

## Smartphone tool to collect repeated 24-hour dietary recall data in Nepal

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**Authorship:** HHF prepared the first draft of the manuscript, developed the overall study design and final tools, and conducted all analyses. NMS formulated the research question and provided detailed technical inputs. AC provided technical oversight. BJB developed the concept of the smartphone components, and supported TH to develop the proof-of-concept for this. TH led the pilot testing and collection of utensil data with PP and HHF. NS collected weights of discrete food items. PP, HHF, and NS trained data collectors and PP and SJ managed the data collection. HHF processed the data, and HHF, NS and PP routinely checked the outputs. DSM and BS were project director and project manager, respectively, and were responsible for day-to-day oversight and coordination of field activities. AC and NMS are principal investigators of the main trial. All authors read and approved the final manuscript.

**Ethical standards disclosure:** Ethical approval was obtained from the Nepal Health Research Council (108/2012) and the UCL Ethical Review Committee (4198/001). Verbal informed consent was obtained from all subjects. Verbal consent was obtained and formally recorded on paper forms

1 **Abstract**

2 **Objective:** To outline the development of a smartphone-based tool to collect thrice-repeated 24-  
3 hour dietary recall data in rural Nepal, and to describe energy intakes, common errors, and  
4 researchers' experiences using the tool.

5 **Design:** We designed a novel tool to collect multi-pass 24-hour dietary recalls in rural Nepal by  
6 combining the use of a CommCare questionnaire on smartphones, a paper form, a QR-coded list of  
7 foods, and a photographic atlas of portion sizes. Twenty interviewers collected dietary data on three  
8 non-consecutive days per respondent, with three respondents per household. Intakes were converted  
9 into nutrients using databases on nutritional composition of foods, recipes, and portion sizes.

10 **Setting:** Dhanusha and Mahottari districts, Nepal.

11 **Subjects:** Pregnant women, their mothers-in-law, and male household heads. Energy intakes  
12 assessed in 150 households; data corrections and our experiences reported from 805 households and  
13 6,765 individual recalls.

14 **Results:** Dietary intake estimates gave plausible values, with male household heads appearing to  
15 have higher energy intakes (median: 12,079 kJ/day (25<sup>th</sup> and 75<sup>th</sup> centiles: 9,293 to 14,108)) than  
16 female members (8,979 (7,234 to 11,042) for pregnant women). Manual editing of data was  
17 required when interviewers mistook portions for food codes, and for coding items not on the food  
18 list. Smartphones enabled quick monitoring of data and interviewer performance, but we initially  
19 faced technical challenges with CommCare forms crashing.

20 **Conclusions:** With sufficient time dedicated to development and pre-testing, this novel  
21 smartphone-based tool provides a useful method to collect data. Future work is needed to further  
22 validate this tool and adapt it for other contexts.

23 **Keywords:** Nutrition, data collection, electronic data capture, smartphones, dietary recall

## 24 **Introduction**

25 Field surveys, traditionally conducted on paper forms, are increasingly using electronic data capture  
26 tools, such as tablets and smartphones. Compared with paper methods, commonly cited relative  
27 benefits of electronic data capture include: quicker access to data, more options to check data  
28 quality and interviewer performance, lower costs for data entry, and reduced risk of data loss  
29 during transport and storage <sup>(1-3)</sup>.

30 However, in low-income countries, these benefits have rarely been realised for the collection of  
31 dietary data, such as 24-hour dietary recalls or weighed food records <sup>(4-6)</sup>. Dietary intake assessment  
32 is well-known to be error-prone <sup>(7, 8)</sup>, so near-instant access to digitised data could facilitate  
33 improvements in data quality and precision of intake estimates, particularly for studies with large  
34 sample sizes. For example, data managers could quickly identify errors, such as implausible  
35 frequencies of food items or portion sizes, outliers in nutrient intake estimates, or missing or  
36 unexpected Global Positioning System (GPS) readings. They could also monitor interviewer  
37 performance by measuring digit preference, time taken to conduct interviews, or systematic under-  
38 or over-reporting.

39 A key challenge associated with the use of electronic capture of dietary data is the complex  
40 interview structure. Respondents may report multiple portions of a food item, from many hundred  
41 possible foods, at many different times of day <sup>(4)</sup>. Dietary surveys also often collect recipes for  
42 mixed dishes and descriptions of leftovers or shared foods <sup>(9)</sup>. These details are iteratively probed in  
43 a non-linear fashion during a dietary recall, and this is difficult to programme on smartphones.  
44 Another level of complexity is added to the data structure for studies collecting repeated dietary  
45 assessments on the same individuals and/ or multiple individuals within households. However, if  
46 these challenges can be overcome, the quality and follow-up rates of dietary intake data might  
47 improve.

48 This article provides a novel solution to electronic collection of dietary data using CommCare  
49 software on smartphones, an atlas of graduated portion sizes, and a list of food items. We also  
50 describe the development and implementation of the tool, characterise the diet to assess the  
51 plausibility of results, and comment on the key benefits and challenges of using this tool.

## 52 **Methods**

### 53 *Study context*

54 This study was conducted in Dhanusha and Mahottari districts in the *Terai*, on the border with the  
55 Indian state Bihar. Being in the Indo-Gangetic floodplains, with fertile land and favourable climatic  
56 conditions, agricultural productivity is higher in the *Terai* than other regions of Nepal <sup>(10, 11)</sup>.

57 Household food security in the *Terai* is higher than the hilly and mountainous regions of Nepal, but  
58 women's nutritional status is among the lowest in the country (23% with BMI <18.5 kg/m<sup>2</sup>, and  
59 52% with haemoglobin concentrations <12g/dl) <sup>(12)</sup>. Nepalese diets are typically monotonous and  
60 characterised by consumption of cereals and pulses, particularly rice and lentils, as well as tubers,  
61 and dairy in high caste groups <sup>(13-15)</sup>. Studies from the *Terai* show that gourd curries (bitter gourd,  
62 okra and snake gourd) are commonly eaten, whereas consumption of fruits, other vegetables, meat,  
63 fish, and eggs is rare <sup>(13, 15)</sup>.

64 2G-connectivity is variable but generally good, and a high proportion of households own a mobile  
65 phone (72% in rural Nepal) <sup>(16)</sup>, suggesting phones may be a feasible and culturally acceptable  
66 mode of data collection. Although unreliable electricity can make it difficult to regularly recharge  
67 mobile phones, simple solutions such as battery packs can help to overcome this. Flooding in the  
68 monsoon season makes some remote areas hard to reach and makes travel time a major demand on  
69 resources, so electronic data capture could enable remote monitoring of data collectors working far  
70 away from the main town (Janakpur). Flooding also poses risks for the security of paper forms, in  
71 comparison with electronically data that can be secured if the forms have been submitted to the web  
72 server.

73 From mid-August 2015, severe political unrest due to discontent over the new Nepal constitution  
74 and proposed federal state boundaries caused strikes, violent protests, road blockages, a border  
75 blockade, closure of markets and banks, and personal insecurity for the field team <sup>(17)</sup>. During this  
76 time, travel across the district was not always safe and so data could be transmitted from  
77 respondents' homes, rather than requiring interviewers to travel with paper forms to the field office.

