Validating fatty acid intake as estimated by an FFQ: how does the 24 h recall perform as reference method compared with the duplicate portion?

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1 VALIDATING FATTY ACID INTAKE AS ESTIMATED BY A FOOD FREQUENCY
2 QUESTIONNAIRE: HOW DOES THE 24 HOUR RECALL PERFORM AS REFERENCE
3 METHOD COMPARED TO THE DUPLICATE PORTION?
4
5 Short title: VALIDATING FATTY ACID INTAKE
6
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Conflict of interest

None

Authorship

The authors' contributions are as follows: LT collected the data and contributed to the study design, data analysis and interpretation of findings and wrote the manuscript. JHMdV, PvtV and AG contributed to the study design, interpretation of findings and revised the earlier versions of the manuscript. HCB contributed to the data analysis, interpretation of findings and revised the earlier versions of the manuscript. PJMH and PCHH contributed to the study design and revised the earlier versions of the manuscript. All authors read and approved the final version of the manuscript.

Ethical standards disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the medical ethical committee of Wageningen University. Written informed consent was obtained from all subjects/patients.

Abstract

Objective: To compare the performance of the commonly used 24 hour recall (24hR) with the more distinct duplicate portion (DP) as reference method for validation of fatty acid intake estimated with food frequency questionnaires (FFQ).

Design: Intakes of saturated (SFA), monounsaturated (MUFA) and n-3 fatty acids and linoleic acid (LA) were estimated by chemical analysis of two DPs and by on average five 24hRs and two FFQs. Plasma n-3 fatty acids and LA were used to objectively compare ranking of individuals based on DP and 24hR. Multivariate measurement error models were used to estimate validity coefficients and attenuation factors for the FFQ with the DP and 24hR as reference methods.

Setting: Wageningen, The Netherlands.

Subjects: Ninety-two men and 106 women (aged 20-70).

Results: Validity coefficients for the fatty acid estimates by the FFQ tended to be lower when using the DP as reference method compared to the 24hR. Attenuation factors for the FFQ tended to be slightly higher based on the DP than those based on the 24hR as reference method. Furthermore, when using plasma fatty acids as reference, the DP showed comparable to slightly better ranking of participants according to their intake of n-3 fatty acids (0.33)and the n-3/LA ratio (0.34) than the 24hR (0.22 and 0.24 respectively).

Conclusions: The 24hR gives only slightly different results compared to the distinctive but less feasible DP, therefore the use of the 24hR seems appropriate as reference method for FFQ validation of fatty acid intake.

Keywords: dietary assessment, validity, measurement errors, fatty acids, duplicate portion, biomarker

Introduction

Inconclusive results about the risks of intake of total fat and various fatty acids on diseases such as breast cancer [1; 2] and coronary diseases [3; 4] plague epidemiological research. This inconclusiveness may originate from limitations and errors in food composition databases and dietary assessment methods to assess total fat and fatty acid intake. Food frequency questionnaires (FFQs) are often used in epidemiological studies, since they are relatively cheap and pose a low burden on the participants. However, they are suspected to be affected by systematic and random errors that together obscure the true variation in fat intake between subjects. The observed association between fat intake and disease can be adjusted for these measurement errors by an attenuation factor derived from a validation study. The reference method used in the validation study should generate unbiased dietary intake data (i.e. no proportional scaling bias should be present) and have uncorrelated errors with the FFQ [5; 6]. However for most nutrients, including fatty acids, only imperfect reference methods are available, e.g. 24-hour recalls (24hRs) or concentration biomarkers. Unfortunately, concentration biomarkers are only informative on ranking of individuals according to their intakes and not on their absolute levels of intake. Furthermore, use of plasma fatty acids as biomarkers of intake is limited to fatty acids that are not endogenously produced (i.e. n-3 and n-6 fatty acids) [7]. 24hRs are able to assess the intake of a wide array of fatty acids, but are biased and showed correlated errors with FFQs for energy and protein [8; 9]. Freedman et al.[10] recently recommended using regression calibration based on 24hRs to adjust diet-health associations when no recovery biomarkers are available. However, based on their investigation on intakes of energy, protein, potassium and sodium, they showed that the 24hR was certainly not a perfect reference method given the presence of intake related bias and errors correlated with those of the FFQ. It is unclear how these limitations affect the use of 24hR as reference method for validation of fatty acid estimates from FFQ.

