



HAL
open science

Chronic and immediate refined carbohydrate consumption and facial attractiveness

Amandine Visine, Valérie Durand, Léonard Guillou, Michel Raymond, Claire Berticat

► **To cite this version:**

Amandine Visine, Valérie Durand, Léonard Guillou, Michel Raymond, Claire Berticat. Chronic and immediate refined carbohydrate consumption and facial attractiveness. PLoS ONE, In press. hal-04483680v1

HAL Id: hal-04483680

<https://hal.science/hal-04483680v1>

Submitted on 29 Feb 2024 (v1), last revised 11 Mar 2024 (v2)

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **Chronic and immediate refined carbohydrate**
2 **consumption and facial attractiveness**

3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

Short title: Refined carbohydrate consumption and facial attractiveness

Amandine Visine¹, Valérie Durand¹, Léonard Guillou^{1,2}, Michel Raymond^{1#}
Claire Berticat^{1*#}

- 1. ISEM, Univ Montpellier, CNRS, EPHE, IRD, Montpellier, France
- 2. Present address: Institut Jean Nicod, Département d'études cognitives, Ecole normale supérieure, Université PSL, EHESS, CNRS, 75005 Paris, France

*. Author for correspondence: claire.berticat@umontpellier.fr
#. Equal contributions

27 **Abstract**

28 The Western diet has undergone a massive switch since the second half of the 20th century, with the
29 massive increase of the consumption of refined carbohydrate associated with many adverse health effects.
30 The physiological mechanisms linked to this consumption, such as hyperglycaemia and hyperinsulinemia,
31 may impact non medical traits such as facial attractiveness. To explore this issue, the relationship between
32 facial attractiveness and immediate and chronic refined carbohydrate consumption estimated by glycemic
33 load was studied for 104 French subjects. Facial attractiveness was assessed by opposite sex raters using
34 pictures taken two hours after a controlled breakfast. Chronic consumption was assessed considering three
35 high glycemic risk meals: breakfast, afternoon snacking and between-meal snacking. Immediate
36 consumption of a high glycemic breakfast decreased facial attractiveness for men and women while
37 controlling for several control variables, including energy intake. Chronic refined carbohydrate consumption
38 had different effects on attractiveness depending on the meal and/or the sex. Chronic refined carbohydrate
39 consumption, estimated by the glycemic load, during the three studied meals reduced attractiveness, while a
40 high energy intake increased it. Nevertheless, the effect was reversed for men concerning the afternoon
41 snack, for which a high energy intake reduced attractiveness and a high glycemic load increased it. These
42 effects were maintained when potential confounders for facial attractiveness were controlled such as age, age
43 departure from actual age, masculinity/femininity (perceived and measured), BMI, physical activity, parental
44 home ownership, smoking, couple status, hormonal contraceptive use (for women), and facial hairiness (for
45 men). Results were possibly mediated by an increase in age appearance for women and a decrease in
46 perceived masculinity for men. The physiological differences between the three meals studied and the
47 interpretation of the results from an adaptive/maladaptive point of view in relation to our new dietary
48 environment are discussed.

49

50

51

52

53

54

55 **Introduction**

56

57 In Western populations, the diet has dramatically changed since the second half of the 20th century. It
58 has been supplemented with highly processed refined food, in particular refined carbohydrates (primary
59 sucrose, fiber depleted gelatinous starches and high sugar corn syrup (1). The mismatch between how human
60 physiology has evolved and Western industrialized lifestyles is seen as a contributing factor to the current
61 epidemic of numerous medical problems. For example, it has been shown that this massive dietary change
62 was involved in obesity, insulin resistance, type II diabetes, cardiovascular diseases, Alzheimer's disease,
63 hypertension or myopia (2–5). Persistent hyperglycemia/hyperinsulinemia, and insulin resistance due to the
64 overconsumption of refined carbohydrates are among the well recognized physiological mechanisms
65 involved in these diseases (1,6,7)

66 The consequences of a diet high in refined carbohydrates on non-medical traits have been little
67 studied to date, and it is conceivable that they materialise in secondary sexual traits such as male or female
68 facial characteristics (8). Indeed, among other things, hyperinsulinemia modulates growth factors and sex
69 hormones, interfering with morphology and secondary sex characteristics (9) This occurs because
70 hyperinsulinemia stimulates androgen synthesis by the ovaries or testes, increasing the quantity of free (and
71 thus active) androgens in the blood which are the precursors of male and female sex hormones such as
72 testosterone and estrogen (10-12). As a consequence, for example, hyperinsulinemia has been linked to
73 diseases associated with significant perturbation of sex hormone levels, such as polycystic ovary syndrome
74 and premature menarche (13,14). Thus, considering that femininity and masculinity influence attractiveness
75 (15), refined carbohydrate consumption via hyperinsulinemia could interact with attractiveness.
76 Attractiveness is an important trait that affects a variety of key social outcomes such as mate choice and
77 social exchange decisions. In the field of evolutionary biology, attractiveness (or preference) refers to an
78 individual's tendency to be drawn to specific traits or characteristics in potential mating or social exchange
79 partners. For example, people who are physically attractive (as opposed to unattractive) are more likely to be
80 rated higher as romantic partners (16), students by teachers (17), and even as political candidates (18).

81 It has been recently proposed that refined carbohydrate consumption, particularly during between-
82 meal snacks, might be correlated with an increase in facial attractiveness of both male and female individuals
83 (8). However, in this pilot study, subjects were sampled at various times of the day, thus at various times
84 since their last meal, and the content of this last meal was not considered. However, immediate consumption
85 of some food or drinks has detectable effects on physiology and behavior. For example, immediate alcohol
86 consumption may influence facial attractiveness (19), and breakfast or snacks may have an immediate effect
87 on behavioral components and cognition according to their glycemic load or energy intake (20,21).
88 Additionally, several confounding variables were not controlled for, such as physical activity (which might
89 indirectly influence attractiveness and diet). Also, energy intake was not considered in the statistical model.
90 Thus, it is unclear from this preliminary study how refined carbohydrate consumption might influence
91 attractiveness.

92 Different daily meals have different nutrient content and therefore do not produce the same glycemic
93 response. In fact, carbohydrates are rarely eaten alone, and their digestion (degradation and absorption) can
94 be affected by other macronutrients. Meals high in refined carbohydrates and low in fat, protein, and fiber
95 result in a higher glycemic response (22,23). The sequence of dietary intake of macronutrients also alters
96 glycemic and insulin responses (23). Thus, meals described as high in refined carbohydrates and low in food
97 content, such as breakfast, afternoon snacks, and between-meal snacks, may increase glycemic risk
98 (20,24,25).

99 Here, we investigated whether refined carbohydrate intake affects facial attractiveness in healthy
100 young women and men, accounting for several confounding variables and experimentally controlling for
101 immediate carbohydrate intake. The present study is a replicate of this previous work (8) designed to
102 overcome its weaknesses. Estimates of refined carbohydrate intake were based on the total glycemic load
103 (representing blood glucose and insulin responses) of three meals with higher glycemic risk (breakfast,
104 afternoon snack, and between-meal snack). The quantities consumed for each diet item were recorded,
105 providing more relevant glycemic load estimation and both glycemic loads and energy intakes were
106 independently considered, with the consequence that refined carbohydrate consumption better represented
107 the effects of insulinemia. Subjects were given a high or low glycemic isocaloric breakfast, completed a
108 dietary questionnaire, and were photographed at the same time after breakfast. This allowed us to examine

109 how immediate and chronic consumption of refined carbohydrates affects facial attractiveness in healthy
110 adults.

