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Status and determinants of intra-household food allocation in rural Nepal

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2 **Abstract**

3 **Background/Objectives:** Understanding of the patterns and predictors of intra-household food allocation
4 could enable nutrition programs to better target nutritionally vulnerable individuals. This study aims to
5 characterise the status and determinants of intra-household food and nutrient allocation in Nepal.

6 **Subjects/Methods:** Pregnant women, their mothers-in-law, and male household heads from Dhanusha and
7 Mahottari districts in Nepal responded to 24-hour dietary recalls, thrice-repeated on non-consecutive days
8 ($n=150$ households; 1278 individual recalls). Intra-household inequity was measured using ratios between
9 household members in: food intakes ('food shares'); food-energy intake proportions ('food shares-to-energy
10 shares', FS:ES); calorie-requirement proportions ('Relative Dietary Energy Adequacy Ratios', RDEARs);
11 and Mean Probability of Adequacy for 11 micronutrients (MPA ratios). Hypothesised determinants were
12 collected during the recalls, and their associations with the outcomes were tested using multivariable mixed-
13 effects linear regression models.

14 **Results:** Women's diets (pregnant women and mothers-in-law) consisted of larger FS:ES of starchy foods,
15 pulses, fruits, and vegetables than male household heads, whereas men had larger FS:ES of animal-source
16 foods. Pregnant women had the lowest MPA (37%) followed by their mothers-in-law (52%), and male
17 household heads (57%). RDEARs between pregnant women and household heads were 31% higher (log-
18 RDEAR coeff=0.27 (95% CI 0.12,0.42), $P<0.001$) when pregnant women earned more or the same as their
19 spouse, and log-MPA ratios between pregnant women and mothers-in-law were positively associated with
20 household-level calorie intakes (coeff=0.43 (0.23,0.63), $P<0.001$, per 1000 kcal).

21 **Conclusions:** Pregnant women receive inequitably lower shares of food and nutrients, but this could be
22 improved by increasing pregnant women's cash earnings and household food security.

23 **Keywords:** intra-household food allocation; nutrition; Nepal; probability of adequacy; inequity; pregnancy;
24 maternal health

25 **Background**

26 Pregnant women in South Asia have inadequate intakes of many micronutrients ^{1,2}, and this can translate
27 into comorbidities of multiple micronutrient deficiencies ³. Inadequate diets during pregnancy are
28 particularly problematic because inadequate weight gain and micronutrient intakes are associated with higher
29 risk of adverse health outcomes, including low birth weight ⁴ and maternal mortality ⁵. In 2013, over half of
30 the world's maternal deaths caused by severe anaemia occurred in South Asia ⁵.

31 In South Asia, nutritional inadequacy may be caused by gender-based inequities. At the macro-level, the
32 Gender Inequality Index displaces Gross Domestic Product as a predictor of low birthweight, suggesting that
33 inequality is a more important determinant of nutrition than poverty ⁶. At the micro-level, women ^{7, 8},
34 particularly pregnant women ⁹, are discriminated against in the allocation of food within households – a trend
35 that is more prominent in South Asia than elsewhere ⁹. This may be explained by food insecurity ¹⁰, or socio-
36 cultural factors ⁷. For example, women often eat last and least ¹¹, fast more than men ¹², and have limited
37 decision-making power over food purchasing decisions ¹³. Additionally, during pregnancy, women have
38 higher nutritional requirements but often have other pregnancy-specific food restrictions ⁷.

39 To improve nutrition during pregnancy, many interventions have aimed to increase household-level food
40 availability, by providing supplements, social transfers ¹⁴, or promoting home food production through
41 gardening or livestock programs ¹⁵. However, if pregnant women are discriminated against, interventions
42 may fail to benefit them.

43 Recent, high quality studies on intra-household food allocation are limited ⁹, and none have used probability
44 methods to estimate nutritional adequacy or examined inequities between pregnant women and mothers-in-
45 law ¹⁶. The present study from Nepal will describe intra-household allocation of food-related behaviours,
46 food groups, and dietary adequacy between pregnant women, mothers-in-law, and male household heads,
47 and use a recent theoretical framework ¹⁶ to identify determinants of intra-household food allocation.

48 **Subjects and Methods**

49 *Study population*

50 The study was conducted in Dhanusha and Mahottari districts, located in Province 2, in the *Terai* (lowland)
51 region of Nepal. Dhanusha and Mahottari districts have a combined population of approximately 1.4 million,
52 and the main source of livelihood is agricultural production¹⁷. Located in the Indo-Gangetic floodplains,
53 land is fertile and there are favourable climatic conditions for agricultural production; yet, the prevalence of
54 undernutrition is the highest in the country; 29% of women in Province 2 are underweight (<18.5 kg/m²),
55 compared with the national average of 17%¹⁸.

56 The pre-specified sampling frame included all male-headed households, with a pregnant woman in their third
57 trimester who was living with their mother-in-law and enrolled in a cluster-randomised controlled trial, the
58 Low Birth Weight South Asia Trial (LBWSAT; <http://www.controlled-trials.com/ISRCTN75964374>)^{19, 20}
59 between June and September 2015. We sampled joint, male-headed households to reduce heterogeneity and
60 because qualitative research indicated that they would be least likely to change food allocation behaviours¹³.
61 Within households, respondents were: pregnant women, their mothers-in-law, and the male household heads.
62 Dietary data were collected from 805 households in all trial arms, based on a target sample size of 200
63 households from 19 clusters per arm, to detect a difference of 0.1 'Relative Dietary Energy Adequacy
64 Ratios' (RDEARs) between two trial arms with 80% power and 95% confidence. This study uses data from
65 the control arm ($n=150$) in 20 Village Development Committee areas.

66 Informed consent was obtained from all respondents and research ethics approval was obtained from the
67 Nepal Health Research Council (108/2012) and University College London Ethical Review Committee
68 (4198/001).

