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Title: Development of the Healthy Purchase Index (HPI): A scoring system to assess the nutritional quality of household food purchases

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Abstract

2 **Objective:** To develop an index to assess the nutritional quality of household food purchases
3 based on food expenditures only.

4 **Design:** A database of monthly food purchases of a convenient sample of low-income
5 households was used to develop the Healthy Purchase Index (HPI). The HPI is the sum of two
6 subscores based on expenditure shares of food categories in total household food expenditure:
7 the *purchase diversity subscore* and the *purchase quality subscore*. The first was adapted from
8 an existing diversity score. The second integrated those food categories identified as the best
9 predictors of the nutritional quality of purchases based on associations between expenditure
10 shares of food categories and two nutritional quality indicators, namely the mean adequacy
11 ratio (MAR) and the mean excess ratio (MER). Correlation between the HPI and a score
12 assessing adherence to French dietary guidelines (PNNS-GSmod) was performed as a first
13 validation.

14 **Setting/Subjects:** Food purchases of 112 households from deprived neighborhoods of
15 Marseille (France), participating in the Opticourses and Jassur projects (2012–2015).

16 **Results:** The *purchase diversity subscore* reflects the presence in food purchases of five food
17 categories, namely fruits, vegetables, starches, dairy products, and meat fish & eggs. The
18 *purchase quality subscore* is based on expenditure shares for fruit & vegetables, added fats &
19 seasonings, sweet snacks, cheese, sugary beverages, refined grains, and fish, as these were
20 identified as predictors of the nutritional quality of purchases. The HPI was positively
21 associated with the PNNS-GSmod ($r_s = 0.378$; $p < 0.001$).

22 **Conclusions:** The HPI helps assess the healthiness of household food purchases.

23

24 **Keywords:** supermarket receipts; food supply; French household; economic barrier; food
25 price; nutrition; low-income

26 Introduction

27 Studies have shown a positive association between diet quality and socio-economic status⁽¹⁾,
28 mediated in part by diet cost⁽²⁾. Low-cost diets tend to have high energy density and low
29 nutrient adequacy given that energy-dense foods are cheaper per calorie than recommended
30 nutrient-dense foods⁽³⁾. Socially-disadvantaged people thus run up against more economic
31 barriers hindering the adoption of healthier diet⁽⁴⁾. However, previous research has found that
32 a healthier diet is not necessarily more expensive when households select foods with good
33 nutritional quality for their price⁽⁵⁾, making it important to develop decision-support tools to
34 help consumers achieve nutritionally optimal choices at affordable cost.

35 Despite recent shifts in eating patterns favoring eating out, dietary energy intake in Europe
36 mostly comes from food consumed at home⁽⁶⁾, especially in France⁽⁷⁾. Food consumption is
37 therefore driven mainly by household food purchases. Consumer purchasing behaviors have
38 been investigated in both interventional and observational studies, based on analyses of sale
39 data or till receipts. Studies exploring the impact on sales of in-store interventions targeting
40 point-of-purchase food-product availability, access, incentives or information have found that
41 modification of the retail store environment can drive consumers toward healthier food
42 purchasing behavior⁽⁸⁻¹⁰⁾. Household till receipts provide unique in-depth information on food
43 sources and food items as well as accurate information on expenditures and quantities
44 purchased^(11,12). Till receipts have been used in observational studies to characterize household
45 food consumption patterns, especially in relation to different socio-economic
46 characteristics^(11,13-15), as they can provide a good estimate of dietary quality and nutrient
47 intakes^(12,16,17). Collecting supermarket and grocery receipts was found to provide relevant
48 information on energy and fat intakes⁽¹²⁾. Moreover, in households with obese individuals,
49 food purchase provided more reliable information than dietary recalls based on self-reported
50 measures, which are subject to desirability bias and memory failure⁽¹⁶⁾.

51 However, nutritional analysis of food purchases can prove tedious and time-consuming,
52 typically restricting studies to a few hundred households^(5,11-18). Participants are asked to
53 collect and annotate receipts from all family members, and to record all food expenditures
54 made without receipts. Estimating the nutrient content of food expenditures entails
55 cumbersome data handling, especially since evaluators often have to contend with missing
56 data on the quantities purchased^(14,19). This study exploited the huge potential of supermarket
57 receipts for monitoring the nutritional quality of household food purchases to develop a

58 simplified measure of the quality of household food purchases, called the 'Healthy Purchase
59 Index' (HPI). Here we present the methodology used to develop the HPI, and the first
60 elements of its validation.