111

112

113 **Materials and Methods**

114

115 ***Subjects***

116 During 2018, subjects were invited to participate in a scientific study on diet via online calls, spread
117 among to various university networks (Paul Valéry University, University of Montpellier, Engineering
118 School Montpellier SupAgro) and social networks. The conditions for participation were being non diabetic
119 and non hemophiliac, lacking food allergies, and without facial tattoo. Subjects were given an early-morning
120 appointment and were asked to come to our laboratory for the experiments in groups of three or four on an
121 empty stomach. They were given, at random, an isocaloric breakfast (approximately 500 Kcal) of type B1
122 (all carbohydrates were non refined) or B2 (all carbohydrates were refined) as described in (26).

123 The following data were self-reported for each subject: sex, age (birth year and month), sexual
124 orientation (heterosexual or other), geographical origin of the grandparents (continents: Europe/Africa/
125 America/Asia/Oceania), couple status (yes or no, coded as 1 or 0, respectively), smoking (yes or no, coded as
126 1 or 0, respectively), parental home ownership as a proxy of socioeconomic status (owner or non-owner,
127 coded as 1 or 0, respectively), physical activity (from 1: low activity, to 5: high activity), and, for women,
128 use of hormonal contraceptive (yes or no, coded as 1 or 0, respectively). A quantitative diet questionnaire
129 using the SU.VI.MAX cohort portion book concerning breakfast, afternoon snack ["goûter" in French,
130 corresponding to an after-school snack] and between-meals snack of the day before was used to estimate
131 participants' chronic refined carbohydrate consumption as previously described (26–28), Table S1).

132 Then, the following body measurements were performed: height (using a measuring board) and
133 weight (using a portable weighing scale). Subject glycemia was also measured 3 times (on an empty
134 stomach, 30 minutes after breakfast and one hour and a half after breakfast), allowing the confirmation that

135 consumption of refined carbohydrates during breakfast had a significant immediate effect on glucose
136 metabolism (26).

137 Approximately two hours after they finished their breakfast, the subjects were photographed.
138 Individual facial photographs were obtained from a frontal perspective at a distance of approximately 1 m
139 using the same digital camera (Canon EOS 20D) with a 50-mm focal length in standardized settings (same
140 room, light and white uniform background). The subjects were asked to express a neutral face (without a
141 smile), to tie their hair and to remove any glasses, earrings, piercing and make-up. All photographs were
142 processed using Adobe Photoshop CS5.1 to normalize size (photographs were aligned on the eye position,
143 with a fixed distance between the eyes and the chin). An index of facial hairiness was estimated from male
144 photographs, from 0 (no beard, no moustache) to 6 (abundant beard and moustache).

145 A total of 52 male and 52 female subjects with completely filled out questionnaires were finally
146 selected according to the following characteristics: aged from 20 to 30, heterosexual, and with their 4 grand
147 parents of European origin to reduce cultural heterogeneity. Descriptive statistics of physical characteristics
148 of subjects are given in Table 1. The different food groups chronically consumed during these 3 meals are
149 reported in Table 2. The proportion of individuals taking a breakfast was 87% for both sexes, those taking an
150 afternoon snack were 38% and 52%, for males and females, respectively, and those taking a between-meal
151 snack were 25% and 29%, respectively (Table 2).

152

153

154 **Table 1. Descriptive statistics of the subjects' physical characteristics.**

| | Women (N = 52) | | | Men (N= 52) | | |
|--------------------------|----------------|------|-----|-------------|------|-----|
| | Range | Mean | SD | Range | Mean | SD |
| Age (years) | 20-28 | 22.5 | 2.0 | 20-30 | 23.0 | 2.1 |
| Perceived age (years) | 19-31 | 24.7 | 2.0 | 21-31 | 25.5 | 2.4 |
| BMI (kg/m ²) | 16-30 | 22.1 | 3.1 | 16-37 | 23.0 | 3.8 |
| Physical activity | 1-5 | 2.9 | 1.1 | 1-5 | 3.3 | 1.2 |

| | | | | | | |
|-------------------------|----------------|-------|------|---------------|------|------|
| Facial hairiness | - | - | - | 0-6 | 2.3 | 1.6 |
| Fem/Masc Index | -5.68 to -0.94 | -3.17 | 1.02 | -1.93 to 1.99 | 0.00 | 0.98 |
| | Range | N | % | Range | N | % |
| Smoker | 0-1 | 2 | 0.04 | 0-1 | 5 | 9.6 |
| Parental home ownership | 0-1 | 45 | 86.5 | 0-1 | 47 | 90.4 |
| Couple status | 0-1 | 27 | 51.9 | 0-1 | 30 | 57.7 |
| Contraceptive | 0-1 | 34 | 65.4 | - | - | - |

155

156

157 **Table 2. Number of individuals consuming the different food groups for each meal.** N indicates the
 158 number of consumers.

| Food group | Women (N = 52) | | | Men (N = 52) | | |
|----------------------------------|----------------------------|----------------------------------|--|----------------------------|----------------------------------|--|
| | Breakfast (N = 45, 87%) | Afternoon snack (N = 27, 52%) | Between-meal snack (N = 15, 29%) | Breakfast (N = 45, 87%) | Afternoon snack (N = 20, 38%) | Between-meal snack (N = 13, 25%) |
| Cereals and bread | 34 | 9 | 2 | 35 | 6 | 3 |
| Biscuits, cakes, and pastries | 9 | 11 | 5 | 9 | 11 | 3 |
| Sweets and chocolate | 18 | 13 | 5 | 27 | 7 | 8 |
| Sweetened beverages | 15 | 5 | 0 | 14 | 3 | 3 |
| Dairy products | 31 | 5 | 3 | 22 | 8 | 3 |
| Fruits | 16 | 12 | 4 | 13 | 6 | 5 |
| Nuts | 5 | 5 | 2 | 2 | 0 | 0 |

159

160

161 **Daily Diet Variables**

As previously described in (26), for each subject and each item of dietary questionnaire, Glycemic load (GL) was calculated by multiplying the glycemic index (GI) according to the International tables of glycemic Index (29) by the amount of available carbohydrates (g) per declared serving estimated from the SU.VI. MAX cohort catalogue divided by 100 (30). Compared with low-GL diets, high-GL diets cause greater glycemic and insulin responses (29). For each subject, the glycemic load for each item was then summed, leading to a total glycemic load (Table 3) estimation for breakfast (GL1), afternoon snack (GL2) and between-meal intake (GL3). In the same way, Energy intake (EI) for each item was obtained from the Anses-Ciqual database (www.anses.ciqua.fr) and calculated for each subject depending on its corresponding declared serving size (Table 3). For each subject, they were summed, leading to a total energy intake estimation for breakfast (EI1), afternoon snack (EI2) and between-meal intake (EI3) and corresponding macronutrient compositions. Mean glycemic load (GL) and energy intake (EI) for each meal were computed considering only consumers (Table 3). According to the general classification (e.g., (31)), the means of GL obtained for breakfast were high (>20).