69 *Data collection*

70 Interviewers collected 24-hour dietary recalls using a smartphone tool, described elsewhere²¹. In brief,
71 interviewers conducted dietary recalls, repeated three times per person on non-consecutive days, following
72 five passes each time: collect a free recall using non-specific probes, ask the time and place that each item

73 was consumed, read a list of commonly forgotten foods, recap in chronological order, and collect details on
74 specific food types and portion sizes^{22,23}.

75 Food types were selected from a pre-coded list of foods, including locally available supplements, or typed
76 manually if missing from the list. Portion sizes were estimated using a photographic atlas that was validated
77 for this study and contained 224 graduated discrete, life-sized portion images for 72 foods. We used the same
78 images for similar foods²⁴. Data were collected on Android smartphones using CommCare (Version 2.22.0,
79 <http://www.comcarehq.org/home/>), an open source, cloud-based data collection platform. Codes for food
80 items and portions were encoded in quick response (QR) codes and entered into the form using a barcode
81 scanning application ('ZXing Barcode Scanner'). To minimise non-response, pregnant women could respond
82 on behalf of others if they felt confident answering comprehensively. This was not permitted during the first
83 visit when anthropometric measurements were taken. The nutritional composition of raw foods were
84 calculated using a Food Composition Table (FCT) compiled from multiple sources²⁵⁻²⁸. For mixed dishes,
85 we calculated average nutritional composition from 174 recipes collected prior to dietary data collection.

86 Body weight and mid-upper arm circumference (MUAC) were measured using Tanita solar weighing scales
87 and Seca 212 circumference tapes respectively. Self-reported activity levels, illness, feasting and fasting,
88 food security (Months of Adequate Household Food Provisioning, MAHFP²⁹ and Household Food
89 Insecurity Access Scale, HFIAS³⁰) and other diet-related questions were collected, plus the following
90 hypothesised determinants: pregnant women earning the same or more cash than their spouses; gravidity (a
91 proxy for seniority); self-reported empowerment level of pregnant woman (scale 0-10); asset score
92 calculated using principal components analysis; household calorie consumption (averaged of the three
93 members, per 1000 kcal); pregnant woman's husband living overseas; caste or religious group; and season
94 (pre-monsoon or during monsoon). We used other socioeconomic data collected by main trial surveillance
95 questionnaires²⁰.

96 *Data analysis*

97 Foods were aggregated into the ten food groups in the Minimum Dietary Diversity Score for Women (MDD-
98 W)³¹: (1) grains, white roots and tubers, (2) pulses (beans, peas and lentils), (3) nuts and seeds, (4) dairy, (5)

99 meat, poultry and fish, (6) eggs, (7) dark green leafy vegetables, (8) other vitamin A-rich fruits and
 100 vegetables, (9) other vegetables, and (10) other fruits. We calculated MDD-W by summing the groups
 101 consumed on the first recall (to use the same reference period for which the score was validated), and
 102 calculated the proportion consuming an ‘adequate’ diet (≥ 5 food groups)³¹.

103 Nutritional intakes were estimated by calculating the nutrients from each portion of each food using the FCT,
 104 and summing the nutrients from each portion to give total daily intakes. We did not apply nutrient retention
 105 factors because of lack of locally appropriate estimates. Intakes were averaged across the three recall visits.

106 Dietary adequacy was calculated using the USA Institute of Medicine (IOM) probability approach^{32,33}. First,
 107 to achieve normality, nutrient intakes were transformed using a Box-Cox model³⁴. Then, using transformed
 108 values, we calculated ‘usual’ intakes from the best linear unbiased predictors (BLUPs) resulting from mixed-
 109 effects models, fitted separately for each household member type. We treated clusters and individuals as
 110 random effects and strata as fixed effects. For all nutrients (except iron for non-pregnant respondents), the
 111 probability of adequacy (PA) was calculated by comparing each back-transformed usual intake to the
 112 population distribution of requirements, which are Normal distributions with means (i.e. Estimated Average
 113 Requirements, EARs) and standard deviations. We used WHO/FAO’s values for nutritional requirements of
 114 vitamin C, thiamin, riboflavin, niacin, vitamin B₆, folate, vitamin B₁₂³⁵, Institute of Medicine’s values for
 115 calcium³⁶ and iron³⁷, and International Zinc Nutrition Consultative Group (IZiNCG)’s recommendations for
 116 zinc³⁸. Iron requirements for non-pregnant women and men are not normally distributed so we calculated
 117 PAs using a table of probabilities for different intake intervals, adapted from IOM³⁷ to assume 5%
 118 bioavailability. The mean probability of adequacy (MPA) was the average PA of all 11 nutrients.

119 To measure intra-household food allocation we calculated food shares (FS), food-share-to-energy-shares
 120 (FS:ES), Relative Dietary Energy Adequacy Ratios (RDEARs), and MPA ratios. FS are ratios of food group
 121 intakes (g) between pairs of individuals for households who consumed any³⁹. FS:ES account for different
 122 energy intakes between individuals³⁹, calculated as:
 123 $(\text{food intake}_a / \text{kcal intake}_a) / (\text{food intake}_b / \text{kcal intake}_b)$, for persons *a* and *b*. Energy allocation was
 124 calculated as the ‘Relative Dietary Energy Adequacy Ratio’, $RDEAR = (\text{intakes}_a / \text{EAR}_a) / (\text{intakes}_b /$

125 EAR_b)⁹. Energy EARs were calculated according to age, gender, pregnancy status, body weight (kg), and
126 self-reported activity levels, using values by Indian Council of Medical Research⁴⁰. The additional cost of
127 pregnancy was taken to be 390 kcal/ d⁴⁰. MPA ratios were calculated as MPA_a/MPA_b .

128 To test for inequity, we adjusted for deviations from normality by log-transforming the ratios and used a
129 random effects linear regression model, treating clusters as a random effect, to test whether the intercept was
130 significantly different from zero.