Previous research concluded that the duplicate portion method (DP) is a suitable reference method and preferable over a 24hR for FFQ validation for nutrients for which no recovery biomarker is available [11]. The DP is a distinctive reference method as it does not depend on the availability and quality of the nutrient values in food composition databases, and also biases related to memory and estimation of portion sizes are less of a problem as compared to methods such as 24hR and FFQ. Altogether, the DP showed less proportional scaling bias and had a lower degree of correlated errors with the FFQ than the 24hR for protein, potassium and sodium [11]. In the present paper, we therefore compare the performance of the often used and more feasible 24hR as reference method for validation of fatty acid estimates from FFQ with the

116 more distinct DP as reference method. We additionally assessed the ability of DP and 24hR to
117 rank individuals according to their intake of n-3 fatty acids, LA and the n-3/LA ratio using an
118 objective biomarker (plasma fatty acids) as reference method.
119
120 **Subjects and Methods**
121 **Subjects and study design**
122 In this Dutch validation study called DuPLO, which is part of the National Dietary Assessment
123 Reference Database (NDARD) [12], 200 Dutch adults (92 men, 108 women) were enrolled. The
124 recruitment and study procedures are described elsewhere [11]. Briefly, between July 2011 and
125 July 2014 each participant collected two DPs (~ 5 months apart), and two blood samples (~13
126 months apart). Also two FFQs (~ 7 months apart) were filled out. An average of five 24hRs per
127 subject was administrated by a telephone interview by a dietician (~ 4 months apart). A varying
128 number of 24hRs per person (between 0 and 8 measurements) was collected because
129 participants were enrolled in different sub-studies of the NDARD study. Participants with
130 missing data for one or more of the methods were included in the analysis because they provided
131 information for the other dietary assessment methods.
132
133 **24-hour recalls and FFQ**
134 The 24hR administration followed a standardized protocol based on the 5-step multiple pass
135 method [13]. Participants got an unannounced phone call from a trained dietician. Portion sizes
136 of foods or recipes were reported using household measures, standard portion sizes, weight in
137 grams, or volume in liters [14].
138 The 180 item FFQ [15; 16] was administered via the web using the online open-source survey tool
139 Limesurvey™. The reference period for the FFQ was one month and frequencies of intake were
140 combined with standard portion sizes and household measures to assess amounts of intake [14].
141 Self-reported dietary intake data from 24hR and FFQ were converted into nutrient data using
142 the Dutch food composition database (FCD) of 2011 [17].
143
144 **Duplicate portion collection and analytical methods**
145 Participants got verbal and written instructions preceding the collection of the DP. Participants
146 collected all edible foods and drinks consumed over a 24-hour period in collection baskets and
147 stored them in a cool box (5°C). At the study center, DPs were weighed, homogenized in a
148 blender (Waring Commercial model 34BL22) and 2.5 mL 0.02% tert-butylhydrochinon (BHQ)
149 in ethanol was added per kg of DP as antioxidant. For each DP, an aliquot of the homogenized