61 **Methods**

62 **Study design and population**

63 Sociodemographic and food purchase data were obtained from studies conducted on
64 disadvantaged populations in socioeconomically-deprived neighborhoods of Marseille (south
65 of France): the Opticourses (2012–2014) and the Jassur (2013–2015) projects. Opticourses
66 participants were 91 adults willing to participate in an education program on food and
67 budget^(5,20). Jassur participants were 21 adults from the same neighborhoods with access to a
68 community garden plot⁽²¹⁾. All participants ($n = 112$) completed a monthly record of their
69 household food purchases. All participants provided written informed consent. The Southern
70 Mediterranean Ethical Research Committee Sud-Méditerranée reviewed and approved the
71 protocols of the Opticourses and Jassur trials (registered at clinicaltrials.gov as NCT02383875
72 and NCT03175575, respectively).

73 **Categorization, price and nutritional composition of household food purchases**

74 In both studies, participants were asked to provide a detailed record of foods entering their
75 household over a 1-month period (including purchases, gifts, and foods from other sources).
76 As previously described in Marty *et al.*⁽⁵⁾, participants were given a notebook with step-by-
77 step instructions on how to collect and annotate all receipts for foods entering the household
78 and record expenditures without receipts. A face-to-face visit was scheduled approximately 15
79 days after the food supply diary was issued to maintain participants' motivation and to ensure
80 correct filling of the diary. A database of monthly food purchases was created by compiling
81 information on date of purchase, quantity and price of all food items purchased. All food
82 items were then classified into nine groups and twenty-three subgroups (**Table 1**). The “mixed
83 dishes”, “sweet products” and “sweet beverages” food groups consist primarily of ultra-
84 processed foods (following NOVA classification) found to be associated with poor dietary
85 quality and obesity^(22,23). For others processed items, such as canned or bottled vegetables,
86 fruits and vegetables or canned fish, various studies have shown no evidence of any extra
87 nutritional benefit of fresh items compared to frozen and canned ones^(24–26). In this regard,
88 fresh and processed items were pooled in the same group, as is the case in most indices of
89 overall diet quality.

90 For each food item purchased, the quantity ‘as purchased’ was transformed into a quantity ‘as
91 consumed’ using a correction coefficient that took into account the changes in weight
92 associated with preparation and waste (e.g. peeling, boning, water loss or gain during

93 cooking, etc.). The nutritional composition of each food item ‘as consumed’ was then
94 determined by linkage with the closest food from the French food composition table⁽²⁷⁾. For
95 each household, energy and nutrient contents of food supplies were calculated as the sum of
96 the energy and nutrient contents of all foods and beverages entering the household during the
97 period of data collection.

98 As previously described⁽⁵⁾, missing receipt information on the weight of a food purchased was
99 estimated using three different methods: 1) information on known packaging sizes (and
100 corresponding weights) for that food was searched for on commercial websites, and the most
101 plausible weight (given the actual expenditure incurred) was chosen; 2) when information on
102 packaging sizes was unavailable but the food item was purchased at least twice (with the
103 receipt showing the weights) among all households, we calculated an observed mean food
104 price per kg and we then estimated the quantity purchased by dividing the actual expenditure
105 by the corresponding observed mean price; 3) if we did not have an observed mean food price
106 and the food item was purchased only once in the sample, the quantity purchased was
107 estimated by dividing the actual expenditure by the corresponding national food price. When
108 the food was gifted, picked from the garden, or came from food aid, we assigned a theoretical
109 price using the mean observed food price.

110 **Indicators of nutritional quality of household food purchases**

111 Mean adequacy ratio (MAR) and mean excess ratio (MER) were used as indicators of the
112 nutritional quality of food purchases and were calculated for 2000 kcal of purchases for each
113 household.

114 MAR is an indicator of overall good nutritional quality⁽²⁸⁾. It was calculated as the mean of 23
115 nutrient adequacy ratios, corresponding to percentage of the daily recommended intakes for
116 23 key nutrients as previously described⁽²⁹⁾:

117

118 where Nut_n is quantity of each nutrient n per 2000 kcal of purchase, and RDA_n is the French
119 Recommended Dietary Allowance⁽³⁰⁾ for that nutrient. As is customary, each nutrient
120 adequacy ratio (Nut_n/RDA_n) was truncated at 1, so that a high intake of one nutrient could not
121 compensate for a low intake of another⁽³¹⁾.

122 Conversely, MER is an indicator of bad nutritional quality. Previously proposed by Vieux *et*
123 *al.*⁽³²⁾, MER is the mean of 3 nutrient excess ratios, corresponding to percentage of daily

124 maximum recommended values for 3 unhealthy nutrients: sodium, saturated fatty acids, and
125 free sugars (added sugars plus sugars naturally present in honey, syrups, and fruit juices), as
126 follows:

127

128 where Nut_p is the quantity of each nutrient p per 2000 kcal of purchase, and MRV_p is the
129 maximum recommended value for that nutrient. Here, unlike the previously published
130 MER⁽³²⁾, each nutrient excess ratio lower than 100 was not truncated to 100 in order to avoid
131 non-normal distribution of the indicator.