131 To identify determinants of food allocation, using RDEARs and MPA ratios as outcomes, we fitted
132 multivariable mixed-effects linear regression models, including all hypothesised determinants. We tested for
133 non-linear effects of wealth on log-RDEAR and log-MPA ratios¹⁶. To assess collinearity among predictors,
134 we calculated variance inflation factors (VIFs)⁴¹. We included all outliers in kcal intakes, and respondents
135 who were fasting or feasting because results were comparable with analyses excluding outliers, but excluded
136 extreme outliers (<-8) in log-transformed MPA ratios to give normally distributed residuals. Significance
137 levels were set at $P<0.05$.

138 *Code availability*

139 All analyses were conducted using Stata SE 14 (College Station, TX: StataCorp LP) and Stata code is
140 available upon request with the corresponding author.

141 **Results**

142 We sampled 75% (150 / 199) of eligible households. Reasons for non-response included non-consent ($n=5$)
143 or non-availability ($n=41$). Some households on the sample list were not sampled because they had become
144 ineligible before the interview, because the women had given birth ($n=108$) or were temporarily not living
145 with their mothers-in-law ($n=101$). The study period also covered pre-monsoon (hottest) and monsoon,
146 mango season, and Ramadan. Cluster-adjusted chi-square tests showed no significant differences in age,
147 caste, assets, land ownership, education, or HFAS between sampled and non-sampled participants (results
148 not shown).

149 Respondent characteristics are summarised in **Table 1**. Almost a third were landless, over a third were from
150 disadvantaged groups (Dalit or Muslim), and over half of pregnant women had not attended school. There
151 was some food insecurity in the month preceding the interview in 30% of households, though only 9% cited
152 any months of inadequate household food provisioning in the preceding year. Male household heads had the
153 lowest incidences of illness and fasting, and prevalence of low MUAC (14% <23 cm⁴²) compared with
154 pregnant women (40%) or mothers-in-law (35%). Men and mothers-in-law were involved in food shopping
155 and decision-making, whereas most pregnant women did the cooking (78%).

156 For all household members, almost all (98%) respondents ate rice, around three quarters ate *dal* (spiced lentil
157 soup), and 65% ate *roti* (flatbread). Other food items, that >20% of respondents consumed at least some of,
158 were: tea with sugar and milk, mango, pointed gourd curry, fried spicy potato (*bhujiya*), and buffalo milk.
159 Only 9% of pregnant women and 32% of mothers-in-law consumed food outside of the home over the 3-day
160 recall, compared with 73% of male household heads. Household heads commonly ate outdoors or in a
161 teashop, and ate: plain, puffed or beaten rice (18%), vegetable curry (13%), tea with sugar and milk (9%),
162 flatbreads (9%), deep fried sweet or savoury snacks like *samosa*, *litti* and *jeri* (9%), *dal* (6%), and alcohol
163 (6%). All household members consumed around two thirds of their calories before 11am or after 7pm.

164 *Intra-household differences in food consumption and nutrient adequacy*

165 The percentage of pregnant women, mothers-in-law, and male household heads consuming any of the 10
166 food groups or alcohol, and the percentage consuming an adequate diet (≥ 5 food groups), is given in **Figure**
167 **1**. Error bars show standard errors of the mean, adjusted for clustering. Mean intakes of those who consumed
168 any of each group are given in **Table 2**. More household heads consumed animal-source foods (flesh foods
169 like meat or fish, eggs, and dairy) than pregnant women or mothers-in-law. 43% of household heads
170 consumed flesh foods compared with a third of pregnant women or mothers-in-law; 73% of household heads
171 consumed dairy compared with 61% of mothers-in-law. More pregnant women ate green leafy vegetables or
172 fruits than mothers-in-law or household heads. Consumption of most other foods – especially common foods
173 like starchy foods, pulses, and vegetables – and mean dietary diversity score (between 4.6 and 4.9) was
174 similar for all three household members.

175 **Table 3** reports the tests for equality in log-FS and log-FS:ES. Women (pregnant women and mothers-in-
176 law) had lower dietary diversity and intakes of starchy foods, pulses, vegetables, and animal-source foods
177 than male household heads. Comparing log-FS:ES, a larger share of women's than men's diets were
178 provided by starchy foods, pulses, vitamin A-rich fruits and vegetables, and green leafy vegetables. Pregnant
179 women had 34% higher shares of green leafy vegetables. Men's diets comprised 18% larger shares of flesh
180 foods than pregnant women and 24% larger shares of dairy than the mothers-in-law. Log-FS and log-FS:ES
181 were not different between pregnant women and mothers-in-law ($P>0.4$ for all foods; results not shown).

182 Intakes, EARs, and PAs for each household member are reported in **Table 4**. Pregnant women had the
183 lowest MPA (37%) compared with mothers-in-law (52%) and male household heads (57%). Vitamin B₁₂
184 intakes were inadequate for almost all respondents.

185 *Testing for equity and the determinants of equity*

186 **Table 5** reports calorie (log-transformed log-RDEARs) and micronutrient (log-transformed MPA ratios)
187 allocations, and determinants of these outcomes. We focus on allocation between pregnant women and other
188 household members because of the nutritional importance of diet during pregnancy.

189 Between pregnant women and household heads, RDEARs were 18% lower, and MPA ratios 38% lower, than
190 perfectly equitable households. Between pregnant women and mothers-in-law, RDEARs were 14% lower,
191 and MPA 42% lower, than perfect equity. In 17% of households, pregnant women consumed <90% of EARs
192 whilst the household heads consumed >110% of EARs. In 11% of households, pregnant women consumed
193 <90% of EARs while mothers-in-law consumed >110% of EARs.