78 We assessed dietary intakes to evaluate a pregnancy-focused, four-arm, cluster-randomised  
79 controlled trial, Low Birth Weight South Asia Trial (LBWSAT; [4](http://www.controlled-</a></p></div><div data-bbox=)

80 trials.com/ISRCTN75964374). The trial tested the impacts of participatory women’s groups, food  
81 transfers with women’s groups, and cash transfers with women’s groups, on birth weight and infant  
82 nutrition <sup>(18)</sup>. The dietary intake tool described in this paper was developed to collect 24-hour  
83 dietary recalls of pregnant women, their mothers-in-law, and male household heads, to assess  
84 whether trial interventions were associated with higher dietary intakes during pregnancy and/ or  
85 more equitable intra-household distribution of food than in the control areas.

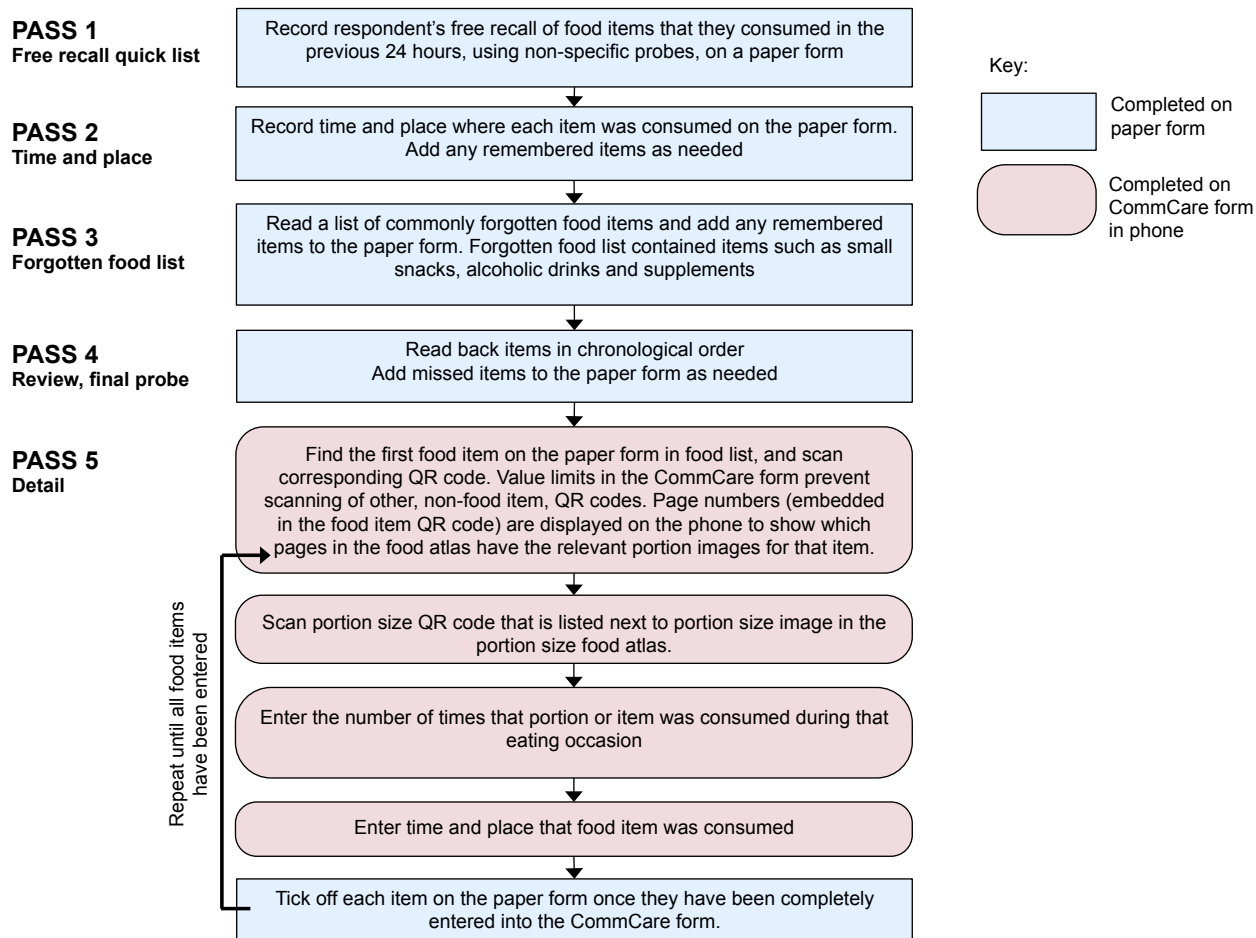
### 86 *Sample size and sampling*

87 The selection of study site, randomisation, and participant eligibility is described in full in the trial  
88 protocol <sup>(18)</sup>. In brief, 80 Village Development Committee areas (administrative units) from  
89 Dhanusha and Mahottari districts were allocated to four study arms by stratified randomisation.  
90 Enrolment of pregnant women from these areas started in December 2013, and the interventions  
91 stopped in October 2015.

92 Between 10 June and 26 September 2015, we conducted a cross-sectional dietary intake survey on a  
93 sub-sample of enrolled women in their third trimester, their mothers-in-law, and male household  
94 heads. A target sample size of 800 households (200 per arm) was based on power calculations to  
95 detect differences between trial arms in Relative Dietary Energy Adequacy Ratios (RDEARs), a  
96 measure of intra-household calorie allocation. Due to the known wide within-person variability of  
97 dietary intakes, we collected three dietary recalls per person, giving a maximum of nine dietary  
98 recalls per household. Households were excluded if the household composition did not include the  
99 pregnant woman, a male household head, and the pregnant woman’s mother in law. To participate  
100 in the trial, women gave consent by signature or thumbprint. For each 24-hour recall interview of  
101 every household member, respondents gave verbal consent.

### 102 *Development of the 24-hour recall tool*

103 To minimise underreporting – a common problem with recall-based methods – we followed a ‘five-  
104 stage multi-pass’ 24-hour dietary recall method that uses five different probing techniques <sup>(19)</sup> and is  
105 recommended for the estimation of nutrient intakes in developing countries <sup>(20)</sup>. The five passes and  
106 the data collection process are outlined in Figure 1.



107

108 **Figure 1** Overview of the five-stage multi-pass 24-hour recall process

109 The passes were ordered as follows: (1) collect a chronological free recall, (2) probe for the time  
 110 and place of consumption, (3) ask about commonly forgotten foods like tea and fruit, (4) review  
 111 information so far and probe for anything missing, and (5) collect detail on specific food names and  
 112 portion size estimates. Interviewers entered information from the first four passes onto a simple  
 113 paper form to enable fluid interviewer-interviewee interactions, then the fifth pass (food names and  
 114 portion sizes) plus the time and place of consumption, was entered onto a smartphone form.