150 sample was stored within 1 hour at -20°C, until further analysis. Total fat was measured
151 gravimetrically by acid hydrolysis (AOAC method 14.019) [18].
152
153 **Blood sampling and fatty acid assessment**
154 Blood samples were collected from the participants in a fasting state. EDTA plasma was stored
155 at -80°C until further analysis. Cholesteryl esters from plasma were isolated using solid phase
156 extraction silica columns and fatty acid profiles of the plasma cholesteryl esters were analyzed
157 by gas chromatography as previously described [19].
158
159 **Statistical analysis and measurement error models**
160 In total 198 participants were included for analysis, 92 males and 106 females. Two participants
161 got pregnant during the study. As it was expected that they had altered their habitual dietary
162 intake they were excluded from analysis. Means and 95% confidence intervals were estimated
163 for SFA, MUFA, n-3 fatty acids, and LA in grams and as a percentage of the total amount of
164 fatty acids for DP, 24hR and FFQ. An n-3/LA ratio (LA is an n-6 fatty acid) closer to one
165 indicates a healthier distribution and this ratio is therefore included as an additional outcome
166 measure in this research. Because of their skewed distribution, a log transformation was used
167 for all variables to obtain a normal distribution.
168 Our measurement error models assumed a linear relationship between the log(intake) according
169 to DP, 24hR, FFQ or biomarker and the true unknown intake T, with intakes of the specific
170 fatty acids expressed as percentages of the total fatty acid intake. Measurement error models
171 were adjusted for BMI and gender. In our measurement error models i indicates the person and
172 j the occasion. Furthermore, in all measurement error models α expresses the constant bias and
173 β the proportional scaling bias. The person specific bias for the method is given by w_{Xi} and the
174 random error by ε_{Xij} with mean zero and constant variance.
175 To evaluate the comparability of the 24hR and the DP as reference methods for the FFQ (for
176 both level of intake and ranking), model 1 (with equations 1 and 2) is defined as below. In this
177 model the assumptions of negligible error correlation between reference method and FFQ and
178 between replicates of the reference method, and absence of proportional scaling bias in the
179 reference method ($\beta_X = 1$) were made to enable estimation of the model parameters.
180
181 Reference method X (24hR or DP): $Xij = T + \varepsilon_{Xij}$ (1)
182 Food Frequency Questionnaire: $Qij = \alpha_Q + \beta_Q T + w_{Qi} + \varepsilon_{Qij}$ (2)

183

184 Validity coefficients (ρ_{XT}, formula 3) were estimated to assess the ability of the dietary
185 assessment method to rank participants according to their intake:
186

187 $$\rho_{XT} = \sqrt{\frac{{\beta_X}^2\ varT}{{\beta_X}^2\ varT + \frac{var\,\varepsilon_{Xij}}{k} + varw_{Xi}}} \qquad (3)$$

188

189 Where varT is the variance of the true nutrient intake; $var\varepsilon_{Xij}$ the variance of the random error
190 of method X and $varw_{Xi}$ the variance of the person specific bias for method X.
191 The attenuation factor (λ_X, formula 4) provides information about the extent to which diet-
192 health associations are affected by measurement error:
193

194 $$\lambda_X = \frac{{\rho_{XT}}^2}{\beta_X} \qquad (4)$$

195

196 As an additional check of the performance of the two reference methods, we used the biomarker
197 to objectively compare the ranking based on individual fatty acid intakes when using the DP
198 and the 24hR. Since the biomarker is only valid for n-3 and n-6 fatty acids [7] this was only done
199 for the n-3 fatty acids, LA and the n-3/LA ratio. Therefore we specified measurement error
200 model 2 (with equations 5 and 6) as given below. In this model the assumptions of negligible
201 error correlation between biomarker and DP or 24hR and between replicates of the biomarker
202 and absence of proportional scaling bias for the biomarker ($\beta_M = 1$) were made to enable
203 estimation of the model parameters.
204

