>1,066.1 ± 396.0</td>
<td>19.1 ± 188.7</td>
<td>&lt; 0.001c</td>
<td>0.05</td>
<td>1.8</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>1,560.6 ± 446.8</td>
<td>1,349.7 ± 389.2</td>
<td>211.0 ± 317.7</td>
<td>0.08</td>
<td>0.50</td>
<td>15.6</td>
</tr>
<tr>
<td>Fruits (cup Eq)</td>
<td>1.1 ± 1.0</td>
<td>1.0 ± 0.8</td>
<td>0.1 ± 0.6</td>
<td>0.27</td>
<td>0.15</td>
<td>13.8</td>
</tr>
<tr>
<td>Vegetables (cup Eq)</td>
<td>1.3 ± 0.9</td>
<td>1.4 ± 0.9</td>
<td>−0.02 ± 0.4</td>
<td>&lt; 0.01c</td>
<td>−0.02</td>
<td>−1.4</td>
</tr>
<tr>
<td>Grains (oz Eq)</td>
<td>5.2 ± 2.3</td>
<td>4.7 ± 2.0</td>
<td>0.5 ± 1.7</td>
<td>0.08</td>
<td>0.23</td>
<td>10.6</td>
</tr>
<tr>
<td>Dairy (cup Eq)</td>
<td>1.3 ± 0.9</td>
<td>1.1 ± 0.7</td>
<td>0.2 ± 0.6</td>
<td>0.41</td>
<td>0.29</td>
<td>21.7</td>
</tr>
<tr>
<td>Protein (oz Eq)</td>
<td>5.6 ± 3.6</td>
<td>4.5 ± 2.6</td>
<td>1.0 ± 1.5</td>
<td>0.40</td>
<td>0.33</td>
<td>22.7</td>
</tr>
<tr>
<td>Saturated fat (g)</td>
<td>21.4 ± 8.4</td>
<td>18.0 ± 8.5</td>
<td>3.4 ± 4.0</td>
<td>0.17</td>
<td>0.40</td>
<td>19.0</td>
</tr>
<tr>
<td>Added sugars (tsp)</td>
<td>6.5 ± 4.6</td>
<td>5.8 ± 3.5</td>
<td>0.8 ± 2.2</td>
<td>0.13</td>
<td>0.18</td>
<td>13.1</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>68.4 ± 23.0</td>
<td>61.7 ± 20.5</td>
<td>6.7 ± 10.5</td>
<td>0.004c</td>
<td>0.31</td>
<td>10.9</td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>68.6 ± 23.9</td>
<td>58.0 ± 20.6</td>
<td>10.6 ± 16.1</td>
<td>0.19</td>
<td>0.47</td>
<td>18.2</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>174.3 ± 66.4</td>
<td>147.8 ± 26.5</td>
<td>39.6 ± 55.9</td>
<td>0.25</td>
<td>0.44</td>
<td>17.9</td>
</tr>
<tr>
<td>Dietary fiber (g)</td>
<td>19.2 ± 12.5</td>
<td>14.7 ± 7.1</td>
<td>4.5 ± 10.1</td>
<td>0.62</td>
<td>0.44</td>
<td>30.5</td>
</tr>
<tr>
<td>Sugars (g)</td>
<td>60.0 ± 29.9</td>
<td>49.4 ± 22.7</td>
<td>10.6 ± 15.8</td>
<td>0.35</td>
<td>0.40</td>
<td>21.5</td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>266.0 ± 203.0</td>
<td>223.6 ± 149.6</td>
<td>42.5 ± 81.4</td>
<td>0.27</td>
<td>0.24</td>
<td>19.0</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>2,724.5 ± 807.8</td>
<td>2,172.7 ± 593.4</td>
<td>551.8 ± 498.5</td>
<td>0.53</td>
<td>0.78</td>
<td>25.4</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>655.8 ± 335.6</td>
<td>619.5 ± 295.8</td>
<td>36.3 ± 200.4</td>
<td>0.02</td>
<td>0.11</td>
<td>5.9</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>20.6 ± 32.2</td>
<td>9.6 ± 2.6</td>
<td>11.1 ± 31.5</td>
<td>0.84</td>
<td>0.48</td>
<td>116.1</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>2,029.7 ± 820.6</td>
<td>1,847.2 ± 637.2</td>
<td>182.5 ± 493.4</td>
<td>0.03</td>
<td>0.25</td>
<td>9.9</td>
</tr>
<tr>
<td>Vitamin D (μg)</td>
<td>4.2 ± 3.3</td>
<td>3.0 ± 2.3</td>
<td>1.2 ± 2.1</td>
<td>0.75</td>
<td>0.40</td>
<td>37.9</td>
</tr>
</tbody>
</table>