132 **Development of the Healthy Purchase Index (HPI)**

133 Food expenditure shares corresponding to the percent expenditure of each food group and
134 subgroup in monthly food expenditure were calculated for each household. Two subscores
135 were defined, the *purchase diversity subscore* and the *purchase quality subscore*, and the HPI
136 was calculated as the sum of the two subscores.

137 *Purchase diversity subscore*

138 The *purchase diversity subscore* is a 5-component score derived from a previously published
139 individual “Dietary Diversity Score” that reflects the presence in diet of 5 food groups and
140 subgroups, namely fruits, vegetables, starches, dairy products, and meat ,fish & eggs⁽³³⁾. We
141 considered that an expenditure share of 5% of total food expenditure would likely correspond
142 to the share accounting for a non-negligible but easily achievable contribution of a food group
143 or subgroup to household food purchases. Therefore, for each of the 5 food groups and
144 subgroups, one point was given when its expenditure share was greater than 5%, leading to a
145 maximum value of 5 for the *purchase diversity subscore*.

146 *Purchase quality subscore*

147 The *purchase quality subscore* is a 7-component score. It was based on food groups and
148 subgroups identified according to known relationships between diet and health⁽³⁴⁾ and/or for
149 which expenditure shares best reflected the nutritional quality of purchases. Identification of
150 best predictors was performed separately for food groups and subgroups. In a first step,
151 regressions were conducted to capture the relationship between each indicator of nutritional
152 quality (i.e. MAR and MER), as the dependent variable, and each food group and subgroup.
153 We then performed multivariate linear regressions for MAR and MER separately, including
154 all main terms yielding $p < 0.20$ in the first step. A change-in-estimate method was further

155 applied to select the best subset of predictors. The MAR, MER and food groups and
156 subgroups expenditure shares were log-transformed to improve normality. Log transformation
157 of food subgroups rarely purchased (i.e. by less than a third of households) did not reduce
158 skewness and so were coded as binary variables (purchased/not purchased). These binary
159 variables were subsequently added to the multivariate models, and only the variables proved
160 significant were kept in the final model. In addition to the identified predictors, several
161 refinements were incorporated based on expert advice from the 2016 report of the French
162 Agency for Food, Environmental and Occupational Health & Safety (Anses) on the update of
163 the French dietary guidelines⁽³⁴⁾.

164 For each predictor significantly associated with one of the nutritional quality indicators,
165 minimum or maximum expenditure shares were defined by identifying breaks in plots
166 crossing predictor expenditure share and nutritional quality indicator. For predictors
167 associated with both MAR and MER, the plot that better reflected breaks in the distribution
168 was chosen to define the cut-off values.

169 **First elements of validation of the HPI**

170 A common method for validating a dietary quality index consists in comparing the new index
171 against a previously validated one⁽³⁵⁾. Here we used Spearman non-parametric correlations to
172 compare the HPI to the MAR and to the MER (expressed as adequacy and excess ratios,
173 respectively, per 2000 kcal of purchases), as well as to each of their constitutive nutrient ratios
174 individually. The association with a modified version of the PNNS–Guideline Score (PNNS-
175 GS), assessing adherence to official French dietary guidelines, was also investigated. Briefly,
176 the PNNS-GS is a 15-point score comprising 13 components: 8 components capture French
177 dietary guidelines, 4 components concern nutrients and food groups whose consumption is to
178 be limited, and 1 component covers adherence to physical activity recommendations⁽³⁶⁾. Here,
179 a modified PNNS-GS (PNNS-GSmod), excluding both the physical activity and alcohol
180 components (absent from our database), was computed on each household’s monthly food
181 purchases. To do so, weight and energy of household food supplies were divided by number
182 of household members and by number of days of data collection, as French dietary guidelines
183 are stated in terms of individual recommended daily servings.

184 Sensitivity analysis was also performed by testing the addition of two penalties to the HPI. A
185 first penalty was added when the red & processed meat expenditure share was higher than the
186 75th percentile in the study population, given epidemiologic evidence linking high

187 consumption of red and processed meat to diseases^(37,38). A second penalty was added when
188 food expenditure was below 3.5 €/day per person, as previous research showed that it is
189 almost impossible to obtain a nutritionally adequate diet below this threshold in France^(3,39),
190 and so it is unlikely that food purchases below this threshold have good nutritional quality.
191 All analyses were performed with the SAS statistical software package Ver. 9.4 for Windows
192 (SAS Institute, Cary, NC, USA), with statistical significance at $p < 0.05$.