205 Biomarker: $$Mij = T + \varepsilon_{Mij} \qquad (5)$$

206 Method X (24hR or DP): $$Xij = \alpha_X + \beta_X T + w_{Xi} + \varepsilon_{Xij} \qquad (6)$$

207

208 All statistical tests were performed in SAS version 9.3 (SAS Institute Inc. Cary, NC, USA,
209 2012).
210

211 **<u>Results</u>**

212 **Baseline characteristics of the study population**

213 At baseline, mean age of the study population was 55.7 (SD 10.2) years and mean BMI was
214 25.1 (SD 3.7) kg/m^2. 52.5 percent completed a high level (university or college) and 18.7
215 percent a low level of education (primary or lower education).
216
217 **Mean intakes of fatty acids**
218 Mean intakes and the lower (2.5) and higher (97.5) percentiles of the specific fatty acids in
219 grams and expressed as percentages of the total amount of fatty acids are shown in Table 1.
220 SFA intake by the DP (31.2 g) and the 24hR (30.1 g) were both higher than by the FFQ (26.9
221 g). Also, MUFA and n-3 intakes were highest when assessed by the DP (32.3 g and 2.5 g),
222 while intakes by the 24hR (27.9 g and 2.0 g) tended to be even lower than those by the FFQ
223 (28.7 g and 2.3 g). For LA, DP (14.3 g) was rather similar to FFQ (14.6 g), while 24hR (13.5
224 g) intake tended to be slightly lower. n-3/LA ratios were rather similar. SFA intake as
225 percentage of total fatty acids was highest when assessed by the 24hR (40.2%), followed by the
226 DP (37.4%) and FFQ (35.5%). The MUFA intake percentage was highest when assessed by the
227 DP (38.4%), followed by the FFQ (37.8%) and 24hR (36.8%). The LA intake percentage was
228 highest when assessed by the FFQ (19.2%), with the 24hR (18.0%) being slightly higher than
229 the DP (17.2%). For n-3 fatty acids and the n-3/LA ratio, percentages were rather similar for
230 the three dietary assessment methods.
231
232 **DP and 24hR as reference methods for FFQ validation**
233 Validity coefficients for the FFQ were lower when the DP was used as reference method than
234 when the 24hR was used as reference method when fatty acids were expressed as percentages
235 of total fatty acids. This was especially true for MUFA (0.37 for DP, 0.65 for 24hR), LA (0.64
236 for DP, 0.80 for 24hR) and the n-3/LA ratio (0.33 for DP, 0.76 for 24hR, Table 2).
237 For SFA and MUFA the attenuation factor was slightly higher when the DP was used as the
238 reference method than when the 24hR was used. The other attenuation factors for the FFQ were
239 rather similar when the DP was used as the reference method compared to the 24hR (Table 2).
240 Also, for fatty acids expressed in grams validity coefficients for the FFQ were lower when the
241 DP was used as reference method than when the 24hR was used as reference method. This was
242 especially true for n-3 fatty acids (0.44 for DP, 0.74 for 24hR) and LA (0.49 for DP, 0.69 for
243 24hR, Table 3). Attenuation factors for the FFQ were higher when the 24hR was used as the
244 reference method for SFA (0.30 for DP, 0.42 for 24hR), MUFA (0.17 for DP, 0.29 for 24hR)
245 and LA (0.29 for DP, 0.48 for 24hR).

Validity coefficients and attenuation factors for the FFQ were similar, whether they were expressed in grams or as a percentage of total fatty acids. However, a few values were lower when expressed in grams: for SFA and LA, both validity coefficients and attenuation factors for both the DP and 24hR as the reference method. Also for MUFA and the n-3/LA ratio for the validity coefficient with the 24hR as the reference method values were lower when expressed in grams (0.47 vs 0.65 and 0.48 vs 0.76 respectively, Table 3).

Ranking ability of DP and 24hR

To additionally compare the performance of the DP and 24hR for ranking in an objective way, concentration biomarker measurements were used as reference method. Validity coefficients were used to assess the ability of both methods to rank individuals according to their fatty acid intake. The validity coefficient for the ranking based on a single DP (k=1) for the n-3 fatty acids (0.33) was slightly higher than for a single 24hR (0.22, Table 4). For LA and the n-3/LA ratio, validity coefficients were similar. A similar pattern was observed for validity coefficients based on two DP and two 24hR measurements as shown in table 4 (k=2).

Discussion

To investigate to what extent the 24hR, often used as a reference method for FFQ, reduces the bias in estimated risk parameters for the intake of fatty acids we compared its performance to the DP as reference method. Fatty acid intakes expressed in grams were (slightly) lower when assessed by the 24hR as compared to the DP. For the fatty acid intakes expressed as percentages of total fatty acids, differences between the dietary assessment methods did not show a clear pattern. Validity coefficients for fatty acid estimates by the FFQ were higher or comparable when the 24hR was used as reference method than when the DP was used for data expressed in grams and percentages of total fatty acids. For attenuation factors, however, the 24hR as reference method showed a slightly lower value for MUFA for data expressed in percentages of total fatty acids and a higher value when expressed in grams. For data expressed in grams, higher attenuation factors were also observed for SFA and LA when the 24hR was used as the reference method. Using plasma fatty acids as reference method showed that the 24hR was able to rank participants according to their intake of n-3 fatty acids, LA and the n-3/LA ratio to a similar degree or slightly worse than the DP.