To measure GL independent of EI, the method described in (32) was applied: linear models were used to produce regressions of EI as a function of GL for each meal using the `lm` function from the `stats` package for R software. These regression residuals were then used as new variables. Thus, each subject's refined residual carbohydrate consumption is now described for breakfast (RGL1), afternoon snack (RGL2) and between-meal intake (RGL3). These variables correspond to the part of the glycemic load that is not explained by energy intake.

Table 3. Descriptive statistics of food consumption for the three meals. Mean and standard deviation (SD) are given for consumers only. GL1, GL2 and GL3 are the three variables representing chronic refined carbohydrate consumption.

| | Women (N = 52) | | | Men (N= 52) | | |
|-----------|----------------|------|------|-------------|------|------|
| | Range | Mean | SD | Range | Mean | SD |
| Breakfast | | | | | | |
| GL1 | 0-92 | 26.6 | 23.0 | 0-142 | 38.5 | 33.3 |

| | | | | | | |
|-------------------|--------|------------|-------|--------|------------|-------|
| EI1 | 0-1039 | 334.1 | 265.0 | 0-1451 | 421.1 | 345.3 |
| Carbohydrates (g) | 0-144 | 37.5 (72%) | 33.7 | 0-224 | 53.2 (70%) | 44.9 |
| Fat (g) | 0-39 | 8.6 (16%) | 9.5 | 0-55 | 14.8 (20%) | 12.6 |
| Protein (g) | 0-27 | 6.0 (12%) | 5.8 | 0-36 | 7.8 (10%) | 8.0 |
| Fiber (g) | 0-17 | 3.3 | 3.5 | 0-22 | 4.2 | 4.3 |

Afternoon Snack

| | | | | | | |
|-------------------|--------|------------|-------|--------|------------|-------|
| GL2 | 0 - 62 | 11.8 | 16.5 | 0-118 | 12.6 | 23.4 |
| EI2 | 0-985 | 166.2 | 241.0 | 0-1065 | 148.2 | 264.5 |
| Carbohydrates (g) | 0-103 | 17.8 (64%) | 26.0 | 0-95 | 13.7 (74%) | 25.5 |
| Fat (g) | 0-72 | 7.1 (25%) | 13.3 | 0-42 | 2.9 (16%) | 7.0 |
| Protein (g) | 0-23 | 3.0 (11%) | 4.9 | 0-30 | 1.9 (10%) | 5.0 |
| Fiber (g) | 0-16 | 3.3 | 3.3 | 0-10 | 1.0 | 2.2 |

Between-Meal Snack

| | | | | | | |
|-------------------|-------|-----------|-------|--------|-----------|-------|
| GL3 | 0-42 | 3.7 | 8.9 | 0-110 | 6.9 | 18.4 |
| EI3 | 0-622 | 61.0 | 143.7 | 0-1010 | 78.5 | 192.0 |
| Carbohydrates (g) | 0-66 | 4.6 (59%) | 11.1 | 0-111 | 8.0 (73%) | 20.2 |
| Fat (g) | 0-39 | 2.2 (28%) | 6.4 | 0-23 | 1.8 (17%) | 5.2 |
| Protein (g) | 0-19 | 1.0 (13%) | 3.2 | 0-22 | 1.1 (10%) | 4.5 |
| Fiber (g) | 0-8 | 0.5 | 1.6 | 0-7 | 0.8 | 1.7 |

185

186

187 *Femininity/Masculinity Index*

188 To generate a morphological facial femininity/masculinity index (Fem/Masc Index), a geometric
189 morphometric analysis of the faces was performed following the methods described in (33–35). First, the
190 coordinates of 142 landmarks (anatomical points present in all individuals, e.g., lips corners) and semi
191 landmarks (sliding points positioned along selected anatomical curves, such as the eyebrow bow) were
192 delineated for each male and female face. Landmark and semi landmark delineation were performed using
193 Psychomorph (36). The R package Geomorph (version 4.0.0) was used to perform Procrustes
194 superimposition of the landmark and semi landmark data, which removes non shape information such as
195 translation, size and rotational effects (37). The coordinates were transformed into shape variables via
196 principal component analysis (PCA). An arbitrary cut-off of minimum 80% variance explained was applied
197 to select the axis, thus the first 16 axes were retained (explaining 83.7% of variance) for further analyses. To
198 compute a data-driven single measure of facial masculinity, a linear discriminant analysis (LDA) was
199 conducted on the PCA coordinates with sex as the grouping variable. The resulting discriminant function
200 correctly classified 90.4% of subjects into two categories (48 women and 46 men out of the 104 individuals;
201 thus, 4 women and 6 men were not rightly sorted). Each individual coordinate on the woman-man axis was
202 used as a Fem/Masc Index, with high values indicating a more masculine facial morphology (33–35).

203

204 ***Apparent Age***

205 The apparent age of each subject was evaluated from their facial photographs using raters. Volunteer
206 raters were recruited in public places in Montpellier, France. For each rater, sex, age (birth year and month),
207 grand-parent geographical origin and study level were recorded.

208 An HTML/PHP computer program was generated to present randomly drawn subject photographs to
209 raters. Each rater estimated the age of 22 distinct subjects. Three photographs randomly chosen among those
210 previously viewed were presented again at the end to estimate judgment reliability. Unreliable raters (with
211 more than fifteen years for the sum of the absolute difference between real ages and attributed ages during
212 the three judgments of reliability) or non-adult raters (less than 18 years old) were removed. If the rater took
213 more than 60 s or less than 0.5 s for the response, the trial was removed. To reduce cultural heterogeneity,
214 only raters with 4 grandparents of European origin were kept in the study. This led to a final sample of 77

215 raters (39 men and 38 women, age range: 18–56, mean age \pm s.d.: 26.5 ± 8 years for men and 25.3 ± 10 years
216 for women), resulting in a total of 820 age estimations towards women and 860 age estimations towards men
217 and a mean of 16.5 (range: 11–22) estimations for each man and 15.8 (range: 12–21) for each woman. The
218 perceived age was on average 2.4 years older than the actual age (mean \pm s.e.m. of 2.4 ± 0.21). It was
219 estimated to be either younger (maximum 2.4 years) or older (maximum 6.2 years) than the actual age (Table
220 1).

221

222 ***Perceived masculinity and femininity***

223 The relative masculinity or femininity of each subject was assessed from the facial photographs
224 using a second rater set. Volunteer raters were recruited in public places in Montpellier, France. For each
225 rater, sex, age (birth year and month), sexual orientation, geographical origin of the grandparents and study
226 level were recorded.