193 **Results**

194 **Characteristics of the households**

195 Average household size was 3.3 persons (range: 1–7) including 1.6 children (range: 0–6);
196 20.5% were single-person households (data not shown). Almost a third (33.1%) declared
197 severe financial difficulties, 45.5% were in a precarious financial situation, 16.1% were in a
198 stable financial situation, and 5.3% did not answer the question. During the 1-month food
199 records, each household shopped in an average of five different stores. A total of 849 different
200 food items were purchased or the whole sample.

201 **The *purchase diversity subscore***

202 Regarding the expenditure share distributions of the five components of the *purchase*
203 *diversity subscore*, 56% of the population reached the minimum expenditure share of 5% for
204 fruits, 75% for vegetables, 93% for starches, 97% for meat, fish & eggs and 85% for dairy
205 products.

206 **The *purchase quality subscore***

207 *Identification of food groups and subgroups for which expenditure shares best predict the*
208 *nutritional quality of purchases*

209 The major contributors to total household food expenditure were meat, fish & eggs
210 ($26.7 \pm 12.8\%$), starches ($17.4 \pm 11.3\%$), fruit & vegetables ($16.6 \pm 10.0\%$), sweet products
211 ($12.4 \pm 7.2\%$), dairy products ($10.3 \pm 5.3\%$) for the food groups, and red & processed meat
212 ($15.0 \pm 10.9\%$), refined grains ($14.2 \pm 11.2\%$), sweet snacks ($10.9 \pm 6.7\%$) and vegetables
213 ($9.5 \pm 6.3\%$) for the subgroups. The expenditure share for condiments was negligible (i.e. less
214 than 1.5%) and this subgroup was thus excluded from the analysis. Of the 22 subgroups, 10
215 were coded as binary variables. Results from bivariate associations and final multivariate
216 models are presented in **Table 2**. A total of 14 predictors—6 food groups and 8 subgroups—
217 were found to be significantly associated with at least one indicator of nutritional quality of
218 purchases in final multivariate models. Expenditure shares for fruit & vegetables (including
219 the fruits, dried fruits, and vegetables subgroups) and meat, fish & eggs were positively
220 associated with MAR, while the added fats & seasonings group (especially vegetable fats)
221 was negatively associated with MAR. Expenditure shares for sweet products, and sweet
222 beverages (especially sugary drinks), and for the cheese and sweet snacks subgroups, were

223 positively associated with MER. Expenditure shares for starches and for refined grains were
224 negatively associated with both MAR and MER.

225 *Choice of components included in the purchase quality subscore*

226 Owing to their nutritional specificity, subgroups were preferentially selected over food groups
227 to be included in the *purchase quality subscore*, apart from the fruit & vegetables group
228 (given that all its subgroups were predictors of the nutritional quality of purchases). Refined
229 grains were not encouraged as they were found to be negatively associated with both MAR
230 and MER. Thus, the *purchase quality subscore* was primarily built on 5 components: fruit &
231 vegetables (with minimum expected expenditure share), sweet snacks, cheese, sugary drinks
232 (with maximum expected expenditure share), and added fats & seasonings (with maximum
233 expenditure share and consideration of vegetable fats purchases). Two further components
234 were added in the light of the updated French national dietary guidelines⁽³⁴⁾ : 1) one limiting
235 the expenditure share of the refined grains subgroup within the starches food group, since
236 cutting back on refined grains and choosing whole grains and higher-quality sources of
237 starches is recommended for health; 2) one encouraging expenditure for the fish subgroup,
238 since fish (especially fatty fish) is a unique source of important nutrients such as vitamin D
239 and omega-3 fatty acids.

240 Finally, the *purchase quality subscore* is a 10-point score that comprises 7 components: 2 with
241 an expenditure share to increase (fruit & vegetables, fish) and 5 with an expenditure share to
242 limit (added fats & seasonings, sweet snacks, cheese; sugary drinks, refined grains). One or
243 two cut-off values were graphically identified for each component, providing the basis for
244 constructing the subscore (Table 3).

245 **The Healthy Purchase Index**

246 The HPI, aimed at evaluating the nutritional quality of monthly household food purchases, is
247 obtained by summing the *purchase diversity subscore* and the *purchase quality subscore*.
248 Scoring and cut-off values of the HPI are presented in **Table 3**. The HPI has a maximum of 15
249 points, where a higher score reflects a higher quality of the household food purchases. The
250 distributions of the HPI score and its subscores in the food purchases of the studied population
251 are presented in **Figure 1**. Average HPI score was 7.4 ± 2.1 (range: 3–12 out of 15), with an
252 average *purchase diversity subscore* of 4.1 ± 0.9 (range: 1–5 out of 5) and an average
253 *purchase quality subscore* of 3.3 ± 1.8 (range: 0–8 out of 10) (**Table 4**).

254 The HPI was positively associated with the MAR ($r_s = 0.552, p < 0.001$) and with the PNNS-
255 GS_{mod} ($r_s = 0.378, p < 0.001$) and negatively associated with the MER ($r_s = -0.426, p < 0.001$).
256 Correlations were higher for the *purchase quality subscore* than for the *purchase diversity*
257 *subscore*.