115 To develop the form, we used CommCare (Version 2.22.0, <http://www.commcarehq.org/home/>), an  
 116 open source, cloud-based data collection platform. Interviewers could choose to view the  
 117 questionnaire in Maithili, Nepali or English. The CommCare form coding is given in Web  
 118 Appendix 1, so researchers can use and adapt the tool by creating a blank form in CommCare and  
 119 importing the .xml file. We used Samsung Galaxy Y smartphones for the first two weeks but faced

120 problems of forms unexpectedly closing mid-survey and losing data, so we used higher  
121 specification Samsung Galaxy J1 phones for the rest of the study.

### 122 *Food lists and portion size estimates*

123 Each interviewer had a list of around 300 food names, and a photographic atlas containing life-sized  
124 pictures of graduated portion sizes of 40 locally prepared foods (list and atlas available on request  
125 from corresponding author). The food list was originally prepared for another study<sup>(21)</sup> but we  
126 refined it after pilot testing. To aid navigation, we organised the list by grouping the foods,  
127 providing a contents page, and creating a list of common foods at the front. The atlas contained  
128 between two and six images per item, depending on how common or nutritionally important the  
129 item was.

130 The development and validity of the photographic atlas has been described in detail elsewhere<sup>(9)</sup>  
131 but we edited the atlas after finding that volumes were not reliably selected. To select representative  
132 images of utensils for inclusion in the atlas, we collected data on utensil volumes by visiting 20  
133 households from 4 randomly sampled clusters. Households were sampled using a spin-the-pencil  
134 technique, starting at the centre of the village, walking in the direction that the pencil pointed, and  
135 sampling every fifth household. Each utensil volume was measured three times. Volumes were  
136 measured using a 50 ml or 500 ml volumetric measuring cylinder and we used the water  
137 displacement method to estimate volumes of handfuls (*muthi*). Looking at the means and frequency  
138 distributions of utensil volumes, we selected the number of images and utensil sizes to include. If  
139 the distributions were bimodal we included two images, otherwise we included one image, and we  
140 chose the photograph of the utensil that was closest to the mean. The means, standard deviation  
141 (SD) and range of these utensil volumes, and the selected volume of each image, are given in Table  
142 1.

143

144 **Table 1** Volumes of common household utensils

Utensil type	Utensil volume (ml)					Chosen volumes atlas images
	<i>n</i>	Mean	SD	Min	Max	
Large ladle	16	113.4	32.1	45	162	100, 130
Small ladle	14	69.4	19.0	33	100	70
Serving spoon	8	26.9	9.5	17	45	30
Table spoon	3	9.3	0.9	8	10	10
Tea spoon	18	5.3	1.6	3	8	6
Bowl	17	487.8	131.9	275	720	410, 250
Small glass	18	181.5	50.4	108	278	180
Large glass	20	347.2	103.7	225	732	310
Man's handful	9	93.7	28.9	38	138	80, 120
Woman's handful	20	77.7	18.6	43	112	60, 100

145 We collected weights of commonly eaten discrete food items by taking three samples of each food  
 146 item from three markets. Non-edible parts, such as bones, stones and skins, were removed, and the  
 147 edible portions were weighed using Tanita weighing scales sensitive to 0.1 g, and average weights  
 148 were reported to the nearest 1 g (Table 2).

149



150 **Table 2** Average weights of edible portions of common foods reported as discrete items

Food item	Average wt of edible portion (g)	Food item	Average wt of edible portion (g)
Stuffed bitter gourd	42	Indian sweet (dairy free)	31
Green chilli, salted and fried	29	Jeri (deep fried sugar/wheat sweet)	28
Phophee (deep-fried snack)	7	Candy	3
Samosa (veg)	91	Khaja (deep fried sugar/wheat sweet)	69
Litti (deep-fried wheat snack stuffed with lentils)	84	Banana	48
Chicken egg	54	Dates	8
Duck egg	54	Pomegranate	107
Momo (veg)	25	Tamarind *	1
Momo (meat)	20	Grapes	7
Omelette	109	Orange	129
Fried meat	10	Lacuca	222
Fried fish	13	Apple	118
Pyajji (whole onion/gram flour deep-fried snack)	62	Rose apple	3
Tilauri * (deep-fried snack)	1	Papaya	523
Pakora (onion and vegetable/gram flour deep-fried snack)	16	Guava	56
Ready-to-eat noodles, small pack	58	Lime	11
Laddu (sweet, made with puffed rice or wheat)	31	Lemon	26
Malpuwa (sweet deep-fried rice flour snack)	47	Bael fruit	442
Indian sweet (milky)	40		

\* This item is very small, so a handful was weighed and the average weight per item was calculated.

151

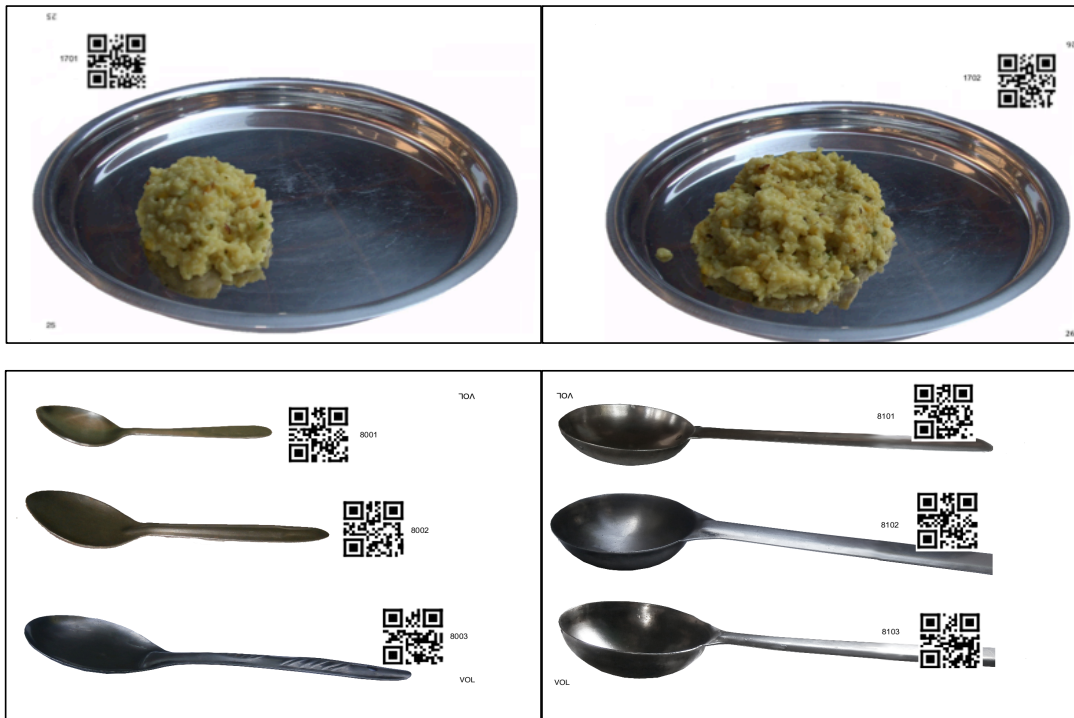
152 *Interview structure*

153 To reduce translation requirements and minimise coding errors, every food item in the food list and  
 154 portion size in the atlas had a unique number (5 and 4 digits, respectively) that was encoded in a  
 155 quick response (QR) code. To create the QR codes, the information to be contained within the QR  
 156 codes was first entered into Microsoft Excel sheets. We designed reports in a Microsoft Access  
 157 database that used the data from Excel to produce the food list with QR codes, and a list of portion

158 size QR codes that were pasted into the photographic atlas. The QR codes in the reports were  
159 generated using the StrokeScribe Barcode Active X Control (<http://www.strokescribe.com/>) (Excel  
160 sheets and Access reports available on request from corresponding author). The QR code could be  
161 scanned using the barcode scanning functionality available in CommCare when the 'ZXing Barcode  
162 Scanner' application was also installed.