227 An HTML/PHP computer program was generated to present randomly drawn pairs of same-sex
228 photographs (Figure 1). Pairs were presented to opposite sex raters. For each male pair, the female raters
229 were instructed to click on the photograph depicting the face that they found the most masculine. For each
230 female pair, the men raters were instructed to click on the photograph they found the more feminine. The
231 photograph position on the screen (left or right) was randomly ascribed. Each rater assessed 25 distinct pairs
232 of photographs, corresponding to different randomly chosen subjects. Three pairs randomly chosen from
233 among those previously viewed were presented again at the end to estimate judgment reliability. Unreliable
234 raters (with more than one incorrect answer during the test of judgment reliability) or non-adult raters (less
235 than 18 years old) were removed. If the rater took more than 60 s or less than 0.5 s for the response, the trial
236 was removed. To reduce cultural heterogeneity, only heterosexual raters with 4 grand-parents of European
237 origin were kept in the study. A total of 150 raters were retained in the final sample (68 men and 82 women,
238 age range: 18–71, mean age \pm s.d.: 35.5 ± 16 years for men, and 33.1 ± 14 for women), corresponding to
239 1,494 judgments of men towards women and 1,802 judgments of women towards men. Each subject was
240 seen by a mean of 69.3 (range: 51–88) raters for men and a mean of 57.5 (range: 41–76) raters for women.
241 No correlation for perceived masculinity was evidenced with the Fem/Masc Index for men (Pearson

242 correlation coefficient = 0.20, $p = 0.159$). Perceived femininity was also not correlated (Pearson correlation
243 coefficient = - 0.18, $p = 0.196$) with the Fem/Masc Index for women.

244

245 **Figure 1. Example of a pair of faces used during the evaluation of women’s facial attractiveness by**
246 **male raters.** For each pair of women, the rater was instructed to click on the photograph of the woman that
247 he found the most attractive. Faces were anonymized for publication.

248

249 *Attractiveness*

250 The subject relative attractiveness was assessed from their facial photographs using a third rater set.
251 Volunteer raters were recruited in public places in Montpellier, France. For each rater, sex, age (birth year
252 and month), sexual orientation, geographical origin of the grandparents and study level were recorded.

253 The same experimental protocol as for perceived masculinity and femininity was used to assess
254 attractiveness. Raters assessed 26 distinct pairs of photographs, and three pairs randomly chosen from among
255 those previously viewed were presented again at the end to estimate judgment reliability. Raters with more
256 than one incorrect answer during the test of judgment reliability or non-adult raters (less than 18 years old)
257 were removed. If the rater took more than 60 s or less than 0.5 s for the response, the trial was removed. To
258 reduce cultural heterogeneity, only heterosexual raters with 4 grandparents of European origin were kept in
259 the study. A total of 252 raters were retained in the final sample (110 men and 142 women, age range: 18–73,
260 mean age \pm s.d.: 35.3 ± 13 years for men and 35.6 ± 13 years for women), corresponding to 2,860 judgments
261 of men towards women and 3,536 judgments of women towards men. Each subject was seen by a mean of
262 136.0 (range: 107–164) raters for men and a mean of 110.0 raters (range: 83–137) for women.

263

264 *Statistical Analyses*

265 The following statistical analyses were performed using R software version 3.6.3 using the packages
266 *blme* (v1.0-5, (38)), *lme4* (v1.1-26), *stats* (3.6.3) and *lavaan* (v0.6-8, (39)). The variance inflation factor was
267 computed using the *vif.mer* function adapted from the *vif* function of the R package *rms* (v6.2-0, (40,41)).
268 The effects of the rater’s age and study level on their perception of subject’s age, masculinity/femininity and

269 attractiveness were tested before proceeding to the analyses of evaluators' preferences in terms of
270 attractiveness, in order to take them into account in case of significance.

271 Effects of rater characteristics on their perception of subject's age, masculinity/femininity and
272 attractiveness.

273 Age perception. To understand the potential effects of rater characteristics on the age perception of
274 subjects, a first model was used. The response variable was the estimated age, and the variables of interest
275 were the rater characteristics (age, sex, and study level). The model also integrated the subject sex. Each
276 subject was viewed by several raters, and each rater evaluated several subjects. Thus, linear mixed-effect
277 models using the lmer function were used. Random slope effects on the raters and on the subjects were
278 integrated into the models. The regression showed no significant effect ($p > 0.05$) of the rater characteristics
279 on their perception of age (Table S2). This allowed us to compute for each subject the mean perceived age as
280 the average age estimated by all raters. Masculinity/femininity perception. A measure of perceived
281 masculinity was computed for men as the number of times a given individual was chosen divided by the
282 number of occurrences in the experiment. To assess a potential effect of rater age on masculinity perception,
283 this measure was computed using only raters below or above the median age. The two resulting masculinity
284 measures were not significantly different (Wilcoxon signed ranks test, $p = 0.96$, Table S3). The measures
285 were also computed from tercile ages, with no significant differences (Friedman two-way analysis of
286 variance, $p = 0.10$). The same procedure was used to test the influence of rater study level on masculinity
287 perception. Masculinity measures from raters below or above the median study level were not significantly
288 different (Wilcoxon signed ranks test, $p > 0.94$) or among the three terciles (Friedman two-way analysis of
289 variance, $p > 0.58$). A measure of femininity was computed for women in a similar way as for men. A
290 potential effect of rater age or study level on femininity perception was evaluated as above, and no
291 significant effect was found (age: for median, $p > 0.33$, for terciles, $p > 0.32$; study level: for median, $p >$
292 0.29 , for terciles, $p > 0.94$, Table S3). Attractiveness perception. A measure of perceived attractiveness was
293 computed for women and men as the number of times a given individual was chosen divided by the number
294 of occurrences in the experiment. To assess a potential effect of rater age on attractiveness perception, this
295 measure was computed using only raters below or above the median age. For both sexes, the two resulting
296 attractiveness measures were not significantly different (Wilcoxon signed ranks test, $p = 0.71$ and $p = 0.36$

297 for women and men faces, respectively, Table S4). The measures were also computed from tercile ages, with
298 no significant differences (Friedman two-way analysis of variance, $p = 0.63$ and $p = 0.48$ for women and
299 men faces, respectively, Table S4). The same procedure was used to test the influence of rater study level on
300 attractiveness perception. For both sexes, attractiveness measures from raters below or above the median
301 study level were not significantly different (Wilcoxon signed ranks test, $p = 0.67$ and $p = 0.94$ for women and
302 men faces, respectively, Table S4) or among the three terciles (Friedman two-way analysis of variance, $p =$
303 0.86 and $p = 0.87$ for women and men faces, respectively, Table S4).