aStandardized effect sizes are represented by Cohen’s d. bMean percent error (mean ± SD) = ([PortionSize − digital photography]/digital photography) × 100; cIndicates significant results of equivalence tests: for primary outcomes, estimated intake of food (grams), energy (kilocalories), and food groups (servings), the significance level was set at 0.05; however, for secondary outcomes (all other outcomes), we set a P value of 0.01.

### Satisfaction and Ease of Use of PortionSize

Participants found PortionSize easy to use (72%) and after (72%) a meal was consumed, as indicated by their choice of the 2 most favorable ratings (Supplementary Table 3). More than half of the participants (58%) reported that the food templates provided in PortionSize were appropriate. In addition, a large proportion of participants rated PortionSize with the 2 most favorable...
ratings for satisfaction when they captured before (57%) and after (72%) meals. Finally, 93% of participants indicated that the iPhone training for PortionSize helped prepare them for using the app.

**DISCUSSION**

In free-living conditions, PortionSize provided equivalent estimates for food intake, but not energy intake, compared with digital photography of foods. In addition, PortionSize provided estimates that were equivalent to digital photography only for vegetables, with relatively minimal errors for fruit and dairy intake. Following 3-days of using PortionSize,
participants were satisfied with the app and found it easy to use. The results of this pilot study indicate that PortionSize was effective in providing estimates for some nutrients similar to those of the validated digital photography and was acceptable to participants. Nonetheless, the validity of PortionSize in free-living conditions requires comparisons against gold standard measures of free-living energy intake, such as the doubly labeled water method.

PortionSize uniquely features superimposed portion templates that assist users in estimating food portions in real-time. Results from this study indicated that the estimated food intake from PortionSize was equivalent to digital photography. However, estimated energy intake differed between the 2 methods. These results were supported by our previous findings in the controlled-feeding phase, in which participants’ dietary estimations with PortionSize during a lunch meal were compared with weigh-back measurements. Taken together, these findings suggest that, although the app and raters estimated similar amounts of food, there may be some discrepancies between the type of food selected in the onboard nutrient database between users and raters. For example, participants may eat a burger and select the condiments and cheese options in the app’s search function but fail to provide these details in the meal description, which is critical to the digital photography process. Furthermore, because raters had access to the entire FNDDS database, they may have selected the exact food type or the available combined (mixed) food option, whereas participants used more generic food types or logged separate ingredients when recording their foods using PortionSize. Based on a recent report, defining the specific food items and types has implications for the estimation of energy intake. Therefore, considering these findings, we revised our training and built-in food database to help participants more accurately find and select the foods that they are eating.

Analyzing the food group estimates for both methods, we found equal estimates only for vegetables. However, the error rate was modest for other food groups, and the effect sizes were small. The controlled phase of the study found similar results, but with higher error rates for fruits and grains. Moreover, only protein was equivalent between the 2 methods, whereas iron had the highest error rate. Similarly, the controlled phase found equivalent estimates for potassium and sugars, and iron estimations had a large error rate. Because food intake encompasses energy intake, nutrient intake (macronutrients, micronutrients, vitamins, minerals), and intake of various food groups (eg, fruits, vegetables), improvements in PortionSize that enhance the estimation of portion sizes have the potential to lead to more accurate estimation of other nutrients.