Intakes of fatty acids in our study population were comparable with those of the general Dutch population based on the 2007-2010 Dutch National Food Consumption Survey (DNFCS) [20].

280 The DNFCS intake data are based on two telephone-based 24hRs and the same FCD (2011) as
281 we used to calculate nutrient intakes. Assessment of nutrient intake is among others limited by
282 the availability and quality of the data in the FCD. Fatty acid composition of foods may change
283 over time and vary amongst different brands. However, a study comparing calculated and
284 analysed test diets for controlled dietary interventions found a reasonable agreement between
285 the two for SFA and MUFA [21] indicating the Dutch FCD performs reasonably well for these
286 fatty acids.
287 Published data on validity coefficients for FFQs for fatty acids intake estimates are scarce. One
288 study, using the method of triads with the biomarker and weighed food records as reference
289 method, found a validity coefficient of 0.50 for n-3 fatty acids assessed by FFQ [22], which is
290 comparable to our results. A study by Kabagambe *et al*, also using the method of triads, found
291 validity coefficients for the FFQ for LA between 0.77 and 0.89 [23], using the biomarker and
292 24hR as reference methods. This is in line with our findings for LA when using the 24hR as
293 reference method. A recent study in Brazilian adults, also using the method of triads with a
294 biomarker, FFQ and 24hR, reported validity coefficients for the FFQ for SFA (0.28) and LA
295 (0.31), which are lower than our results[24]. Although differences in the statistical method to
296 assess validity coefficients, adjustment for different covariates, study population, validity of the
297 FCD and characteristics of the FFQ may hamper comparability of studies, our findings were in
298 the same order of magnitude as the results previously published.
299 To be able to estimate model parameters, assumptions have to be made. These assumptions are
300 universally made when the 24hR is used as reference method and are not specifically related to
301 the use of measurement error models. In our first model we made the assumption of negligible
302 error correlation between FFQ and DP or 24hR and between replicates of the reference
303 methods, and the absence of proportional scaling bias for the DP and 24hR. Previous research
304 showed that correlated errors between FFQ and 24hR and also between FFQ and DP were
305 present and so was proportional scaling bias for the DP and 24hR for energy, protein, potassium
306 and sodium intake [8; 9; 11]. It would thus be likely that correlated errors and proportional scaling
307 bias are also present when assessing fatty acid intake. The presence of correlated errors between
308 FFQ and reference method will lead to an overestimation of validity coefficients and attenuation
309 factors for the FFQ when using DP or 24hR as reference method [25]. We previously showed
310 that less correlated errors were present between DP and FFQ than between 24hR and FFQ [11].
311 This would imply that the validity coefficients of the FFQ obtained with the DP as the reference
312 method would show less overestimation. We indeed observed lower validity coefficients for
313 fatty acid estimates by the FFQ when the DP was used as reference method than when the 24hR