304 *Statistical analyses for perceived attractiveness.*

305 A logistic regression was used to analyze the rater preferences. The binary response variable
306 corresponded to being chosen or not for the focal subject (arbitrarily, the subject presented at the left
307 position) during each pair presentation. Subjects and raters occurred repeatedly (each subject was viewed by
308 several raters, and each rater evaluated several pairs of subjects) and were thus random-effects variables.
309 Therefore, generalized linear mixed models with a binomial error structure were applied. To force the models
310 to fit away from singularities, the Bayesian bglmer function was used. The maximum random-effects
311 structure (intercept and slope) was tentatively included according to (42). For each choice made by a rater,
312 the difference (left minus right) between the focal RGL1 and the non-focal subject was calculated, and the
313 same procedure was performed for RGL2, RGL3, EI1, EI2 and EI3. These differences were integrated into
314 the model as the variables of interest. The difference between focal and non-focal subjects concerning their
315 type of immediate breakfast was also integrated as a qualitative variable of interest with three modalities (B1
316 versus B2, same breakfast type and B2 versus B1). Because subject pairs were rated by the opposite sex
317 (men rated by women and women rated by men), two models were performed, one for each subject's sex.
318 For both, several control variables potentially affecting facial attractiveness were added: age, age departure
319 from actual age (further referred to as 'age departure'), Fem/Masc index, perceived masculinity/femininity,
320 BMI, physical activity, parental home ownership (43), smoking, couple status, hormonal contraceptive use
321 (for women) and facial hairiness (for men). For each control variable, values associated with the left
322 individual minus values associated with the right individual were computed. All quantitative variables were
323 centered. The significance of each term was assessed from the model including all of the other variables.
324 Because the dietary variables (RGL1, RGL2, RGL3, EI1, EI2, EI3 and breakfast type) could potentially

325 affect certain control variables directly (e.g., age departure, Fem/Masc Index and perceived
326 masculinity/femininity) or be affected by control variables (physical activity), this could indirectly influence
327 the effect of the GL variables on the dependent variable. To evaluate this possibility, structural equation
328 modeling was performed using the variables from the model displaying $p < 0.1$, conservatively. An
329 attractiveness measure was constructed for each individual, computed as the number of times this individual
330 was chosen over the number of occurrences. A hypothesized path model was constructed for each sex,
331 incorporating linear regressions with the diet variables. For women, it aimed to explain attractiveness, age
332 departure from actual age, perceived femininity and contraception with EI1, RGL1, RGL2, RGL3 and the
333 breakfast type. Parental home ownership, physical activity and age were also included as control variables
334 (Figure 2). For men, the model incorporated linear regressions of EI1, EI2, RGL2, RGL3 and the breakfast
335 type to explain attractiveness, Fem/Masc Index and perceived masculinity (Figure 3). Facial hairiness,
336 physical activity, age and couple status were also included as control variables.

337

338 **Figure 2. Hypothesized path model for women's attractiveness with the variables of the generalized**
339 **linear mixed model.**

340

341 **Figure 3. Hypothesized path model for men's attractiveness with the variables of the generalized linear**
342 **mixed model.**

343

344 Assessment of systematic and random errors.

345 We have sought to reduce the influence of systematic and random errors in our study and ensure the
346 robustness of our results. To assess systematic errors, we meticulously designed our study by following
347 established protocols and ensuring that experimental conditions were standardized as much as possible for
348 participants and raters. This included the fact that we implemented carefully recruitment procedures to limit
349 the risk of selection bias by defining clear inclusion and exclusion criteria for our study samples. In addition,
350 all assessments of photographs and facial attractiveness were carried out in a controlled environment, with
351 constant lighting, background and ambient temperature, to reduce variability caused by external factors. We
352 used validated questionnaires. Participants and raters were not informed of the study objectives in order to

353 minimize potential biases related to knowledge of the research objectives. We used appropriate statistical
354 methods to control for potential confounding factors concerning subjects and raters (see Statistical Analyses
355 section). To minimize random errors and improve the reliability of our measurements, we used highly
356 reliable and reproducible measurement techniques for the photographs and for the assessment of facial
357 attractiveness. The evaluation process was conducted randomly and independently by several raters to ensure
358 the robustness of our results. The sample sizes of participants and raters were determined on the basis of an
359 effect size of 0.1 (based on the results of a previous pilot study (8)), a power of 80% and a threshold of 0.05
360 to ensure that the study had sufficient statistical power to detect significant differences in attractiveness
361 ratings, and were chosen to minimize the impact of random variability.

362

363 ***Ethical Statement***

364 The protocol used to recruit participants and collect data was approved by the French Committee of
365 Information and Liberty (CNIL #1783997V0) and the Committee for the protection of persons (CPP IDRCB
366 2018-A00505-50). For each participant, the general purpose of the study was explained (“Effects of diet on
367 major phenotypic traits”), and written voluntary agreement was requested for statistical use of data (private
368 information and photographs). Data were analyzed anonymously and no authors had access to information
369 that could identify individual participants during or after data collection.

370

371

372 **Results**

373

374 Chronic and immediate refined carbohydrate consumption, energy intake and controlling variables
375 had different effects on attractiveness (Figure 4, Table 4). The breakfast consumed by subjects just before the
376 photo session had a significant effect on attractiveness for both sexes. Individuals who had B2 were
377 considered less attractive than those with B1 (men: $\beta = -1.01$, $se = 0.187$, $p < 10^{-6}$; women: $\beta = -1.31$, $se =$
378 0.191 , $p < 10^{-10}$). Some chronic diet variables of interest had the same effect between men and women: the
379 probability that a subject was chosen as the most attractive was significantly influenced by the energy intake

380 variable EI1 (men: $\beta = 0.26$ se = 0.057, $p < 10^{-5}$; women: $\beta = 0.38$, se = 0.097, $p < 10^{-3}$). For breakfast,
381 women preferred men, and men preferred women, with the highest energy intake. The variable RGL3
382 decreased attractiveness; this effect was marginally non-significant for women ($\beta = -0.274$, se = 0.158, $p =$
383 0.083) and significant for men ($\beta = -0.434$, se = 0.089, $p < 10^{-5}$). For RGL1, RGL2 and EI2, preference was
384 influenced by different meals and had different directions for men and women: RGL1 and RGL2
385 significantly decreased women's attractiveness (RGL1: $\beta = -0.202$, se = 0.097, $p = 0.037$; RGL2: $\beta = -0.235$,
386 se = 0.098, $p = 0.017$), whereas for men, RGL2 increased attractiveness ($\beta = 0.410$, se = 0.082, $p < 10^{-6}$) and
387 EI2 decreased attractiveness ($\beta = -0.315$, se = 0.079, $p < 10^{-4}$). Men preferred women with lower breakfast
388 and afternoon snack glycemic load, and women preferred men with a higher afternoon snack glycemic load
389 and a lower energy intake.

390 Some control variables significantly influenced the choice of raters. For male and female subjects,
391 age decreased the probability of being chosen as the most attractive (men: $p < 10^{-4}$; women: $p < 10^{-4}$). The
392 age departure from actual age decreased women's attractiveness ($p < 10^{-4}$): at equal actual age, men preferred
393 women with the youngest perceived age. As expected, physical activity had an increasing effect for both
394 sexes but effect was marginally non-significant for men (men: $p = 0.063$; women: $p < 10^{-3}$): individuals with
395 higher physical activity were found to be more attractive. Perceived masculinity/femininity significantly
396 increased attractiveness (men: $p = 0.042$; women: $p = 0.004$), while the effect of Fem/Masc Index on
397 increasing male attractiveness was marginally non-significant ($p = 0.062$). Women preferred men considered
398 more masculine, and men preferred women considered more feminine. Facial hairiness decreased the
399 probability of being chosen ($p < 10^{-5}$): men with more abundant facial hairiness were considered less
400 attractive by women. Women also preferred men who were involved in a couple ($p = 0.002$). Parental home
401 ownership increased women's attractiveness ($p = 0.007$), and the use of a hormonal contraceptive also
402 increased women's attractiveness ($p < 10^{-5}$).