Previous studies suggest that adherence to more burdensome methods of assessing dietary intake can be low and we found that methods that were perceived as more burdensome were less preferred. Thus, the use of PortionSize may be negatively affected by user burden because, for example, it is more burdensome than apps that require the user to only capture an image of their foods. Specifically, the app provides users with real-time feedback on dietary selection, intake, and adherence to USDA MyPlate recommendations. In this pilot validity study, participants were instructed to follow their regular eating routines without making any attempt to align their food and energy intake with the provided real-time information. The use of real-time feedback to alter participant eating behavior may increase motivation and lead to a better overall experience. In addition, because this study used an early version of the app, participants experienced app glitches and data transfer issues. We attempted to address these issues by communicating with participants through EMA prompts; however, these issues increased participant burden when using PortionSize. Despite these practical issues, we found that users were satisfied with PortionSize and found it easy to use. In addition, almost half of the participants were satisfied with the feedback provided by the app regarding their portion sizes, which indicates that users were satisfied with the real-time feedback provided by the app.

The user satisfaction results, however, should be interpreted with caution as the participants only used PortionSize for 3 days.

A strength of this pilot study is that the participants captured dietary intake over 3 days in ecologically valid free-living conditions, which included a weekend day. Another strength is that the images captured with PortionSize were used for the digital photography method. Therefore, we pilot-tested the validity of the app compared with human raters using an identical data source. The study also has important limitations that must be considered. First, we excluded influential points. Second, PortionSize was only available for iPhones. Third, the sample was entirely White and predominantly female, which may preclude the generalization of the findings to larger, more heterogeneous samples. Finally, the food items in PortionSize contained only a subset of the FNDDS database, which may have influenced the current findings and participants’ experience in the free-living conditions.

PortionSize was developed to provide real-time feedback on food selection and intake, and USDA MyPlate food groups were developed to assist individuals in adhering to dietary recommendations. Based on Fogg’s behavior model, behavior change is effective only if motivation, ability, and triggers are present at the same time. Thus, with its real-time feedback, PortionSize has the potential to promote healthy eating across large groups. Evaluation of PortionSize’s validity in free-living settings found that PortionSize produced accurate food intake estimates compared with digital photography without requiring human rating. However, PortionSize overestimated energy intake, indicating additional app improvements are needed for free-living conditions.

**IMPLICATIONS FOR RESEARCH AND PRACTICE**

PortionSize estimated food intake accurately and provided reasonable effect sizes for other dietary estimates compared with digital photography. These findings provided insight into
areas in which PortionSize needs to be improved, such as portion templates and EMA features. The findings also informed the addition of a feature to reduce misuse of PortionSize and to minimize influential data points. Specifically, the app now prompts participants when their portion estimate is 4 times larger than the standard portion. This change was made after the study reported herein. For a proper validity test for dietary intake estimates, the app needs to be further tested in various conditions with a more diverse and gender-balance sample to ensure the study results are more representative. Because app development is a dynamic and continuous process, for future versions, it may be possible to reduce the burden and increase engagement by incorporating emerging technologies, such as automated food identification and volume estimation.35,36

There are several unique aspects of the app that make PortionSize a promising approach for use in various settings, including real-time portion estimation and personalized dietary intake guidance regarding the extent to which a person’s consumption throughout the day meets specific energy intake and nutrition goals. Considering the ongoing trials and improvements, PortionSize has the potential to advance nutrition counseling and dietary assessment and serve as a useful intervention tool. Decreasing participant burden while increasing engagement can help to fulfill the eventual goals of the app and maximize clinical utility while minimizing researcher burden, costs, and time.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jneb.2024.05.226.

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