314 was used. Correlation of errors between replicates would cause the validity coefficient to be
315 underestimated [25]. We carefully designed the study in such a way that replicates were taken
316 independently with enough time in between. However, this does not remove correlated errors
317 due to e.g. underreporting because of social desirability. For attenuation factors the influence
318 of the proportional scaling bias also needs to be taken into account. Assuming this bias is mostly
319 smaller than one [8; 11; 26], the attenuation factor will be overestimated.
320 In our second model we assumed negligible error correlation between biomarker and DP or
321 24hR and between replicates of the biomarker. In addition, absence of proportional scaling bias
322 for the biomarker was assumed, however if this assumption is not met this does not affect the
323 comparability of validity coefficients for DP and 24hR. The assumption of uncorrelated errors
324 between biomarker and DP or 24hR is likely to hold since the errors in the biomarker
325 measurement are assumed to be mostly physiological where the errors in DP and 24hR are due
326 to the reporting of dietary intake, although complete absence of error correlation cannot be
327 assumed. However, an individual's digestion, absorption and metabolism are likely to influence
328 concentration biomarker measurements [27], causing error correlations between replicates of the
329 biomarker. Due to this error correlation, validity coefficients for the DP and 24hR will be
330 underestimated which limits their interpretation as the calculated values should be interpreted
331 as lower limit of the range of potential validity coefficient estimates. However, errors in the
332 biomarker estimates are assumed to influence the validity coefficients for DP and 24hR equally,
333 therefore the finding that the DP had comparable or slightly better ranking abilities than the
334 24hR is sound. Lastly, given that the collection of DP is expensive and labour intensive our
335 sample size is relatively large, but compared to other validation studies, like the OPEN study[8],
336 the sample size of this study is relatively small.
337 Using DP or 24hR as reference methods for FFQ validation enables to assess the validity of a
338 wide range of fatty acids, while plasma fatty acids can only be used to evaluate ranking based
339 on intakes of fatty acids that are not endogenously produced. Furthermore, DPs and 24hRs can
340 be used to assess the validity of absolute FFQ fatty acid intakes, while the plasma fatty acids
341 can only be expressed as percentage of total fatty acids. Using 24hR as reference method has
342 previously been found to reduce but not eliminate the bias in diet-health associations with
343 intakes on a continuous scale and is recommended to be used when no recovery biomarker is
344 available [10]. DPs are assumed to be superior as they are not affected by errors originating from
345 the FCD, while also portion size estimation bias and the influence of memory are expected to
346 be small[11]. However DP are expensive to collect and less feasible to include in validation
347 studies. Also, 24hR with other software or instructions and DP with other instructions, or in

348 other study populations can yield other results, therefore possible extrapolation of our results
349 has to be done carefully.
350
351 In conclusion, taking into account that the assumptions made in our models prevent us from
352 drawing firm conclusions, validity of assessment of fatty acid intake by FFQ differs slightly
353 when the conventionally used 24hR is the reference method as compared to the DP. The 24hR
354 seems to perform slightly worse than the DP when used to obtain validity coefficients for the
355 FFQ, where for attenuation factors for the FFQ the use of DP or 24hR as reference method
356 seem comparable. Therefore, the 24hR seems an acceptable reference method, given it is less
357 burdensome for participants and researcher, for FFQ validation of fatty acid intake.
358

359 Table 1: Mean intake of SFA, MUFA, n-3 fatty acids, LA, and n-3/LA ratio in grams and as a percentage of total fatty acids for the DP, 24hR
360 and FFQ

	N	SFA		MUFA		n-3		LA		n-3/LA ratio	
		Mean	CI	Mean	CI	Mean	CI	Mean	CI	Mean	CI
Intake in grams											
DP	198	31.2	29.9-32.6	32.3	31.0-33.7	2.49	2.26-2.71	14.3	13.5-15.2	0.18	0.17-0.20
24hR	155	30.1	28.7-31.5	27.9	26.6-29.2	2.02	1.89-2.15	13.5	12.7-14.2	0.17	0.16-0.18
FFQ	196	26.9	25.6-28.3	28.7	27.4-30.0	2.25	2.14-2.35	14.6	13.9-15.4	0.16	0.16-0.17
Intake in percentage of total FA											
DP	198	37.4	36.6-38.3	38.4	37.7-39.0	2.98	2.76-3.20	17.2	16.5-18.0	0.18	0.17-0.20
24hR	155	40.2	39.4-41.1	36.8	36.1-37.4	2.83	2.66-3.01	18.0	17.3-18.7	0.17	0.16-0.18
FFQ	196	35.5	34.7-36.2	37.8	37.4-38.1	3.04	2.93-3.14	19.2	18.7-19.7	0.16	0.16-0.17