403 The full models for men and women explained 4.5% and 6.0% of the total deviance, respectively.
404 For both, the variance inflation factors (VIFs) were less than 2.50 (less than 3.20 for the qualitative variable
405 of breakfast type for men). The VIF values for both models indicated that the multicollinearity between
406 covariables was weak and not of concern (41).

407 Structural equation modeling indicated that the effect of RGL2 for women on attractiveness could be
 408 mediated by an effect on age departure from actual age ($p = 0.013$, Table S5): a higher snack glycemic load
 409 increased the appearance of women towards an older age. These analyses also showed that the effect of
 410 physical activity on women's attractiveness could be mediated by an effect on EI1, although marginally non-
 411 significant ($p = 0.08$): women who had higher physical activity were more likely to have breakfast with
 412 higher energy intake. For men, structural equation modeling indicated that the effect associated with RGL3
 413 and EI2 on attractiveness could be mediated by an effect on perceived masculinity (RGL3: $p = 0.015$; EI2: p
 414 $= 0.01$, Table S5). Men having a higher between-meal glycemic load or a higher energy intake during snacks
 415 were perceived as more feminine by women. The effect on EI1 on male attractiveness could also be
 416 mediated by an effect on perceived masculinity but in an opposite direction, although marginally non-
 417 significant ($p = 0.057$). Men with a higher breakfast energy intake were perceived as more masculine by
 418 women. Concerning the effect of physical activity on male attractiveness, analyses suggested that it could be
 419 mediated by RGL3 ($p = 0.0140$). Men practicing more sports had a lower between-meal glycemic load.

420
 421 **Table 4. Effects of different variables on the probability of being chosen during the test of**
 422 **attractiveness for male or female faces.** Raters were instructed to choose the individual found to be the
 423 most attractive between two facial photographs. RGL1, RGL2 and RGL3 are the three variables representing
 424 chronic refined carbohydrate consumption. For each variable, the difference between the two individuals
 425 (left minus right) presented was integrated into the model. For the immediate breakfast type variable, the
 426 estimates are given for one category compared with the reference category corresponding to focal with B1
 427 and non-focal with B2 (underlined term). The estimate (β), standard error of the mean (se), χ^2 statistic, and
 428 corresponding p-value are given. F Bold characters indicate significant ($p < 0.05$) effects.

| | Male faces evaluated by women | | | | Female faces evaluated by men | | | |
|-----------|-------------------------------|-------|----------|--------------|-------------------------------|-------|----------|--------------|
| | β | se | χ^2 | $p(>\chi^2)$ | β | se | χ^2 | $p(>\chi^2)$ |
| Intercept | 0.455 | 0.160 | | | 0.558 | 0.180 | | |
| RGL1 | -0.014 | 0.056 | 0.063 | 0.802 | -0.202 | 0.097 | 4.349 | 0.037 |

| | | | | | | | | |
|-------------------------------------|---------|-------|-------|--------------------|---------|-------|-------|---------------------|
| RGL2 | 0.410 | 0.082 | 25.23 | < 10 ⁻⁶ | - 0.235 | 0.098 | 5.673 | 0.017 |
| RGL3 | - 0.434 | 0.089 | 23.64 | < 10 ⁻⁵ | - 0.275 | 0.158 | 3.008 | 0.083 |
| EI1 | 0.259 | 0.057 | 20.30 | < 10 ⁻⁵ | 0.377 | 0.097 | 15.05 | < 10 ⁻³ |
| EI2 | - 0.315 | 0.079 | 15.88 | < 10 ⁻⁴ | 0.006 | 0.088 | 0.005 | 0.942 |
| EI3 | 0.045 | 0.064 | 0.500 | 0.480 | 0.124 | 0.112 | 1.222 | 0.269 |
| Breakfast type | | | 30.70 | < 10 ⁻⁶ | | | 48.41 | < 10 ⁻¹⁰ |
| (Same breakfast/ <u>B1 vs. B2</u>) | - 0.421 | 0.123 | | | - 0.534 | 0.129 | | |
| (B2 vs. B1/ <u>B1 vs. B2</u>) | - 1.008 | 0.187 | | | - 1.313 | 0.192 | | |
| Age | - 0.281 | 0.072 | 15.24 | < 10 ⁻⁴ | - 0.370 | 0.091 | 16.65 | < 10 ⁻⁴ |
| Age departure from actual age | - 0.116 | 0.094 | 1.895 | 0.169 | - 0.371 | 0.085 | 18.99 | < 10 ⁻⁴ |
| Fem/Masc Index | 0.119 | 0.063 | 3.490 | 0.062 | 0.023 | 0.075 | 0.094 | 0.759 |
| Perceived masculinity/femininity | 0.167 | 0.085 | 4.133 | 0.042 | 0.182 | 0.062 | 8.460 | 0.004 |
| BMI | 0.035 | 0.064 | 0.311 | 0.577 | - 0.044 | 0.083 | 0.284 | 0.594 |
| Physical activity | 0.124 | 0.066 | 3.458 | 0.063 | 0.261 | 0.075 | 12.12 | < 10 ⁻³ |
| Smoker | - 0.079 | 0.146 | 0.295 | 0.587 | - 0.092 | 0.252 | 0.132 | 0.716 |
| Parental home ownership | - 0.148 | 0.149 | 0.983 | 0.321 | 0.461 | 0.170 | 7.315 | 0.007 |
| Contraceptive | - | - | - | - | 0.581 | 0.124 | 21.95 | < 10 ⁻⁵ |
| Couple status | 0.282 | 0.090 | 9.765 | 0.002 | - 0.125 | 0.113 | 1.237 | 0.266 |
| Facial hairiness | - 0.345 | 0.078 | 19.73 | < 10 ⁻⁵ | - | - | - | - |

429

430 **Figure 4. Graphical representation of the adjusted odd ratios with their 95% confidence intervals from**
431 **the model studying the probability of being chosen in the attractiveness test for male or female faces.**

432 Raters were instructed to choose the individual found to be the most attractive between two facial
433 photographs. RGL1, RGL2 and RGL3 are the three variables representing chronic refined carbohydrate

434 consumption. For each variable, the difference between the two individuals (left minus right) presented was
435 integrated into the model. For the immediate breakfast type variable, estimates are given for one category
436 compared with the reference category corresponding to focal with B1 and non-focal with B2 (underlined
437 term). * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

438

439

440 **Discussion**

441

442 In this study, we investigated the relationship between refined carbohydrate intake and facial
443 attractiveness in healthy adults, women and men. We observed that facial attractiveness is not independent of
444 immediate or chronic consumption of refined carbohydrates. Immediate consumption of a high glycemic
445 breakfast decreases facial attractiveness for men and women. Chronic refined carbohydrate consumption
446 displays different effects on attractiveness depending on the meal and/or the sex. Chronic refined
447 carbohydrate consumption, estimated by the glycemic load, during the three studied meals (breakfast,
448 afternoon snack and between-meal intake) reduced attractiveness, while a high energy intake increased it.
449 Nevertheless, the effect was reversed for men concerning the afternoon snack, for which a high energy intake
450 reduced attractiveness and a high glycemic load increased it. These effects were maintained when potential
451 confounders for facial attractiveness were controlled such as age, age departure from actual age,
452 masculinity/femininity (perceived and measured), BMI, physical activity, parental home ownership,
453 smoking, couple status, hormonal contraceptive use (for women), and facial hairiness (for men).