163 Examples of the portion size QR codes and food list are shown in Figure 2.

Pages from photo atlas with life-sized portion sizes, page numbers and QR codes (not to scale)



Pages from the food list, with food names and QR codes



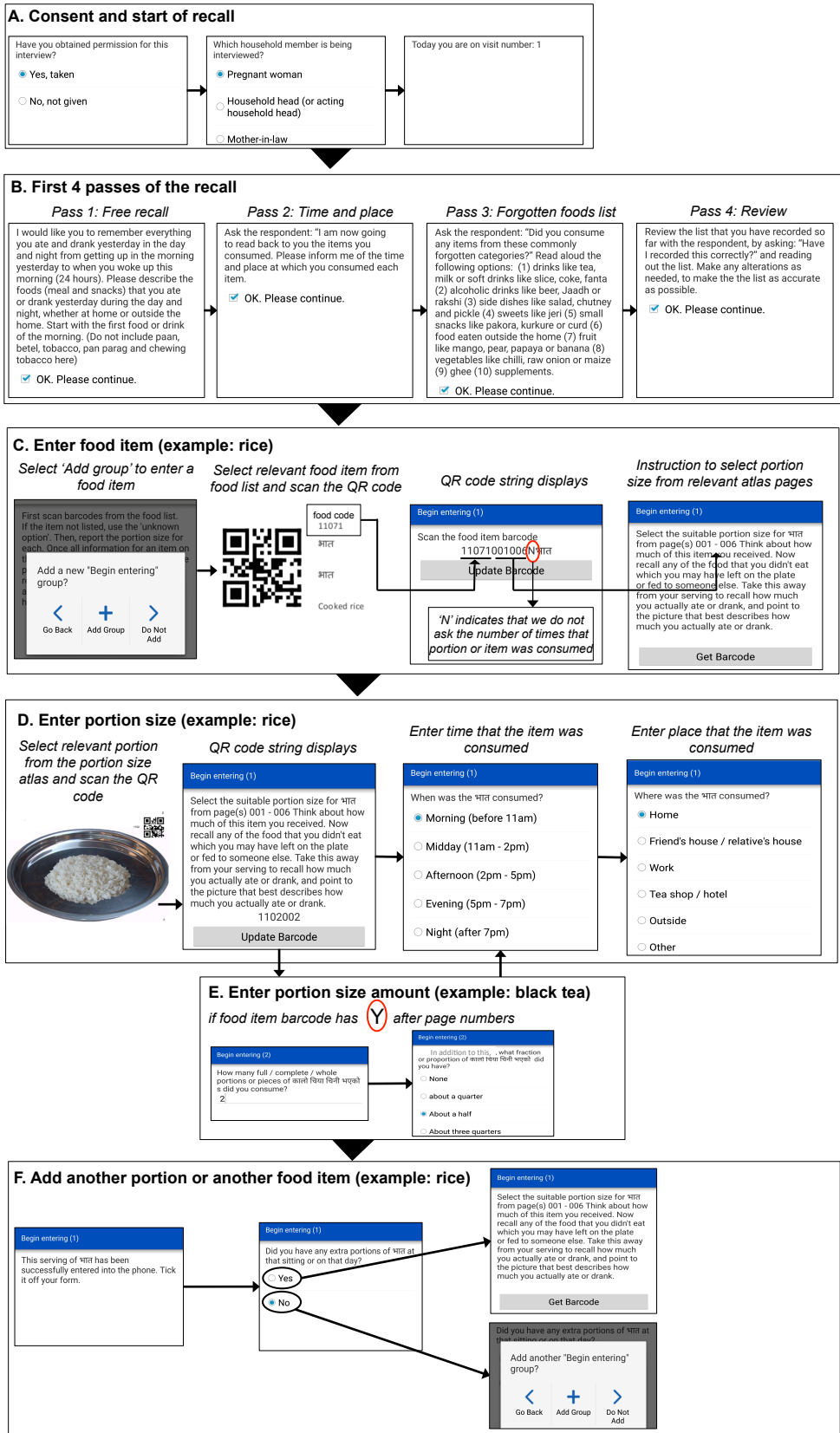
164

165 **Figure 2** Sample of pages from the photographic atlas and food list, giving portion sizes (not to  
 166 scale) and food names with their corresponding QR codes

167 In addition to the 5-digit food code, the food item QR codes contained the names of the food items  
168 in Nepali and the page numbers in the photographic atlas corresponding to that food so that this  
169 information could be displayed to the interviewer. The food item QR code also contained  
170 information (coded as 'Y' or 'N') about whether the food should be reported in frequencies, so  
171 questions about food frequencies were conditionally displayed. For example, rice was amorphous  
172 so no frequencies were reported, bananas were discrete so frequencies were needed, and cups of tea  
173 were discrete but varied in size, so their sizes (e.g. small teacup or large tea glass) and frequencies  
174 were reported.

175 After entering a portion, the interviewers could enter another portion of the same food type, add a  
176 different food, or end the recall. Although the portions were probed and entered onto paper forms  
177 chronologically, portions of the same food from different time points could be entered into the  
178 CommCare form sequentially, to streamline the data entry process. So, for example if rice was  
179 consumed two or three times in a day all the portions of rice consumed at the different eating  
180 occasions could be recorded one after another to save repeated scanning of QR codes for the same  
181 food. The time of day that each portion was consumed was recorded so that the chronology was  
182 retained.

183 The instructions given on the smartphone during the dietary recall, including the QR code scanning  
184 process, are shown in Figure 3.



185

186 **Figure 3** Screenshots of the CommCare form for collecting 24-hour dietary recall data, illustrating  
 187 the full 24-hour recall process and entry of food items and portion sizes

188 There were constraints on the type of portion size QR code that could be scanned depending on the  
189 food item selected, and so interviewers could not scan portion codes instead of food codes. We also  
190 made questions ‘required’ (an option in CommCare) so interviewers could not accidentally skip  
191 past a question and provided ‘don’t know’ options in case the questions could not be answered.