194 RDEARs were positively associated with women earning the same or more than their spouse, and the
195 pregnant women's husband living overseas. Household-level intakes were associated with MPA ratios. There
196 was no evidence of a non-linear relationship between wealth and calorie or micronutrient allocation, as there
197 was no association with a quadratic term or when testing different quintiles.

198 Discussion

199 Foods and nutrients are allocated inequitably within households, with clear male advantage. Male household
200 heads consume more animal-source foods, eat special foods like deep-fried snacks and alcohol outside of the
201 home, and have the highest dietary adequacy, whereas women eat more low status foods and have lower
202 dietary adequacy, particularly pregnant women due to their elevated requirements. The intra-household
203 gradient in dietary adequacy (men > mothers-in-law > pregnant women) mirrors the gradient in MUAC and
204 is determined by within-household disparities in earned cash income, pregnant women's husband working
205 overseas, and household-level calorie consumption.

206 The gender-division in food allocation is consistent with other studies from Nepal. One study found that men
207 were preferentially allocated 'luxury' foods such as tea and deep-fried snacks⁴³, and another found that men
208 had higher micronutrient adequacy than women¹¹. We found no clear disparity in food allocation between
209 pregnant women and their mothers-in-law, which is surprising given the well-reported social hierarchy
210 between women in South Asia⁴⁴. However, pregnant women's intakes were less adequate because their
211 elevated requirements were not compensated for, perhaps due to male favouritism, fear of giving birth to a
212 large baby, fasting for a boy child¹³, food proscriptions⁷, or feeling full since women were in their third
213 trimester⁴⁵.

214 We found higher nutrient intakes than studies from urban Nepal² and rural Bangladesh¹. This may be
215 because rural populations eat more, because they engage in physically strenuous agricultural labour, whereas
216 urban populations may be more sedentary. We did not measure the physical activity levels of respondents,
217 beyond a basic self-assessment of activity levels, nor did these other studies, so we cannot determine whether
218 differences in workloads could explain these differences in dietary intakes. Future work could examine
219 urban-rural differences, and improve the accuracy of these dietary adequacy estimates (particularly calorie
220 adequacy ratios and RDEARs), by incorporating the use of accelerometers to quantify energy balance.
221 During data collection, we also noticed some very high intakes, which interviewers explained were due to

222 Muslims feasting after sunset. Only 13% of our sample was Muslim, and analyses without fasting and
223 feasting households gave similar results.

224 Other variance between studies may be explained by temporal and methodological differences, such as
225 different dietary assessment methods. We used a repeated 24-hour recall method using a photographic atlas
226 to estimate portion sizes, whereas other the studies from Nepal and Bangladesh used weighed food records
227 over a 24-hour recall period ², and/ or direct observations ^{1 11} to measure diets. Ideally, we would have used
228 weighed methods to give a continuous measure of portion sizes (rather than the categorical measure
229 introduced by the atlas), and also used observations rather than recall-based methods to reduce error
230 introduced by respondents' inaccuracies in their conceptualisation and recall of portion sizes ^{46 47}. During
231 pilot testing, we found direct observations were not feasible because they were time consuming and
232 burdensome on respondents. Also, it was culturally inappropriate for male interviewers to spend long periods
233 of time in or near the kitchen with the female cook, making both weighed and observational methods
234 difficult for male interviewers. The few female interviewers we did employ (few local women were
235 sufficiently qualified) were not permitted to spend nights away from home or travel in the dark to conduct
236 direct observations ²⁴. Nevertheless, our validation study, which found moderate agreement between portion
237 sizes that were weighed and estimated 24-hours later using a photographic atlas ²⁴, gives us some confidence
238 in our dietary intake estimates.

239 Relative cash incomes predicted intra-household calorie allocations, which is consistent with the limited
240 evidence on this association ¹⁶, and could be due to perceptions of deservedness ¹², a way of rewarding
241 earners ⁴⁸, or because nutritional investment in economically productive members yield higher incomes ⁴⁹.
242 We found an association between household-level calorie consumption and micronutrient allocation but not
243 calorie allocation; other studies have also found no association between food security and calorie allocation
244 ¹⁶. The association between husbands living overseas and food allocation may be explained by women
245 receiving overseas remittances, although a study from the same district found that women worried about the
246 care they would receive from in-laws when their husbands were away ⁵⁰.

247 The external validity is limited by our selective sampling of joint, male-headed households, sampling of only
248 three respondents within each household, and the four-month survey period, although we found no effect of
249 season on food allocation. We focused on comparisons between pregnant women and household members
250 who we hypothesised to be favoured in the allocation of foods, and who we hoped would change their
251 behaviours due to our intervention. However, this prevented us from comparing pregnant women with less
252 senior household members (such as children, adolescents, or more junior non-pregnant women), who might
253 also be nutritionally vulnerable.

254 There are a few limitations in the analyses. We are unable to attribute causality to the associations, and are
255 also limited by the sample size. Using data from all study arms could have increased statistical power, but we
256 anticipated interactions between the predictors and study arm. To limit non-response, pregnant woman
257 sometimes answered on behalf of others, (34% and 37% of household heads, and 17 and 21% of mothers-in-
258 law, in the second and third visits respectively). Therefore, food eaten outside may have been missed. If so,
259 dietary intakes of mothers-in-law and male household heads, as well as allocation ratios, would be
260 underestimated. This was particularly concerning for the 73% of household heads who consumed at least
261 some food outside of the home. However, there were no significant differences between self-reported and
262 proxy-estimated calorie intakes, suggesting that any bias introduced by using a proxy respondent is likely to
263 be minimal. Using standard rather than individual recipes might have falsely reduced variance in intakes, but
264 are unlikely to have affected allocation estimates; whereas, it is possible that not applying retention factors
265 biased the adequacy ratios, if certain household members consumed systematically more raw or cooked
266 foods.