454

455 ***How refined carbohydrate consumption could affect facial attractiveness?***

456 Immediate breakfast consumption influenced attractiveness. Women and men who had eaten a high-
457 glycemic breakfast were considered less attractive than those who had eaten a low-glycemic breakfast. The
458 two types of breakfast were isocaloric, although they differed in the resulting glycemic dynamics (28). Two

459 hours after breakfast consumption, when facial pictures were taken, only the high-glycemic breakfast
460 generated hypoglycemia (44). Hypoglycemia is known to have visible symptoms, as it affects blood flow and
461 skin (45–47), which could be detectable on photos and thus affect attractiveness perception.

462 Chronic refined carbohydrate-rich food consumption leads to chronic hyperinsulinemia as a
463 consequence of hyperglycemia, which interferes with growth factors and sex hormones, which in turn could
464 modulate morphology and secondary sex characteristics (9). Moreover, saturated fat is a known antagonist of
465 insulin and a contributor to insulin resistance (48). Thus, a large energy intake due to saturated fat
466 consumption, even associated with low refined carbohydrate consumption, could lend some support to the
467 hyperinsulinemic theory of (9,12). Chronic hyperinsulinemia influences the synthesis of androgens which are
468 the precursors of male and female sex hormones (49). It has been shown that facial femininity/masculinity
469 can be influenced by sex hormones, which in turn could affect attractiveness: in general men prefer more
470 feminine faces and women prefer more or less masculine faces, depending on the tradeoff between the costs
471 and benefits of mating with a masculine male (for a review see (15)). In this study, for men, the perceived
472 masculinity and the morphological Fem/Masc indices were positively linked with attractiveness. Structural
473 equation modeling suggested that the negative effect of chronic between-meal glycemic load and afternoon
474 snack energy intake on attractiveness could be mediated by an effect on perceived masculinity (chronic
475 glycemic load reducing masculinity, thus indirectly decreasing attractiveness).

476 Repeated hyperglycemia due of chronic consumption of refined foods rich in carbohydrates could
477 also have an impact on facial attractiveness. Indeed, it has been shown that chronic hyperglycemia
478 accelerates glycation processes which, in turn, have an impact on skin aging (50,51). As skin aging directly
479 impacts age appearance (52), hyperglycemia could affect age perception. Moreover, age is known to
480 influence attractiveness (53). For women, this influence is generally negative, as men generally prefer
481 younger women (53). For men, preference studies based only on facial photographs (thus no information on
482 social status) have found a decrease in men's attractiveness with age (54–56). For women, both actual age
483 and age departure from actual age lead to a decrease in attractiveness. Structural equation modeling showed
484 that the effect of afternoon snack glycemic load on attractiveness could be indirectly mediated through a
485 direct effect on age departure from actual age, leading to an older appearance at equal actual age.

487 Why could the three chronic meals affect facial attractiveness differently between sexes?

488 Lipid and glucose metabolism are tuned to distinct sex-specific functions under the action of sex
489 chromosomes and hormones. Considering glucose metabolism, women have higher whole-body insulin
490 sensitivity than men (57,58). Glucose homeostasis, prediabetic syndromes, and type 1 and 2 diabetes show
491 strong sex differences with a partial role of sex hormones (59). The prevalence of type 2 diabetes and insulin
492 resistance is higher in men than in women, and the opposite pattern is found for obesity (58). Obese men are
493 characterized by a progressive decrease in testosterone levels with increasing body weight, whereas obese
494 women, particularly those with the abdominal phenotype (i.e., with insulin resistance), tend to develop a
495 condition of functional hyperandrogenism (60). Thus, the consequences of hyperglycemia and
496 hyperinsulinemia could be different between men and women. For women, because of their higher
497 sensitivity to insulin than men (and thus their lower risk of developing insulin resistance), sex hormones, and
498 consequently facial femininity/masculinity, could be less affected by a large consumption of refined
499 carbohydrates. This could explain why the effects of refined carbohydrate consumption on attractiveness
500 were mediated by perceived masculinity for men, but not by perceived femininity for women.

501

502 Why do the three chronic meals affect facial attractiveness differently?

503 For women, chronic refined carbohydrate consumption during breakfast decreased facial
504 attractiveness, whereas energy intake increased it. The effect of energy intake was estimated in the model at
505 equal glycemic load and thus primarily represented the effects of fat and protein intake. Thus, breakfasts
506 resulting in an increase in attractiveness comprised mainly fats and proteins (such as dairy) with few refined
507 carbohydrates (Table 2). Breakfast is an important meal of the day, and skipping it (for those who usually
508 take one) may be related to health issues, such as overweight and obesity (61–63) or bad health habits. For
509 instance, skipping breakfast is linked to a decrease in physical activity in women (64). Structural equation
510 modeling showed a marginally non-significant effect of physical activity on women's breakfast energy
511 intake. Indeed, women exercising more could be likely to have a higher protein and fat and a lower refined
512 carbohydrate intake at breakfast, and to be involved in better life hygiene with a higher diet quality.
513 Moreover, the intensity of physical activity can be a strong indicator of attractiveness (65), principally

514 because it shows good health and because good health is associated with facial cues that affect attractiveness
515 perception (66). For men, an increase in energy intake during breakfast also increased attractiveness,
516 probably for the same physiological and environmental reasons as those for women. However, the reduced
517 attractiveness resulting from an increase in glycemic load during breakfast was restricted to women.

518 Afternoon snacking, a usual mid-afternoon meal known called “goûter” in France, corresponds (for
519 people who are used to it) to a real food need. This meal is associated with a preprandial drop in plasma
520 glucose and insulin concentrations and a strong motivation to eat (67), although only men were evaluated in
521 that study. This could explain the increased attractiveness of men with a high glycemic load food
522 consumption during the afternoon snack, providing immediately available glucose. Interestingly, also for
523 men, energy intake had a reversed effect during this meal. One possibility is that a large proportion of
524 saturated fat is involved in this meal, such as those found in pastries, as such fat is known to be an antagonist
525 of insulin and a contributor to insulin resistance and thus hyperinsulinemia (48), thus mimicking the potential
526 negative effects of refined carbohydrates on masculinity/femininity. This hypothesis was supported by
527 structural equation modeling, which suggested that the decrease in attractiveness due to afternoon snack
528 energy intake was mediated by a decrease in perceived masculinity for men. For women, the results were
529 different: a negative effect of afternoon snack glycemic load on attractiveness was observed, and this effect
530 was mediated by an older appearance (at equal chronological age), probably due to the consequence of
531 hyperglycemia on aging.

532 Between-meal snacks are generally not associated with physiological hunger and are instead a
533 consequence of social or other external stimuli, with little impact on satiety and compensation mechanisms
534 (20). The decreased attractiveness associated with an increase in refined carbohydrates consumption during
535 between-meal snacks was observed for both sexes. For men, it could be modulated by physical activity and
536 mediated by masculinity, as suggested by structural equation modeling: men who exercise less tend to eat
537 more refined carbohydrates outside of regular meals, affecting their masculinity and their attractiveness.