192 Data collection for a household was complete if all three visits were complete, and a visit was  
193 complete if all three household members were interviewed. We expected that using paper registers  
194 to track this would be error-prone, so we developed an automated counting system with a short  
195 registration questionnaire in CommCare (Web Appendix 2), using the ‘case management’ function  
196 that allowed the completion status to be updated after completing each dietary recall. If a household  
197 member became unavailable and the first visit needed to be redone another day, the interviewer  
198 recorded the non-response and the count was reset accordingly. The logic (CommCare coding) for  
199 this counting is provided in Web Appendix 3). Interviewers could complete and save the forms  
200 offline, but then required internet connection (typically 2G connection, or occasionally the office  
201 Wi-Fi) to send the forms to a cloud-based, password-protected server hosted by CommCare.

#### 202 *Survey implementation and data quality checks*

203 In August 2014, we piloted the first version of the CommCare form, and refined it before  
204 finalisation in April 2015. Between 3 and 11 June 2015, interviewers were trained on the 24-hour  
205 recall method, including techniques for showing interest in respondents’ answers without showing  
206 surprise or disapproval and entering data quickly. Data could not be edited after form submission,  
207 so we instructed interviewers to record errors in their notebooks and reassured them that we could  
208 correct errors in the dataset. After training, interviewers had two days of field practice. Interviewers  
209 also received a handbook on dietary assessment protocols.

210 Interviewers were required to visit unavailable households three times before categorizing them as  
211 ‘non-respondents’. Due to the long time required to interview three household members, a small  
212 thank-you gift was given to the household on each visit. The gifts were: prickly heat powder (~  
213 USD 1), a small towel (~ USD 0.80), and two bars of soap (~ USD 0.50).

214 Supervisors completed an observation checklist on 10% of households to ensure that interviewers  
215 were adhering to protocols. The checklist assessed interview technique such as whether or not the

216 interviewer gave a friendly greeting, obtained consent, used a non-judgmental interview manner,  
217 and used non-specific probes. Supervisors also completed ‘back check’ forms by revisiting sampled  
218 households and checking that protocols had been followed. We had monthly meetings with the  
219 whole team to discuss any problems, share experiences, and review the progress against targets  
220 (minimum target was two households per day).

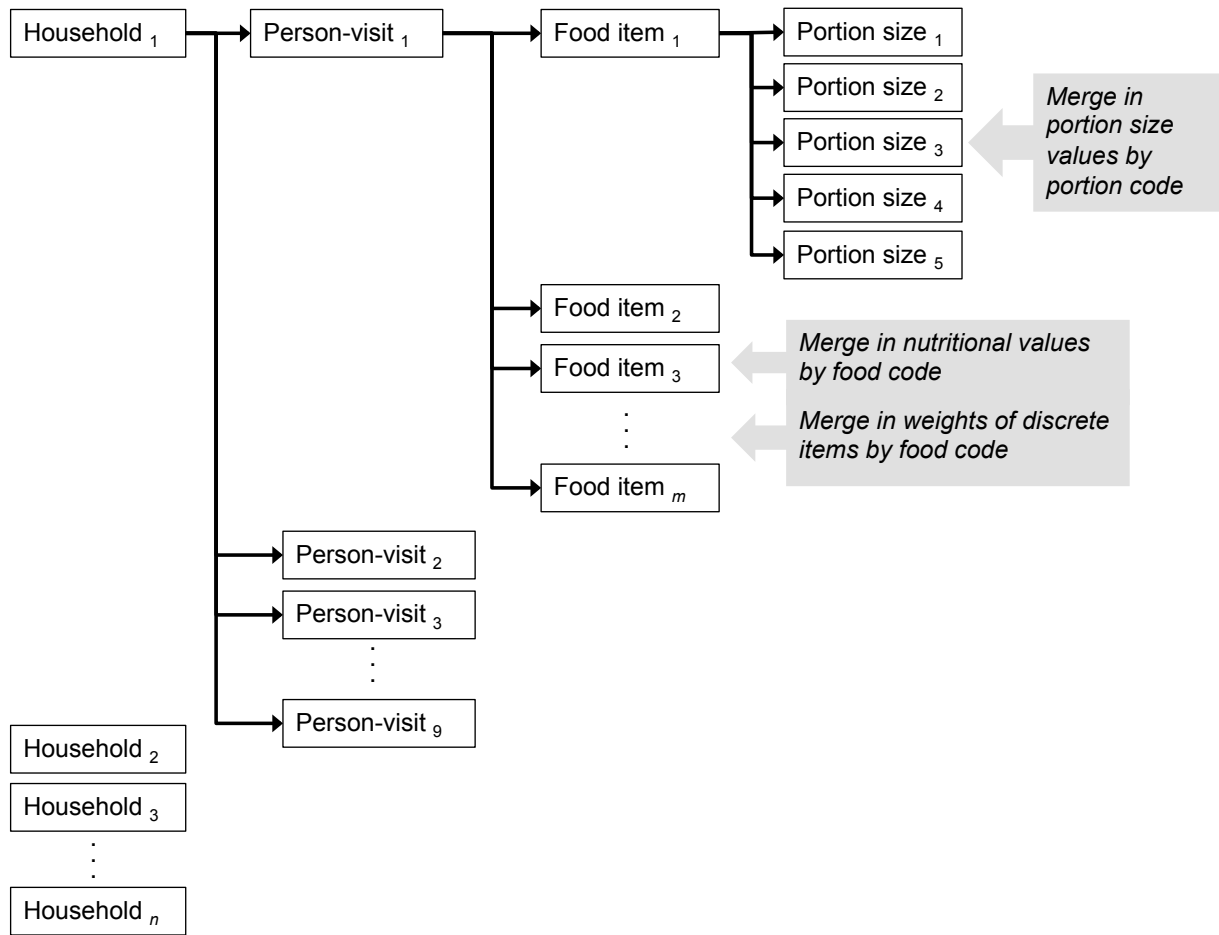
221 We checked the data at least once per week. The main data checks were: number of interviews  
222 conducted each day by interviewer, percentage of GPS readings recorded by interviewer, mapping  
223 of GPS locations, time taken to complete interviews, digit preference, and frequency of outliers in  
224 dietary intakes. For implausibly high daily dietary intakes (>4000 kcal (16,736 kJ) per day), we  
225 reviewed respondents’ recorded food items and intakes for that day. We also reviewed all cases  
226 where respondents had eaten any food portions at very high ( $\geq 20$ ) frequencies. Implausible or  
227 unlikely data were verified or explained by back-checks with the households.

#### 228 *Calculating nutrient intakes*

229 To calculate nutrient intakes, we first compiled a food composition table (FCT) using published  
230 sources and collected recipes, as described in Harris-Fry *et al.* <sup>(9)</sup>. In brief, we took values for raw  
231 ingredients from FCTs from Bangladesh <sup>(22)</sup>, USA <sup>(23)</sup>, UK <sup>(24)</sup>, and Nepal <sup>(25)</sup>. Rather than collect  
232 individual recipes in each household, we used average nutritional content from a sample of recipes.  
233 We collected 174 sample recipes for 127 dishes by weighed observation (between one and 32  
234 samples per dish for rare foods and common items respectively). We collected data from rural  
235 households, local vendors, and interviewers’ own homes for rare items. Full detail is given in  
236 Harris-Fry *et al.* <sup>(9)</sup>.