361 SFA=saturated fatty acids, MUFA= mono-unsaturated fatty acids, n-3=n-3 fatty acids, LA=linoleic acid, CI=confidence interval,
362 DP=duplicate portion, 24hR= 24hour recall, FFQ=food frequency questionnaire, FA=fatty acids
363
364
365 Table 2: Validity coefficients and attenuation factors of the FFQ for fatty acids (expressed as % of total fatty acids) with DP or 24hR as reference
366 methods

Ref method	N	SFA	CI	MUFA	CI	n-3	CI	LA	CI	n-3/LA ratio	CI
Validity coefficient*†											
DP	198	0.76	0.63-0.89	0.37	0.19-0.54	0.47	0.32-0.62	0.64	0.48-0.79	0.33	0.17-0.48
24hR	196	0.82	0.77-0.86	0.65	0.56-0.74	0.62	0.48-0.76	0.80	0.75-0.85	0.76	0.70-0.82
Attenuation factor*‡											
DP	198	0.57	0.46-0.68	0.34	0.17-0.50	0.63	0.41-0.85	0.60	0.45-0.76	0.49	0.25-0.73
24hR	196	0.46	0.38-0.53	0.21	0.15-0.27	0.56	0.41-0.71	0.55	0.44-0.66	0.45	0.32-0.58

367 SFA=saturated fatty acids, MUFA= mono-unsaturated fatty acids, n-3=n-3 fatty acids, LA=linoleic acid, CI=confidence interval,
368 DP=duplicate portion, 24hR= 24hour recall
369 *Models were adjusted for BMI and gender
370 †Estimates were obtained using model 1 (equation 1 and 2) and formula 3
371 ‡Estimates were obtained using model 1 (equation 1 and 2) and formula 4
372
373

374 Table 3: Validity coefficients and attenuation factors of the FFQ for fatty acids (in grams) with DP or 24hR as reference methods

Ref method	N	SFA	CI	MUFA	CI	n-3	CI	LA	CI	n-3/LA ratio	CI
Validity coefficient*†											
DP	198	0.56	0.43-0.70	0.37	0.23-0.51	0.44	0.30-0.58	0.49	0.35-0.64	0.33	0.17-0.48
24hR	196	0.62	0.51-0.73	0.47	0.34-0.60	0.74	0.63-0.83	0.69	0.59-0.79	0.48	0.29-0.66
Attenuation factor*‡											
DP	198	0.30	0.21-0.40	0.17	0.08-0.25	0.44	0.28-0.59	0.29	0.19-0.39	0.49	0.25-0.73
24hR	196	0.42	0.32-0.52	0.29	0.19-0.39	0.53	0.42-0.64	0.48	0.38-0.58	0.39	0.22-0.56

375 SFA=saturated fatty acids, MUFA= mono-unsaturated fatty acids, n-3=n-3 fatty acids, LA=linoleic acid, CI=confidence interval,
376 DP=duplicate portion, 24hR= 24hour recall
377 *Models were adjusted for BMI and gender
378 †Estimates were obtained using model 1 (equation 1 and 2) and formula 3
379 ‡Estimates were obtained using model 1 (equation 1 and 2) and formula 4
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383 Table 4: Validity coefficients*† of the DP and 24hR for n-3, LA and n-3/LA ratio where the mean of two plasma fatty acid values (expressed as
384 % of total fatty acids) were used as reference method

	k	n-3	CI	LA	CI	n-3/LA ratio	CI
DP	1	0.33	0.20-0.45	0.18	0.07-0.30	0.34	0.22-0.47
	2	0.39	0.25-0.54	0.22	0.09-0.36	0.41	0.26-0.56
24hR	1	0.22	0.11-0.32	0.21	0.12-0.29	0.24	0.15-0.34
	2	0.28	0.15-0.41	0.27	0.16-0.39	0.32	0.20-0.45

385 n-3=n-3 fatty acids, LA=linoleic acid, k = number of measurements,
386 CI=confidence interval, DP=duplicate portion, 24hR= 24hour recall
387 *Models were adjusted for BMI and gender
388 †Estimates were obtained using model 2 (equation 5 and 6) and formula 3
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