267 Our findings can be used to predict how interventions might influence intra-household food allocation.
268 General increases in food security could increase nutritional equity, but programs increasing availability of
269 low status foods (such as green leafy vegetables) could disproportionately benefit women whilst increasing
270 availability of animal-source foods may disproportionately benefit men. This hypothesis is supported by two
271 Bangladeshi studies. One found that vegetables promoted in a gardening intervention, that were considered
272 inferior, were selectively channelled to women ⁵¹; another found that rice transfers (high status) were

273 disproportionately consumed by men, whereas wheat transfers (low status) were channelled to women⁵².
274 Furthermore, numerous kitchen garden interventions have improved women's consumption of fruits and
275 vegetables¹⁵, whereas livestock programs have produced mixed effects on consumption of animal-source
276 foods^{15, 53}. Programs targeting women could try to influence perceptions about the status of foods, and
277 (preferably) also influence women's socio-cultural status, although qualitative research is needed to
278 understand how these changes in perceptions could be achieved. Beyond these gender dynamics, we can also
279 predict how interventions might affect allocation to pregnant women specifically. Given that household-level
280 calorie consumption was positively associated with higher equity for pregnant women, these above-
281 mentioned interventions may selectively benefit pregnant women simply by increasing household-level food
282 availability. Other interventions to increase pregnant women's relative cash income, such as employment
283 opportunities, higher wages, or cash transfers, might also increase the allocation of foods to pregnant
284 women. If so, a crucial next step would be to explore how these income-generating interventions can benefit
285 women without adding to their work burdens, energy expenditure, or compromising their ability to care for
286 themselves and their children.

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293 **Author contributions:** HHF prepared the first draft of the manuscript, developed the overall study design
294 and final tools, and conducted analyses with input from MCB and NMS. AC provided technical oversight.
295 BJB developed the concept of the smartphone components, and supported TH to develop the proof-of-
296 concept for this. TH led the pilot testing and collection of utensil data with PP and HHF. NS collected
297 weights of discrete food items. PP, HHF, and NS trained data collectors and PP and SJ managed the data
298 collection. HHF processed the data, and HHF, NS and PP routinely checked the outputs. DSM and BS were

299 responsible for day-to-day oversight and coordination of field activities. All authors read and approved the
300 final manuscript.

301 **Ethical standards disclosure:** Research ethics approval was obtained from the Nepal Health Research
302 Council (108/2012) and the UCL Ethical Review Committee (4198/001). All trial participants gave written
303 consent at enrolment in the trial. Verbal informed consent was obtained from all subjects for subsequent
304 interactions. Verbal consent was obtained and formally recorded on paper forms.

305 **Figure legends:**

306 Figure 1: Percentage of pregnant women, mothers-in-law, and male household heads consuming any of each
307 food group, based on three days of dietary recall, and consuming minimum dietary diversity based on one
308 day of dietary recall

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□ Pregnant women ▨ Mothers-in-law ▩ Male household heads

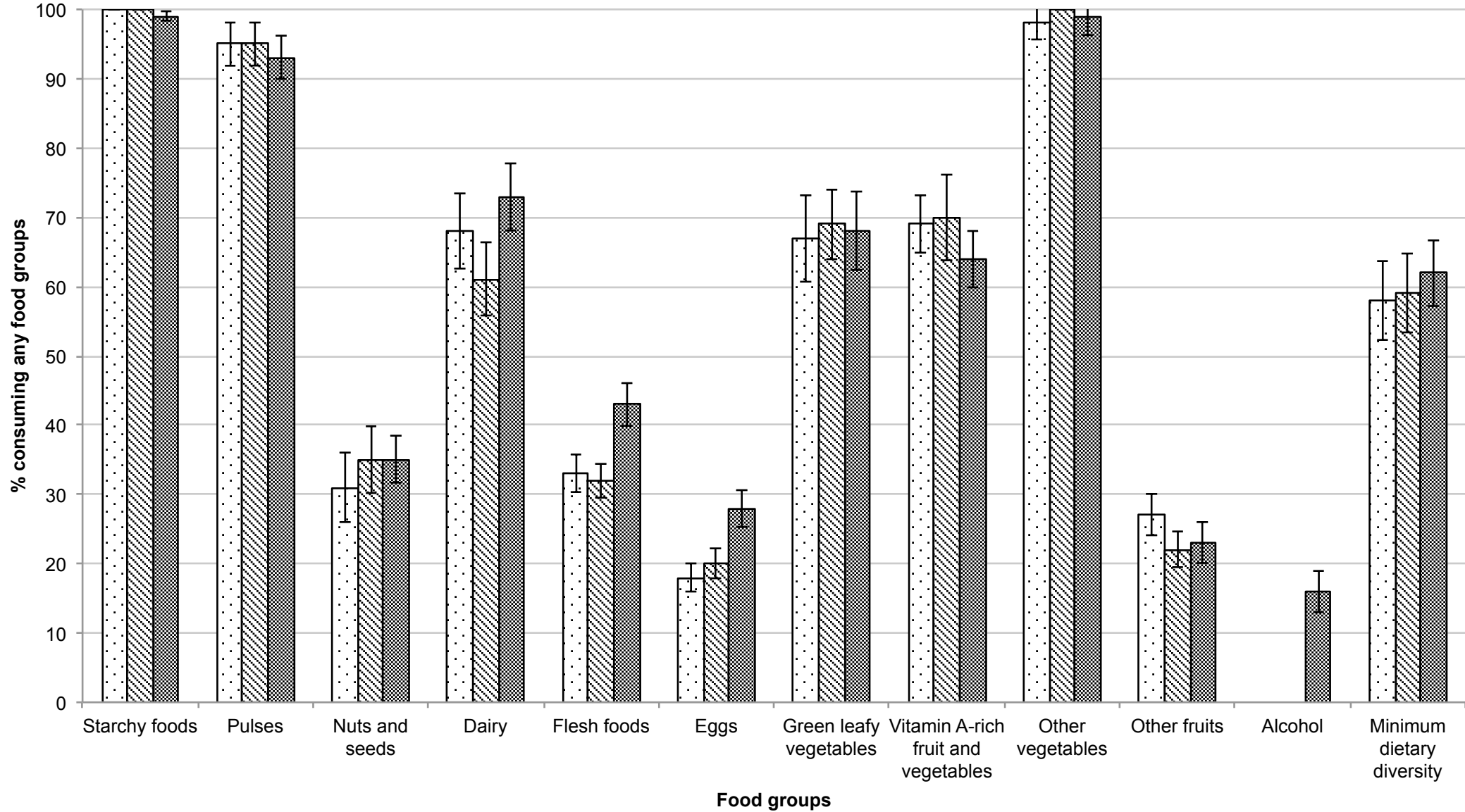


Table 1: Household and individual socioeconomic and demographic characteristics, and food-related behaviours