237 We calculated their nutrient composition using the ingredient weights and nutritional values of the  
238 raw ingredients. Nutrients of all weighed ingredients in the recipe were summed, divided by the  
239 total weight of the final cooked dish (measured after cooking), and we reported the mean per 100 g  
240 of the mixed dish in the FCT. Food items in the FCT were coded to correspond with the codes in  
241 the food list. We chose not to use retention factors because none of the published factors were from  
242 local food preparation methods and because many of the nutrient requirement estimates <sup>(26)</sup> have  
243 already accounted for nutrient losses in their estimates.

244 Next, we linked the dietary recall data (with food and portion codes) with the FCT and other  
 245 datasets with portion size data, as illustrated in Figure 4.



246

247 **Figure 4** Data structure and method of merging datasets to calculate total nutrient intakes per day

248 We merged the FCT by matching the food codes in the food composition table with the food codes  
 249 from the food list. A dataset containing a list of discrete items, their food codes, and gram weights  
 250 per item, was also merged by food code. We then merged in the portion size data, which was a  
 251 simple dataset of the portion codes and their weight in grams, by matching the portion codes with  
 252 the codes embedded in the portion size QR code. After multiplying the portion or item sizes by the  
 253 number of times each portion size was consumed, and calculating the nutrients per quantity of food  
 254 item consumed, all nutrients were summed to give the total nutrients consumed per person on a  
 255 given day.



256 *Analysis methods*

257 We used simple descriptive methods to describe respondent characteristics, and reported median  
258 (and 25<sup>th</sup> and 75<sup>th</sup> centiles) energy intakes in kJ/day. We used data from the control arm only  
259 because respondents from intervention arms would not be representative of the wider population.  
260 Dietary data management and analyses were conducted using Stata SE 14 (College Station, TX:  
261 StataCorp LP). The frequencies of different errors were described by reviewing and counting the  
262 corrections made in a data cleaning Stata .do file. Our experiences of using the tool were assessed  
263 and summarised by collating discussions between co-authors (from tool development, testing and  
264 personal observations), and by reviewing the authors' notes from team meetings with interviewers  
265 and supervisors.

266 *Ethical standards disclosure and data security*

267 Ethical approval was obtained from the Nepal Health Research Council (108/2012) and the UCL  
268 Ethical Review Committee (4198/001). Verbal informed consent was obtained from all subjects.  
269 Verbal consent was obtained and formally recorded on paper forms.

270 The server, downloaded data files, and the data collectors' smartphones were all password-  
271 protected. Paper forms were stored in a locked cupboard for cross-referencing with the electronic  
272 forms.

273 **Results**

274 *Description of dietary intakes from the control arm*

275 In the control arm we collected data in 150 households, with a total of 1,230 individual dietary  
276 recalls. Of sampled households, almost a third (31%) were landless, over a third (36%) were  
277 disadvantaged groups (Dalit or Muslim), and over half (54%) of the pregnant women had not  
278 attended school.

279 Taking the first day of dietary recall (before loss to follow-up on subsequent visits), for all  
280 household members, almost all (98%) respondents ate rice, around three quarters ate *dal* (spicy  
281 lentil soup), and around 65% ate *roti* (unleavened flatbread). Other commonly consumed items, i.e.

282 food items that >20% of respondents consumed at least some of, were: tea with sugar and milk,  
 283 mango (which was in season at the time), pointed gourd curry, fried spicy potato (*bhujiya*), and (for  
 284 the pregnant woman only) buffalo milk.

285 The median (25<sup>th</sup> and 75<sup>th</sup> centiles) daily kJ intakes (averaged over the three days of recall) were  
 286 8,979 (7,234 to 11,042) for pregnant women; 9,159 (6,937 to 11,368) for mothers-in-law; and  
 287 12,079 (9,293 to 14,108) for male household heads.

288 *Summary of errors and corrections made*

289 Table 3 summarises the frequencies of different errors (or intended corrections), also reported as a  
 290 percentage of the total number of person-visits or food items recorded during the course of the  
 291 study. More explanation of these errors is also described below.

292 **Table 3** Types and frequency of errors and corrections made to dietary intake raw data

<b>Corrections to raw data</b>	<b><i>n</i> (%)</b>
<i>Total number of individual dietary recalls collected</i>	6,765
Recalls that had to be conducted on paper forms	8 (<0.1)
<i>Total number of food items collected</i>	51,006
Food items mistakenly entered by scanning portion size QR codes	322 (0.6)
Food item not on the food list	288 (0.6)
Various errors identified by interviewer after form was completed	9 (<0.1)
Typographical error in frequency of portions	12 (<0.1)
Error entering glucose syrup (respondents had one teaspoonful in a glass, but the interviewers mistakenly entered a full glass)	37 (<0.1)
Error entering portion sizes of unknown items (some selected the portion size from the atlas, but then recorded the frequency of the portion size as the respondents' estimate of the portion in grams).	13 (<0.1)
<b>Total food item corrections as a percentage of total foods recorded</b>	<b>681 (1.3)</b>

293 A few errors arose from the counting mechanism that tracked completion of the household's visit  
 294 and the number of visits. In some cases, households were accidentally re-registered on the second  
 295 visit, so the questions associated with the first visit would display. In other cases when interviewers  
 296 could not interview the respondents during a visit, they did not record the reasons for non-response

297 (required to reset the counting logic). In these few cases, we provided a paper form and manually  
298 removed duplicate registrations from the dataset.

299 In the first two weeks, some food items were mistakenly entered using the portion size QR code  
300 rather than the food item QR code. Most items ( $n=286$ ) could be intuitively recoded based on the  
301 pictures that they scanned, and for items such as bowls we referred back to their paper forms and  
302 recoded the items ( $n=36$ ) manually. To prevent further mistakes, we provided refresher training and  
303 reprogrammed the forms with additional QR code restrictions, using string length as the restriction  
304 since food item codes were always longer than the portion codes.

305 If an item was not included in the food list, interviewers could enter the 'unknown' food code and  
306 type the food name. These items needed re-coding for analysis. Occasionally, interviewers selected  
307 the portion size from the atlas but then also mistakenly entered the respondents' estimate of the  
308 portion size in grams or ml, instead of the number of times that portion was consumed (e.g.  
309 selecting the tea glass and then entering 100 to indicate 100 ml rather than 100 tea glasses).

310 Some other errors arose from mistakes identified and reported by the interviewers, or implausible  
311 values identified by our regular analysis and identification of outliers. Typographical errors all  
312 came from the entry of the frequency of portions. Sometimes glucose syrup was incorrectly entered  
313 because respondents added one teaspoonful to a glass, but the interviewers mistakenly entered a full  
314 glass of glucose.