258 Adding a penalty to HPI for households with expenditure shares for red & processed meat \geq
259 20% (75th percentile) barely attenuated the associations with the three indicators [MAR:
260 $r_s = 0.492$; MER: $r_s = -0.396$; PNNS-GS_{mod} $r_s = 0.334$; all $p < 0.001$]. Adding a penalty for
261 food budget below 3.5 €/day per person (62% of households) barely changed the associations
262 [MAR: $r_s = 0.523$; MER: $r_s = -0.398$; PNNS-GS_{mod} $r_s = 0.401$; all $p < 0.001$] (data not shown).

263 Associations with nutrient adequacy ratios and nutrient excess ratios of each component of the
264 MAR and MER, respectively, are presented in **Table 5**. HPI correlated significantly with 19
265 nutrients of the MAR ($-0.277 < r_s < 0.557$) and with 2 nutrients of the MER
266 ($-0.478 < r_s < -0.217$).

267 Discussion

268 Since healthy diet results in part from healthier choices at the grocery store, the HPI was
269 designed as a tool to evaluate the nutritional quality of household food purchases. Its major
270 strength is that the HPI only needs expenditure shares of specific food groups and subgroups
271 to be calculated. The methodology used to develop the HPI followed a step-by-step process
272 guiding the identification of food groups and subgroups for which expenditure shares best
273 predict the nutritional quality of purchases, the choice of the cut-off values for the identified
274 predictors, and the development of the scoring system.

275 Compared to declarative dietary surveys, food expenditure surveys present the advantage of
276 limiting memory bias and social desirability bias. In particular, when both expenses and
277 quantities are recorded through annotated receipt collection, very detailed data on household
278 food purchases can be obtained⁽¹¹⁾. Quantities purchased are more difficult to obtain, but when
279 recorded in addition to expenditure data, they yield reliable information on the cost of food⁽³⁾.
280 Moreover, when linked to a food composition table, till receipts were found to provide good
281 estimates of the household intakes of energy and percentage energy from fat^(12,16). More
282 recently, Appelhans *et al.* found that household food purchases yielded a reasonable estimate
283 of overall diet quality for primary household food shoppers⁽¹⁷⁾. However, using this
284 information (expenditure on food quantities purchased, energy and nutrient contents) to assess
285 household food purchases patterns and nutritional quality is a tedious and costly task (data
286 entry, coding, linkage with nutrition information, analysis, etc.), and can burden both research
287 staff and participants. Such methodological difficulties in evaluating the quality of household
288 food purchases can be solved by an approach based solely on food expenditure. To the best of
289 our knowledge, only two studies have used food budget shares to assess the nutritional quality
290 of food purchases. In 2012, considering that most food choices are made at the supermarket
291 or grocery store, the United States Department of Agriculture proposed several tools to assess
292 the overall healthfulness of food purchases, including scores based on food category
293 expenditure shares⁽⁴⁰⁾. These scores compared observed expenditure shares to reference
294 expenditure shares, the latter being derived from mathematically-optimized food baskets
295 meeting the recommended dietary allowance for all nutrients⁽⁴¹⁾. However, the cultural
296 acceptability of such theoretical baskets has been questioned⁽⁴²⁾. In 2015, the *Healthy Trolley*
297 *Index*—in which daily servings of food groups (in % of total recommended daily serving)
298 were simply translated into proportion of monthly expenditure per food groups—was
299 developed by an Australian research team to compare food expenditure with the Australian

300 Guide to Healthy Eating⁽⁴³⁾. The HPI, by design, has the advantage of directly accounting for
301 food group and subgroup expenditure shares without needing information on the weight and
302 nutritional composition of the foods. The HPI thus overcomes the fact that proportion by
303 weight does not necessarily align with proportion by price, as some food groups are more
304 expensive than others⁽⁴⁴⁾. This food price hierarchy was ignored in the Australian *Healthy*
305 *Trolley Index*⁽⁴³⁾, which did not take into account that fruit, vegetables and meat provide more
306 costly calories than starches and fats⁽³⁾.