Respondent characteristics	Pregnant woman	Mother-in-law	Household head
Age, years			
Median (25 th , 75 th centiles)	21 (19, 24)	50 (44, 56)	39 (25, 56)
Age at marriage, years			
Mean (SD)	16.4 (1.8)	NA	NA
Number of previous pregnancies, %			
0	32.4	NA	NA
≥ 1	67.6	NA	NA
Gestational age, weeks			
Median (25 th , 75 th centiles)	37 (35, 38)	NA	NA
Mid-Upper Arm Circumference, MUAC			
Low MUAC, <23 cm, %	40	35.3	14
Mean (SD)	23.5 (2.1)	24.3 (3.3)	25.9 (2.9)
Illness and fasting, %			
Any illness in the 3 dietary recall reference periods	13.3	12	6.7
Any fasting in the 3 dietary recall reference periods	10	13.3	8.7
Ate more during pregnancy, compared to when not pregnant	15.1	NA	NA
Ate same during pregnancy, compared to when not pregnant	32.5	NA	NA
Ate less during pregnancy, compared to when not pregnant	52.4	NA	NA
Involvement in food production and preparation, %			
Main cook in the household	77.8	3.2	0
Involved in decisions about purchasing food	16	50.7	50
Goes outside to do the shopping	13.4	38.8	57.5
Education level, %			
Never went to school	56.1	NA	NA
Primary to lower secondary	27	NA	NA
Secondary and above	16.9	NA	NA
Household level characteristics			
Caste group, %			
Dalit / Muslim (most disadvantaged groups)	36.2		
Janajati / other Terai castes	42.9		
Yadav / Brahmin (least disadvantaged)	20.9		
Land ownership, %			
Owns no land	30.9		
Household food security, %			

Households with enough food to meet household needs in the year prior to interview (MAHFP)	91
Households experiencing no food insecurity over the past 4 weeks prior to interview (HFIAS)	69.4

NA= Not available or applicable.

n=150; response rates for these variables ranged from 89% (food security) to 100% (age, caste).

HFIAS = household food insecurity access scale; MAHFP = months of adequate household food provisioning

Table 2: Mean consumption of food groups for household members who consumed any, and mean dietary diversity score, for each household member

Food group ^a	Pregnant women				Mothers-in-law				Household head			
	Ate any of the food group		Intake, g, if any consumed		Ate any of the food group		Intake, g, if any consumed		Ate any of the food group		Intake, g, if any consumed	
	<i>n</i>	(%)	mean	(SD)	<i>n</i>	(%)	mean	(SD)	<i>n</i>	(%)	mean	(SD)
Starchy staples	150	(100)	896	(319)	150	(100)	886	(367)	149	99	1098	(427)
Pulses (beans, peas, lentils)	143	(95)	96	(57)	142	(95)	96	(56)	140	93	113	(69)
Nuts and seeds	47	(31)	6.3	(21)	52	(35)	6.7	(13)	53	35	6.6	(20)
Dairy	102	(68)	257	(224)	91	(61)	240	(197)	109	73	324	(272)
Flesh foods (meat, fish, shellfish)	49	(33)	52	(53)	48	(32)	57	(43)	65	43	73	(61)
Eggs	27	(18)	4.8	(12)	30	(20)	7.9	(26)	42	28	7.1	(20)
Green leafy vegetables	100	(67)	25	(31)	103	(69)	24	(29)	102	68	22	(24)
Other vitamin A-rich fruits and vegetables	103	(69)	201	(239)	105	(70)	226	(282)	96	64	214	(239)
Other vegetables	147	(98)	158	(103)	150	(100)	154	(95)	148	99	189	(122)
Other fruits	40	(27)	52	(47)	33	(22)	55	(65)	35	23	32	(28)
Alcohol	0	(0)	0	(0)	0	(0)	0	(0)	24	16	45	(111)
% (n) consuming ≥ 5 groups; mean dietary diversity ^b	87	(58)	4.6	(1.2)	88	(59)	4.7	(1.3)	93	62	4.9	(1.3)

^a Intakes based on average over 3-day recall period

^b Dietary diversity score based on 1-day recall period

Table 3: Differences in food shares (FS) and food shares-to-energy shares (FS:ES) for each food group, between different pairs of household members who ate any of each food group