### 315 *Experience of using the 24-hour recall tool and smartphones*

316 Overall, we found that data monitoring was made easier with the use of smartphones because  
317 electronically entered data could be quickly converted into nutrient intake estimates; whereas, paper  
318 forms would have needed manual checking and translation of food item names and portions.  
319 Having access to digitized data enabled us to analyse nutrient intakes, quickly detect and correct  
320 errors or outliers, make any final minor edits to the tool in the first weeks of data collection, identify  
321 topics for refresher trainings, and provide more support to interviewers who were making more  
322 errors or not meeting their targets. Access to the data also allowed us to refer to the data during our  
323 review meetings, so we could discuss the plausibility of outliers, emphasize to interviewers the

324 importance of their accuracy and data quality, show the level of concern and attention being given  
325 to their data, and demonstrate that the data have meaning and use after their household interactions.

326 We found the form structure and tool components worked well. A key benefit of having a printed  
327 food list, rather than including the list of foods within the CommCare form, was that we could make  
328 edits after piloting without changing the form. The counting mechanism was helpful to track the  
329 number of repeats collected and ensure that all three household members were interviewed, and it  
330 also enabled us to spread other questions on food behaviours, food security and socioeconomic  
331 status across the three visits.

332 In terms of time and resources, the setup time required to develop the tools was much higher than  
333 paper forms, but this time was saved in data entry of paper forms. Few, highly skilled personnel  
334 were required for tool development (e.g. to generate QR codes and write the logic for tracking  
335 multiple visits and multiple household members) although CommCare has a very user-friendly web  
336 interface so did not generally require computer programmers to write code. For paper forms, data  
337 entry would have required more staff of lower-skilled levels over roughly the same length of time.

338 We faced some technical issues with the equipment. Unreliable electricity supply for charging  
339 phones in villages and limited battery life of smartphones led us to provide external battery packs,  
340 but phone power would still occasionally run out after a full day of data collection. Daily form  
341 submission was required to monitor progress and also minimise risk of data loss, but in some areas  
342 interviewers had to travel for thirty minutes to find cellular (2G) connection and submit their forms.  
343 Bugs in the CommCare system caused the forms to crash occasionally, particularly when using the  
344 QR code scanning or GPS functionalities, forcing interviewers to re-enter the data. CommCare were  
345 quick to respond, and released two new versions of the application to overcome some of these  
346 issues. After two weeks of data collection, the phones were upgraded to a higher specification, after  
347 which forms rarely crashed. Some interviewers would also note the portion codes on the paper  
348 forms, as a backup.

349 Regarding interviewers' experiences of using the tool, despite having limited computing  
350 knowledge, they found the smartphone tool easy to use after practice and detailed training.  
351 However, they reported frustrations when the form crashed. Interviewers found the food list and  
352 photographic atlas easy to navigate, and quickly became familiar with the page numbers and

353 locations of common items. Some interviewers placed sticky notes in the food list when  
354 interviewing the first respondent of the household to help find the foods again for the next  
355 respondents, since members of the same household tended to eat the same foods.

356 Points that were commonly reiterated in the review meetings included: showing the photographs the  
357 correct way up (so the respondents could see the images, rather than the interviewers); showing all  
358 portion size options; probing whether the respondent had any leftovers; scenarios for foods not on  
359 the list; not skipping over the passes during questioning; allowing time for respondents to recall  
360 forgotten foods during the review pass; and ensuring phones and battery packs were fully charged at  
361 the start of each day.

## 362 **Discussion**

363 In this paper we have described the process and experiences of using a novel smartphone-based tool  
364 for collecting and counting repeated 24-hour dietary recalls. To our knowledge, this is the first  
365 study to report the use of an Android platform combined with QR codes to enter dietary data, and it  
366 is also the first to collect and count repeated 24-hour dietary recalls within individuals and within  
367 households. We found that smartphones provided a useful tool for collecting dietary recall data. The  
368 constraints embedded in the form prevented the entry of implausible values, and the quick access to  
369 data enabled regular checks on interviewer performance and data quality. Some manual edits to the  
370 raw data were required, but this was a small proportion of the total number of food items recorded  
371 and could be easily minimised in future by including more constraints and more items on the food  
372 list.

### 373 *Assessment of the plausibility of results by comparing other studies*

374 Our findings that diets were monotonous are consistent with findings from other paper-based  
375 dietary studies from Nepal<sup>(14)</sup>. Energy intakes were generally higher in this study than other studies  
376 using paper forms to collect data, but gender differences in energy intakes were consistent with  
377 other Nepali studies<sup>(13, 27)</sup>.

378 Comparing the median daily kJ intakes from a study in Bhaktapur, lactating women from Bhaktapur  
379 consumed 619 kJ/day (148 kcal/day) less than pregnant women in our study in rural Dhanusha and

380 Mahottari <sup>(14)</sup>. Although there is six years difference in the studies' survey periods, it is unlikely that  
381 pregnant women's intakes from our rural, poor, socially conservative region were higher than  
382 intakes from lactating women in the urban area of Bhaktapur. We conclude that this difference is  
383 marginal, and it is likely that these differences are attributable to different interview techniques and  
384 measurement error. Sudo *et al.* <sup>(13)</sup> also reported 1,859 kJ/day lower intakes in their sample of non-  
385 pregnant women from rural areas of the *Terai* (Nawalparasi district) than in our study. Actual  
386 differences are less likely in this study, because it was conducted in a rural part of the *Terai*, but  
387 observed differences may be explained by their different study method (FFQ compared with our 24-  
388 hour recall), different survey season (April vs June to September), and different respondent  
389 inclusion criteria.

390 For men, we found that male household heads (aged 14-37 years) had a median daily intake of  
391 12,079 kJ, whereas Gittelsohn <sup>(28)</sup> reported a mean intake of 9803 kJ/day for men aged 25 to 50  
392 years and Sudo *et al.* <sup>(13)</sup> reported a median intake of 8723 kJ/day for men aged  $\geq 20$  years.  
393 Particularly for the Gittelsohn study, we would expect intakes to be higher in our study due to the  
394 difference in study year (1987 vs 2015), location (hills vs *Terai*), the general trend of increasing  
395 energy intake per capita over time <sup>(29)</sup>, and also because we selectively sampled the most senior  
396 household members. As with women's intakes, the difference between our results and Sudo *et al.*  
397 <sup>(13)</sup> is less likely to be related to major differences in the study population dietary patterns and more  
398 likely to be explained by the different measurement methods.

399 Few studies from Nepal have compared intra-household differences in intakes. Comparing gender  
400 differences, Sudo found that men's intakes were 1603 kJ/day higher than women's, Gittelsohn  
401 found men's intakes were 542 kJ/day higher, and we found that they were 3100 kJ/day higher than  
402 pregnant women and 2,920 kJ/day higher than mothers-in-law. These trends are difficult to compare  
403 between studies, due to temporal and geographical heterogeneity in household behaviours and  
404 norms, but are indicative of a generally consistent trend of gender inequality. The results are also  
405 indicative of inequitable intra-household allocation of calories between pregnant women and their  
406 mothers-in-law. To our knowledge, this latter relationship has not been assessed quantitatively.  
407 Forthcoming work will report on the dietary patterns in this context, accounting for the differential  
408 nutritional requirements of different respondents.