307 To be consistent with many dietary guidelines that emphasize the importance of increasing
308 both diversity and quality to achieve a healthy balanced diet⁽⁴⁵⁻⁴⁷⁾, the HPI included two
309 subscores: the *purchase diversity subscore* and the *purchase quality subscore*. Various indices
310 differing in the number of food categories used have been developed to assess dietary
311 diversity^(28,48). For the *purchase diversity subscore* we settled on fruit, vegetables, starches,
312 meat, fish & eggs, and dairy products, as an omission of one or more of these 5 categories was
313 found to be associated with increased risk of mortality^(49,50). The *purchase diversity subscore* is
314 therefore a 5-component score designed to reflect the presence of 5 food groups (and
315 subgroups) in total household food expenditure. Rather than encouraging diversity, the
316 subscore can be viewed as a way to penalize unbalanced food baskets in which at least one of
317 the 5 food groups (and subgroups) is lacking. The *purchase quality subscore* is aimed at
318 capturing the nutritional quality of household food purchases through expenditure shares of
319 specific groups (and subgroups) and French dietary guidelines. The *purchase quality subscore*
320 is a 7-component score: 2 components with expenditure shares to be increased and 5
321 components with expenditure shares to be limited to pursue health objectives. Furthermore,
322 the *purchase quality subscore* indirectly encourages intra-group diversity through its design
323 including various food groups and subgroups. The HPI, which sums the two subscores,
324 showed good agreement with MAR and MER, two indicators of diet quality based on
325 nutrients only. This association may have resulted in part from the fact that MAR and MER
326 were closely related to the HPI, as they were used to construct the *purchase quality subscore*.
327 However, similar correlations were obtained with an unrelated indicator of diet quality based
328 on foods and food groups (the PNNS-GSmod), thereby providing preliminary evidence of the
329 capacity of the HPI index to assess food purchase quality. In addition, associations between
330 the HPI and either MAR, MER or PNNS-GSmod were relatively strong, of the same order of
331 magnitude as or greater than values previously found between MAR and other diet quality
332 indicators^(51,52). No stronger association was found between HPI and the other index scores

333 when adding penalties for expenditure shares for red & processed meat $\geq 20\%$ of food budget,
334 and for household food purchases below 3.5 €/day per person. However, given the specific
335 economic constraints and cultural habits of the studied population⁵, which may impact food
336 purchase patterns, it might be worth considering the use of penalties on a larger population
337 with more diverse purchasing behaviors.

338 Our study has limitations. First, the degree to which HPI reflects actual household
339 consumption patterns is limited by a number of factors: it is based on data at the household
340 level without knowledge of food allocation between different household members or visitors,
341 information on meals eaten away from home was not collected, and what is purchased is not
342 necessarily eaten (waste, leftovers, etc.)⁽¹⁷⁾. For all these reasons, it is clear that the HPI cannot
343 claim to be a tool to assess the quality of diets. Second, the HPI was developed based on data
344 from a convenient sample of a limited number of households. Using relatively small
345 convenient samples is a common limitation of studies estimating the nutritional quality of
346 household food purchases^(5,11,12,14–18). This limitation is explained by the technical complexity
347 of exploiting annotated supermarket receipts and records, fully justifying the development of
348 a simplified tool like the HPI. Third, keeping records of foods entering the household over a
349 1-month period places demands on participants that may increase the risks of errors and
350 omissions. Nevertheless, a shorter time-window for recordkeeping does not seem relevant
351 when salaries and social benefits are paid monthly (as is the case in France). This might be
352 particularly true in disadvantaged populations, where dietary quality was shown to decline
353 over the 30 days following the receipt of a household's major source of income⁽⁵³⁾. Fifth, the
354 HPI was developed based on expenditure shares in deprived households with specific food
355 purchase patterns. Individuals involved in the 'Opticourses' and 'Jassur' studies^(5,20), which
356 provided the data, are people living in very poor neighborhoods, many of them born abroad,
357 in North Africa in particular. It would be useful to assess the external validity of the HPI
358 based on food purchasing data from a more heterogeneous population. Testing the method in
359 other socioeconomic and geographical contexts will help refine the index. In particular, it is
360 important to examine HPI ability to capture the influence of sociodemographic and economic
361 determinants on the nutritional quality of food choices. Spending on food is a key indicator of
362 household welfare. Engel's law⁽⁵⁴⁾ states that as income drops, the proportion of income spent
363 on food increases, but the absolute amount of money available to buy food decreases.
364 Assessing the validity of the HPI at different income levels is therefore a research priority.

365 Another line of enquiry would be to examine how the index is affected by the variability of
366 food prices.

367 **Conclusion**

368 The Healthy Purchase Index is a score evaluating the nutritional quality of household food
369 purchases based exclusively on food expenses incurred. The HPI offers a simple and effective
370 tool to assess the nutritional quality of household food purchases that may help improve the
371 healthfulness of food purchases.

372

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377 institutional review board approval was necessary for this research. Written informed consent
378 was obtained from all participants at enrolment and the trials were registered at
379 clinicaltrials.gov as NCT02383875 and NCT03175575, respectively.