Food group ^a	n	Log FS			Log FS:ES		
		Mean	95% CI	P	Mean	95% CI	P
Pregnant woman / household head							
Starchy staples	149	-0.21	(-0.28,-0.13)	<0.001	0.05	(-0.00,0.10)	0.068
Pulses (beans, peas, lentils)	137	-0.11	(-0.22,-0.00)	0.047	0.14	(0.03,0.26)	0.017
Nuts and seeds	35	-0.05	(-0.33,0.22)	0.70	0.14	(-0.11,0.39)	0.271
Dairy	88	-0.31	(-0.53,-0.10)	0.004	-0.07	(-0.30,0.17)	0.578
Flesh foods (meat, fish, shellfish)	43	-0.44	(-0.62,-0.26)	<0.001	-0.20	(-0.37,-0.04)	0.015
Eggs	24	-0.47	(-0.81,-0.12)	0.007	-0.28	(-0.63,0.07)	0.115
Green leafy vegetables	94	0.0	(-0.16,0.25)	0.69	0.29	(0.06,0.52)	0.012
Other vitamin A-rich fruits and vegetables	79	0.23	(-0.13,0.59)	0.20	0.47	(0.10,0.83)	0.012
Other vegetables	146	-0.22	(-0.31,-0.14)	<0.001	0.0	(-0.06,0.11)	0.593
Other fruits	21	0.53	(-0.68,1.73)	0.39	0.74	(-0.42,1.90)	0.213
Dietary diversity ^b	149	-0.07	(-0.11,-0.03)	0.001	-0.06	(-0.11, -0.01)	0.022
Mother-in-law / household head							
Starchy staples	149	-0.23	(-0.33,-0.13)	<0.001	0.0	(-0.00,0.08)	0.07
Pulses (beans, peas, lentils)	136	-0.15	(-0.30,-0.01)	0.035	0.12	(0.02,0.22)	0.017
Nuts and seeds	39	-0.28	(-0.62,0.06)	0.107	0.0	(-0.36,0.30)	0.84
Dairy	81	-0.47	(-0.67,-0.27)	<0.001	-0.28	(-0.47,-0.08)	0.005
Flesh foods (meat, fish, shellfish)	40	-0.38	(-0.65,-0.10)	0.008	-0.13	(-0.37,0.10)	0.27
Eggs	27	-0.34	(-0.63,-0.06)	0.019	-0.12	(-0.42,0.19)	0.45
Green leafy vegetables	95	0.0	(-0.20,0.24)	0.862	0.29	(0.07,0.52)	0.011
Other vitamin A-rich fruits and vegetables	83	0.32	(-0.18,0.82)	0.213	0.55	(0.09,1.02)	0.020
Other vegetables	148	-0.24	(-0.33,-0.14)	<0.001	0.0	(-0.06,0.12)	0.56
Other fruits	17	0.32	(-0.96,1.60)	0.623	0.57	(-0.77,1.91)	0.41
Dietary diversity ^b	149	-0.07	(-0.13,-0.01)	0.013	-0.02	(-0.09,0.05)	0.54

^a Intakes based on average over 3-d recall period; kcal intakes adjusted for by calculating Food Share to Energy Share [FS:ES between persons *a* and *b* = (intake_{*a*} / kcal_{*a*}) / (intake_{*b*} / kcal_{*b*})]

^b Dietary diversity score is based on 1-d recall period, and ‘log-FS’ was the log-transformed ratio between dietary diversity scores, whereas ‘log-FS:ES’ used the same log- dietary diversity ratio but adjusted for the corresponding log-transformed kcal intake ratios.

Table 4: Daily estimated average requirements, nutrient intakes, and probability of adequacy by household member

Nutrient	Pregnant women							
	Requirements ^a			Intakes ^b		Probability of adequacy, %		
	EAR	(SD)	Mean	(SD)	Median	Mean	(SD)	Median
	Pregnant women							
Energy, kJ/d	-	-	9372	(3056)	8983	-	-	-
Energy, kcal/d	-	-	2239	(730)	2146	-	-	-
Protein, g/d	-	-	68	(24)	65	-	-	-
Vitamin C, mg/d	40	(4.0)	133	(144)	96	91	(24)	100
Vitamin A, RE	370	(74)	486	(449)	359	17	(25)	7
Thiamin, mg/d	1.2	(0.1)	1.5	(0.7)	1.5	65	(39)	86
Riboflavin, mg/d	1.2	(0.1)	1.1	(0.6)	1.0	20	(34)	0
Niacin, mg/d	14	(2.1)	16	(7.1)	15	54	(36)	53
Vitamin B ₆ , mg/d	1.6	(0.2)	2.2	(0.8)	2.1	79	(33)	99
Folate, µg/d	520	(52)	639	(624)	325	24	(40)	0
Vitamin B ₁₂ , µg/d	2.2	(0.2)	0.8	(0.9)	0.4	0	(0.0)	0
Iron, mg/d ^c	22	(2.1)	25	(25)	17	20	(36)	0
Zinc, mg/d ^d	12	(1.5)	11	(4.0)	11	29	(33)	10
Calcium, mg/d ^e	800	(100)	654	(462)	505	14	(31)	0
Mean PA	-	-	-	-	-	37	(20)	36
	Mothers-in-law							
Energy, kJ/d	-	-	9326	(3324)	9163	-	-	-
Energy, kcal/d	-	-	2228	(794)	2189	-	-	-
Protein, g/d	-	-	67	(28)	65	-	-	-
Vitamin C, mg/d	30	(3.0)	138	(136)	98	96	(17)	100
Vitamin A, RE	270	(54)	511	(646)	333	40	(38)	29
Thiamin, mg/d	0.9	(0.1)	1.5	(0.7)	1.4	88	(28)	100
Riboflavin, mg/d	0.9	(0.1)	1.0	(0.6)	0.9	39	(41)	17
Niacin, mg/d	11	(1.7)	16	(7.2)	16	79	(32)	99
Vitamin B ₆ , mg/d	1.1	(0.1)	2.2	(0.8)	2.1	100	(0)	100
Folate, µg/d	320	(32)	350	(165)	325	34	(38)	14
Vitamin B ₁₂ , µg/d	2	(0.2)	0.6	(2.1)	0.3	0	(0)	0
Iron, mg/d ^c	-	-	15	(7)	14	2.7	(7.6)	0
Zinc, mg/d ^d	7	(0.9)	11	(5)	11	87	(28)	100
Calcium, mg/d ^e	800	(100)	511	(277)	434	6.2	(20)	0