409 These results indicate that the tool gives plausible and consistent results, but that our tool may lead  
410 to an over-estimate of dietary intakes. More work is needed to validate the tool, by comparing with  
411 other methods of dietary assessment such as weighed food records, or doubly labelled water and  
412 biomarkers. To fully determine the comparative benefits, feasibility, and accuracy of dietary intake  
413 methods of electronic versus paper-based methods, a comparative study (randomly allocating  
414 respondents to a paper or electronic-based interview) could be conducted using a ‘gold standard’  
415 reference, for example using biochemical markers. This could then compare the frequency of errors,  
416 the costs associated with each, and the accuracy and precision of the two methods. Such  
417 comparisons have been made for many studies in Europe and North America, but are lacking from  
418 low-income countries such as Nepal <sup>(6)</sup>.

#### 419 *Key benefits of electronic data capture for dietary intake assessment*

420 Some of the key reported benefits associated with electronic data capture include cost savings  
421 (higher fixed costs for start up compared with paper methods but lower average costs) <sup>(30)</sup> and  
422 quicker access to data <sup>(31)</sup>. These are generally consistent with our findings; although we did not  
423 conduct a cost analysis we also faced high initial setup costs, and tool development took longer than  
424 anticipated. Studies have reported time savings from using computerised methods <sup>(30)</sup>, but without a  
425 paper comparator, it is difficult to know if the interviews would have been quicker on paper or  
426 smartphone. However, the monotony of diets in this context meant that dietary data could be  
427 collected quickly, and the ability to repeat additional servings of the same food type (a feature that  
428 was introduced after pilot testing) may have sped up the data entry process. Furthermore, given that  
429 most of the time burden for interviewers was in travelling between remote areas, it is unlikely that  
430 any time costs or savings would have affected overall productivity in terms of households visited  
431 per day.

432 Most other electronic tools for entry of dietary intake data originate from large-scale dietary intake  
433 studies conducted in developed countries that use computers rather than portable tablets. For  
434 instance, the USDA use an Automated Multiple-Pass Method <sup>(19)</sup>, and the European Prospective  
435 Investigation into Cancer and Nutrition uses a standardised computer program, ‘EPIC-SOFT’ <sup>(32)</sup>.  
436 Self-administered tools are also not appropriate for illiterate populations <sup>(33)</sup>. A computerised system  
437 was recently developed for use in India – the New Interactive Nutrition Assistant – Diet in India  
438 Study of Health (NINA-DISH) <sup>(34)</sup> – but this requires computers rather than more portable tablets or

439 phones. These bespoke systems for large, national or multi-country studies require high  
440 specification computers with large memory <sup>(4)</sup>.

441 Few have reported on low-cost, easily developed tools for smartphones or tablets, required for field  
442 studies and resource-poor contexts <sup>(4)</sup>. One way to reduce costs is to use existing data collection  
443 platforms, such as CommCare, that provide simple, user-friendly tools to create and conduct  
444 surveys. These however, require careful development to facilitate the collection of dietary data. To  
445 our knowledge, only one study has reported on the use of existing data collection platforms, in their  
446 case Open Data Kit (ODK), to collect dietary recalls <sup>(4)</sup>. In contrast, we used CommCare, a platform  
447 based on ODK but with additional functions for case management and collecting multiple recalls  
448 within a household. Another key difference is that our method used printed food lists with QR  
449 codes instead of including the food items within the CommCare form. Indeed, a key strength of our  
450 tool is that only minor edits are needed to adapt the smartphone form and logic for use in other  
451 contexts, because the main context-specific information (food lists and portion size images) can be  
452 developed independently of the CommCare form. As such, it is hoped that this tool can be used and  
453 adapted by other researchers, so that setup costs may be lower for future studies.

#### 454 *Study limitations, and future application of the tool for improved dietary assessment*

455 In future, automated visualisation software using segmentation analysis could quantify portion sizes  
456 from images <sup>(35, 36)</sup>. Instead of scanning QR codes, future studies could take photographs and  
457 estimate portion sizes from photographs. Research is needed to advance the technological capability  
458 of image analysis, assess the cultural acceptability of these methods in different contexts, and apply  
459 image analysis technologies to South Asian diets. In the meantime, portion size data could simply  
460 include more weighed portions, rather than relying exclusively on photographs.

461 A limitation of the study was that we did not collect individual recipes for each household (instead  
462 using average recipes, as described in the methods), and so this component of the dietary recall has  
463 not been programmed into the CommCare form. Since the main aim of the study was to compare  
464 relative allocations of food, we used average nutrient composition calculated from pre-collected  
465 recipes, but the collection of more recipes could improve the accuracy of the tool. Researchers  
466 aiming to estimate nutritional adequacy more precisely, rather than relative allocation, could add  
467 another section to the form used in this study, to collect recipe ingredients and their weights.



468 Another component that was not included in this tool was a checklist for respondents to document  
469 their intakes. Gibson and Ferguson<sup>(20)</sup> recommend researchers to provide respondents with an  
470 image-based checklist the day before the recall, so respondents can tick the items they consume  
471 during the day. These additions would have required each household to be visited for at least three  
472 additional days (one per recall), which would have been burdensome on the respondents, and  
473 logistically infeasible given the resources available and the long travel time to reach households.

474 An unusual approach used in this study was to ask respondents to recall the portion sizes in the  
475 order of the food items (e.g. rice in the morning and then evening), rather than each food in strict  
476 chronology. Although the food items were recalled in chronological order during the free recall, the  
477 portion sizes were only collected later. This sped up the process (which was especially helpful since  
478 there were three respondents per households and so the interview was already long and  
479 cumbersome) but it may have been more challenging for respondents recall portions out of the order  
480 in which the food items were consumed.

481 More rigorous qualitative assessment of interviewers' and respondents' experiences of using the  
482 tool, for example by conducting in-depth interviews and thematic analyses, may identify more  
483 issues and opportunities for tool development. Future work by an independent researcher, rather  
484 than by line managers and study coordinators, may be required to ensure that interviewers feel  
485 comfortable reporting these experiences.

486 Finally, we hope that this tool will be used, adapted, and improved by other researchers, so that  
487 dietary intake data collection may become more feasible, and nutrition interventions can be more  
488 informed and better designed.

## 489 **Conclusion**

490 Smartphone technology, existing data collection platforms, and simple visual portion size aids can  
491 be combined to collect detailed dietary intake data from rural households. With sufficient time and  
492 effort dedicated to setup and pre-testing, in addition to the usual intensive process of developing 24-  
493 hour dietary recall tools, smartphones can provide a useful method for collecting and enabling quick  
494 access to data. The main benefits include: no need to translate food items for each respondent, no  
495 costs associated with paper data entry systems, ability to detect outliers in intake estimates, and

496 regular, detailed information on interview performance. Challenges, such as lack of electricity,  
497 programming bugs, and inflexibility introduced by electronic data capture can be overcome with  
498 planning, flexibility in making edits to the dataset after data collection, and if interviewers are  
499 encouraged to report their mistakes.

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