Abbreviations: Healthy Purchase Index (HPI); month (mo); Mean Adequacy Ratio (MAR); Mean Excess Ratio (MER); modified PNNS—Guideline Score (PNNS-GSmod);

380

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Table 1. Food group and subgroup categorizations of food items purchased by $n = 112$ socially-disadvantaged households of Marseille (France)

Food group	Food subgroup	Examples of food items included
Fruit & vegetables	Fruits	Fresh fruit, canned fruit, stewed fruit
	Dried fruits	Unsalted dried fruit, nuts, seeds
	Vegetables	Fresh vegetables, vegetable soup, canned vegetables
Starches	Refined grains	Bread rolls, fresh bread, pasta, rice, flour
	Unrefined starches	Potatoes, legumes, wholegrain products
Dairy products	Cheese	Hard cheese, soft cheese, cream cheese
	Milk & yogurt	Refrigerated and long-life milk, plain yogurt, sweetened yogurt, fruit yogurt, yoghurt drink
Meat, fish & eggs	Eggs & poultry	Hard-boiled egg, fried egg, omelet, chicken, duck, turkey
	Red & processed meat	Beef, pork, lamb, sausages, bacon, offal
	Fish	Fresh fish, canned fish, shellfish, surimi
Mixed dishes	Ready meals	Frozen ready meals, canned meals, salads
	Savory snacks	Crackers, chips, salted and roasted nuts, olives
	Other snacks	Sandwiches, burgers, quiche, pizza
Sweet products	Sweet snacks	Cakes, biscuits, pastries, candies, chocolate
	Breakfast cereals	Breakfast cereals
	Dairy desserts	Cream dessert, ice cream
Added fats & seasonings	Animal fats	Cream, butter
	Vegetable fats	Vegetable oil, margarine, salad dressing
	Sauces	Ketchup, sauces including soy/tomato/barbecue, etc.
Sweet beverages	Sugary drinks	Soda, nectars
	Fruit juices	Fresh fruit juice, concentrated fruit juice
	Diet soft drinks	Diet soft drinks
Condiments	Spices	Salt, pepper, herbs, spices, mustard, pickles

Tables

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Table 2. Bivariate and multivariate associations between indicators of nutritional quality (MAR: mean adequacy ratio, and MER: mean excess ratio) of 2000 kcal of food purchases (as dependent variables) and food-group and subgroup expenditure shares (in %) (as independent variables) for $n = 112$ socially-disadvantaged households of Marseille (France).

	Bivariate associations	Final multivariable models ^a		
	MAR	MER	MAR	MER
Food groups				
Fruit & vegetables ^b	0.088***	-0.006	0.098***	
Starches ^b	-0.051**	-0.224***	-0.043**	-0.186***
Dairy products ^b	0.018	0.180***		0.104**
Meat, fish & eggs ^b	0.039*	-0.042	0.048**	
Mixed dishes ^b	-0.017	0.096**		
Sweet products ^b	-0.025	0.188***		0,107***
Added fats & seasonings ^b	-0.033*	0.056	-0,042**	
Sweet beverages ^b	-0.023*	0.142***		0,114***
Food subgroups				
Refined grains ^b	-0.051**	-0.196***	-0.048***	-0.139***
Unrefined starches ^b	0.030*	-0.005		
Fruit ^b	0.060***	-0.052	0.039**	
Dried fruits ^c	0.046*	0.134**	0.045**	
Vegetables ^b	0.068***	0.013	0.043**	
Cheese ^b	0.015	0.157***		0.109***
Milk & yogurt ^b	0.020	0.085**		
Eggs & poultry ^b	-0.011	0.026		
Red & processed meat ^b	0.021	0.015		
Fish ^b	0.030**	-0.020		
Ready meals ^c	0.020	0.110**		
Savory snacks ^c	-0.031	0.193***		
Other snacks ^c	0.010	0.160**		
Sweet snacks ^b	-0.032*	0.197***		0.109***
Breakfast cereals ^c	0.016	0.021		
Dairy desserts ^c	-0.004	0.191***		
Animal fats ^c	0.049*	0.198***		

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Vegetable fats ^b	-0.055**	-0.003	-0.065***	
Sauces ^c	0.008	0.095*		
Sugary drinks ^b	-0.033**	0.154***		0.115***
Fruit juices ^c	-0.016	0.146**		
Diet soft drinks ^c	0.049	0.141		

^aThe final multivariate models included all independent variables with $p < 0.20$ in the bivariate analyses, followed by change-in-estimate analyses to select the best subset of predictors.

^bVariables were log-transformed. Bivariate associations were assessed by simple linear regressions.

^cVariables were coded as binary variables (purchasers/non-purchasers). Bivariate associations were assessed by analysis of variance models with non-purchasers as reference.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$.