Mean PA	-	-	-	-	-	52	(16)	51
Male household heads								
Energy, kJ/d	-	-	11892	(3692)	12085	-	-	
Energy, kcal/d	-	-	2841	(882)	2887	-	-	
Protein, g/d	-	-	87	(29)	84	-	-	
Vitamin C, mg/d	40	(4.0)	128	(105)	91	90	(27)	100
Vitamin A, RE	300	(60)	502	(402)	355	45	(38)	36
Thiamin, mg/d	1	(0.1)	2.0	(1.0)	1.9	95	(19)	100
Riboflavin, mg/d	1	(0.1)	1.3	(0.7)	1.2	65	(40)	88
Niacin, mg/d	12	(1.8)	22	(9.8)	21	95	(17)	100
Vitamin B ₆ , mg/d	1.1	(0.1)	2.8	(1.0)	2.7	99	(9)	100
Folate, µg/d	320	(32)	402	(158)	385	60	(41)	77
Vitamin B ₁₂ , µg/d	2	(0.2)	0.9	(1.2)	0.6	2.7	(15)	0.0
Iron, mg/d ^c	-	-	19	(6.7)	19	25	(24)	20
Zinc, mg/d ^d	15	(1.9)	14	(4.7)	14	29	(31)	16
Calcium, mg/d ^e	800	(100)	686	(407)	597	16	(32)	0.1
Mean PA	-	-	-	-	-	57	(17)	60

^a EARs using WHO/FAO values (33), unless otherwise stated.

^b Intakes reported as mean intakes, averaged across the three dietary recalls.

^c Institute of Medicine values for iron (35). We assumed low bioavailability of iron (5%), except for iron in pregnant women who have higher absorption (23%) during pregnancy. Iron probabilities of adequacy for mothers-in-law and men were calculated using a table of probabilities for different intervals of usual intakes, adapted from IOM but assuming 5% bioavailability.

^d Based on International Zinc Nutrition Consultative Group (IZiNCG) recommendations (36). We assumed a low bioavailability of zinc (25% absorption for women; 18% for men).

^e Institute of Medicine values for calcium (34).

Table 5: Tests for intra-household equity and the determinants of inequity in the allocation of energy (RDEARs) and nutrients (MPA ratios) using multivariable linear regression

	<i>log-RDEAR</i>					
	Pregnant woman : household head			Pregnant woman : mother-in-law		
	Coeff.	(95% CI)	<i>P</i>	Coeff.	(95% CI)	<i>P</i>
Crude mean outcome (<i>n</i> =149)	-0.20	(-0.26,0.15)	<0.001	-0.15	(-0.22,-0.07)	<0.001
<i>n</i> (fitted in multivariable model)	145			145		
Earning disparities between pregnant women and their spouse						
Earns less than spouse	Ref			Ref		
Earns more or same as spouse	0.27	(0.12,0.42)	<0.001	0.16	(0.02,0.30)	0.023
Number of previous pregnancies						
0	Ref			Ref		
≥ 1	-0.01	(-0.13,0.11)	0.88	0.04	(-0.08,0.15)	0.52
Empowerment						
Self-reported empowerment level	0	(-0.02,0.03)	0.78	0.02	(-0.01,0.04)	0.16
Food security						
Asset score	0.03	(-0.01,0.06)	0.15	-0.01	(-0.04,0.03)	0.75
Household mean intakes per capita	0.13	(0.04,0.22)	0.007	-0.02	(-0.10,0.07)	0.70
Husband working overseas						
Not working overseas	Ref			Ref		
Working overseas	-0.06	(-0.20,0.08)	0.39	0.14	(0.01,0.27)	0.035
Caste / religious group						
Dalit or Muslim (disadvantaged)	Ref			Ref		
Janajati/other Terai castes	0.05	(-0.08,0.17)	0.49	0.08	(-0.04,0.20)	0.19
Yadav/ Brahmin (least disadvantaged)	-0.04	(-0.20,0.12)	0.60	-0.04	(-0.19,0.10)	0.56
Season						
Pre-monsoon	Ref			Ref		
Monsoon	-0.03	(-0.14,0.08)	0.58	-0.02	(-0.12,0.08)	0.71
	<hr/> <i>log-MPA ratio</i> <hr/>					
Crude mean outcome (<i>n</i> =149)	-0.47	(-0.72,-0.22)	<0.001	-0.54	(-0.76,-0.31)	<0.001
<i>n</i> (fitted in multivariable model)	144			145		
Earning disparities between pregnant women and their spouse						
Earns less than spouse	Ref			Ref		
Earns more or same as spouse	-0.05	(-0.80,0.70)	0.90	0.14	(-0.18,0.46)	0.39
Number of previous pregnancies						
0	Ref			Ref		
≥ 1	0.29	(-0.32,0.90)	0.35	0.08	(-0.19,0.34)	0.56
Empowerment						

Self-reported empowerment level	-0.03	(-0.15,0.08)	0.57	0.00	(-0.05,0.05)	0.89
Food security						
Asset score	0.03	(-0.14,0.21)	0.71	0.02	(-0.05,0.10)	0.55
Household mean intakes per capita	0.07	(-0.39,0.52)	0.78	0.43	(0.23,0.63)	<0.001
Husband working overseas						
Not working overseas	Ref			Ref		
Working overseas	0	(-0.69,0.68)	0.99	0.22	(-0.07,0.52)	0.14
Caste / religious group						
Dalit or Muslim (disadvantaged)	Ref			Ref		
Janajati/other Terai castes	0.33	(-0.31,0.97)	0.32	0.2	(-0.08,0.48)	0.16
Yadav/ Brahmin (least disadvantaged)	0.89	(0.11,1.67)	0.026	0.25	(-0.09,0.59)	0.14
Season						
Pre-monsoon	Ref			Ref		
Monsoon	0.18	(-0.37,0.72)	0.53	-0.06	(-0.30,0.17)	0.60
Variance inflation factors ≤ 1.5						