Table 3. Construction of the Healthy Purchase Index (total out of 15)

Components	Scoring criteria^a	Score
<i>Purchase diversity subscore</i>		
Fruit	[0–5[	0
	≥ 5	1
Vegetables	[0–5[	0
	≥ 5	1
Starches	[0–5[	0
	≥ 5	1
Meat, fish & eggs	[0–5[	0
	≥ 5	1
Dairy products	[0–5[	0
	≥ 5	1
<i>Purchase quality subscore</i>		
Fruit & vegetables	[0–15[	0
	[15–25[	1
	≥ 25	2
Added fats and seasoning	≥ 3	0
	[0–3[, and Vegetable fats = 0	0
	[0–3[, and Vegetable fats > 0	1
Sweet snacks	[0–5[	2
	[5–10[	1
	≥ 10	0
Cheese	[0–5[	1
	≥ 5	0
Sugary beverages	[0–3[	1
	≥ 3	0
Refined grains	≥ 1/2 Starches ^b	0
	< 1/2 Starches	1
Fish	[0–5[	0
	[5–10[	1
	≥ 10	2

^aExpressed as percentage of household monthly food expenditure, unless indicated otherwise.

^bExpenditure share of the refined grains subgroup within the starches group.

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Tharrey, M., Dubois, C., Maillot, C., Vieux, F., Méjean, C., Perignon, M., Darmon, N. (2018).
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quality of household food purchases. *Public Health Nutrition, First View.* , DOI : 10.1017/S1368980018003154

Table 4. Spearman correlations between HPI and its subscores and the mean adequacy ratio (MAR), mean excess ratio (MER), and modified PNNS–Guideline Score (PNNS-GS_{mod})

	Mean score	Spearman correlations		
		MAR	MER	PNNS-GS _{mod}
HPI	7.4±2.1	0.522***	-0.426***	0.378***
<i>Purchase diversity subscore</i>	4.1±0.9	0.386***	-0.001	0.135
<i>Purchase quality subscore</i>	3.3±1.8	0.419***	-0.499***	0.403***

p* < 0.1; *p* < 0.05; ****p* < 0.001.

Table 5. Spearman correlations between HPI and its subscores and the adequacy and excess ratios of each nutrient included in the MAR and MER, respectively

	Purchase diversity subscore	Purchase quality subscore	HPI
<i>Nutrient adequacy ratios^a</i>			
Proteins	0.0243	0.301**	0.274**
DHA	0.161*	0.263**	0.255**
Vitamin A	0.429***	0.194**	0.360***
Fiber	0.378***	0.452***	0.543***
Linolenic acid	-0.011	0.026	0.036
Linoleic acid	0.0014	-0.328***	-0.277**
Thiamin	0.192**	0.360***	0.388***
Riboflavin	0.283**	0.075	0.149
Niacin	-0.010	0.231**	0.172*
Vitamin B-6	0.123	0.398***	0.355***
Folates	0.374***	0.411***	0.519***
Vitamin B-12	-0.068	0.135	0.054
Vitamin C	0.224	0.135	0.197*
Vitamin E	0.014	-0.193**	-0.127
Vitamin D	0.110	0.231**	0.231**
Calcium	0.268**	0.027	0.127
Potassium	0.278**	0.438***	0.469***
Magnesium	0.307**	0.498***	0.557***
Iodine	0.279**	0.373***	0.431***
Selenium	0.175*	0.484***	0.483***
Copper	0.318***	0.414***	0.480***
Zinc	0.009	0.241**	0.201**
Iron	0.152	0.263**	0.271**
<i>Nutrient excess ratios^b</i>			
Sodium	-0.047	-0.083	-0.089
Saturated fatty acids	0.077	-0.308***	-0.217**
Free sugars	-0.037	-0.526***	-0.478***

^a Percentage of the daily recommended intakes for 2000 kcal of purchases

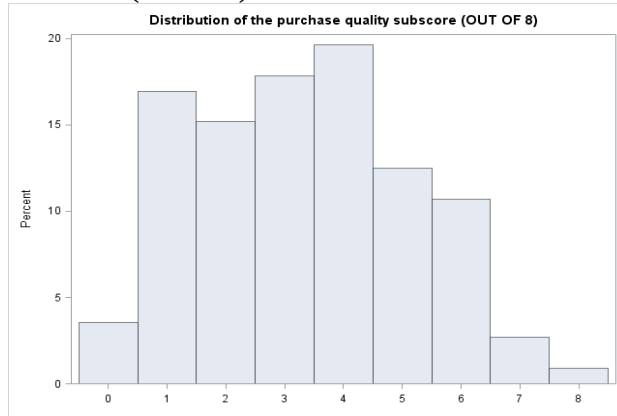
^b Percentage of daily maximum recommended values for 2000 kcal of purchases

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$.

Figures

Figure 1. Distribution of the *purchase diversity subscore* (out of 5), *purchase quality subscore* (out of 10) and final *Healthy Purchase Index score* (out of 15)

A) Distribution of the *purchase diversity subscore* (out of 5)



B) Distribution of the *purchase quality subscore* (out of 10)

C) Distribution of the HPI (out of 15)