538 Thus, the three types of meals might affect subjects’ facial attractiveness differently because they
539 correspond to different ecological eating habits that have different physiological consequences.

540

541 ***How can the influence of diet on facial attractiveness be evolutionary triggered?***

542 In general, traditional foods (pre-industrial or non-refined) do not generate hyperglycemia, with the
543 exception of ripe fruits or honey which are energetically rewarding but are traditionally seasonal or scarce. In
544 fact, humans did not evolve with constant access to food provoking a high glycaemic response, even after the
545 rise of agriculture in the Neolithic era. It has been previously proposed that in the current industrial dietary
546 environment, consumption of food that generates hyperglycemia is no longer a signal of quality, because this
547 type of food is now not limited (8). Its massive consumption generates phenotypic and physiological changes
548 in the body, such as obesity and type 2 diabetes, which are attracting medical attention due to their life-
549 threatening effects. It is thus not surprising that other negative effects not directly affecting health are also
550 generated, such as reduced facial attractiveness.

551

552 ***Limitations***

553 In this study, the chronic effect of refined carbohydrate intake on attractiveness may have been
554 confounded by several variables that were not considered here. For example, attractiveness was not
555 controlled for skin color (redness, yellowness) and aspect (brightness, luminance), although these factors are
556 known to impact health perception (68) and could thus impact attractiveness (69,70). However, all facial
557 photographs were taken indoors in the same technical room with fully controlled lighting conditions, thus
558 reducing environmental variance for these traits. Skin color can also be modulated by diet and health habits
559 (71–74). For instance, fruit and vegetable consumption is known to increase skin yellowness (75,76). In
560 addition, because lunch and dinner were not recorded in this study, it was not possible to calculate an overall
561 index of diet quality that could have accounted for other aspects of food that influence attractiveness.
562 However, diet quality index and glycemic load values are correlated: higher index values are associated with
563 increased low GL foods, see, e.g., (77,78) and high fruit and vegetable consumption. Thus, diet quality with
564 fruit and vegetable consumption was partially described by glycemic load measures. Another potential
565 confounding variable we do not control is menstrual cycle, in woman sample of subject and raters. It has
566 been shown that facial attractiveness may increase during ovulation, as assessed by male raters (79) and that
567 women's perception of men's facial attractiveness could be influenced by their menstrual cycle (80). We only
568 control for contraception in woman sample of subjects (65 % of the sample took a contraception). However,
569 the bias associated with not taking this variable into account could be offset by the sample size, with the

570 assumption that each participant's menstrual cycle stage is randomized for the day of sampling. In addition,
571 future studies should aim to control sleep, as sleep deprivation has been shown to have an effect on facial
572 attractiveness (81). Finally, the sample size of participants was relatively small. However, when 10 % of the
573 dataset was randomly deleted (1000 repetitions), for both women and men, the results did not change
574 qualitatively (Table S6). This indicates that the effects observed are strong enough to be detected even in a
575 smaller sample.

576

577 **Conclusion**

578 The recent Western dietary change, mainly the massive increase in refined carbohydrate
579 consumption, has well described adverse health consequences. Traits not under medical competence but still
580 with large social importance seem also impacted, such as facial attractiveness. Facial attractiveness, an
581 important factor of social interactions, seems to be impacted by immediate and chronic refined carbohydrate
582 consumption. Further studies are needed to investigate how diet effects are mediated and which other social
583 traits could be affected by refined carbohydrate consumption.

584

585 **Acknowledgments**

586 The authors thank the City Hall of Montpellier, Luc Gomel and all staff from Serre Amazonienne for
587 providing places for rater recruitment and the women and men who participated in this study. This is
588 contribution ISEM 2024-032.

589

590 **Author contributions**

591 CB and MR planned and supervised study. AV, CB, LG and VD conducted different parts of study.
592 AV and CB analyzed study. AV, CB and MR wrote the manuscript. All authors read and approved the final
593 manuscript.

594

References

1. Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, et al. Origins and evolution of

the Western diet: health implications for the 21st century. *The American Journal of Clinical Nutrition*. 2005;81(2):341-54.

2. Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, et al. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *New England Journal of Medicine*. 2001;345(11):790-7.
3. Jellinger PS. Metabolic consequences of hyperglycemia and insulin resistance. *Clinical Cornerstone*. 2007;8:S30-42.
4. Johnson RJ, Segal MS, Sautin Y, Nakagawa T, Feig DI, Kang DH, et al. Potential role of sugar (fructose) in the epidemic of hypertension, obesity and the metabolic syndrome, diabetes, kidney disease, and cardiovascular disease. *The American Journal of Clinical Nutrition*. 2007;86(4):899-906.
5. Gentreau M, Chuy V, Féart C, Samieri C, Ritchie K, Raymond M, et al. Refined carbohydrate-rich diet is associated with long-term risk of dementia and Alzheimer's disease in apolipoprotein E ϵ 4 allele carriers. *Alzheimer's & Dementia*. 2020;16(7):1043-53.
6. Al-Badrani SM, Al-Sowayan NS. Consequences of insulin resistance long term in the body and its association with the development of chronic diseases. *Journal of Biosciences and Medicines*. 2022;10(12):96-109.
7. Janssen JAMJL. Hyperinsulinemia and its pivotal role in aging, obesity, type 2 diabetes, cardiovascular disease and cancer. *International Journal of Molecular Sciences*. 2021;22(15):7797.
8. Berticat C, Durand V, Raymond M. Refined carbohydrate consumption and facial attractiveness. *Evolutionary Psychology*. 2020;18(4):147470492096044.
9. Cordain L, Lindeberg L, Hurtado AM, Hill K, Boyd Eaton S, Brand- Miller J. Acne vulgaris: a disease of Western civilization. *Archives of Dermatology*. 2002;138:1584-90.
10. Pitteloud N, Hardin M, Dwyer AA, Valassi E, Yialamas M, Elahi D, et al. Increasing insulin resistance is associated with a decrease in Leydig cell testosterone secretion in men. *The Journal of Clinical Endocrinology & Metabolism*. 2005;90(5):2636-41.
11. Pateguana NB, Janes A. The contribution of hyperinsulinemia to the hyperandrogenism of polycystic ovary syndrome. *Journal of Insulin Resistance*. 2019;4(1):1-3.
12. Cordain L, Eades MR, Eades MD. Hyperinsulinemic diseases of civilization: more than just Syndrome X. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*. 2003;136(1):95-112.
13. Chaudhuri A. Polycystic ovary syndrome: Causes, symptoms, pathophysiology, and remedies. *Obesity Medicine*. 2023;39:100480.
14. Zhang Z, Hu X, Yang C, Chen X. Early age at menarche is associated with insulin resistance: a systemic review and meta-analysis. *Postgraduate Medicine*. 2019;131(2):144-50.
15. Puts DA, Jones BC, DeBruine LM. Sexual selection on human faces and voices. *The Journal of Sex Research*. 2012;49(2-3):227-43.
16. Eastwick PW, Luchies LB, Finkel EJ, Hunt LL. The predictive validity of ideal partner preferences: a review and meta-analysis. *Psychological Bulletin*. 2014;140(3):623-65.
17. Ritts V, Patterson ML, Tubbs ME. Expectations, impressions, and judgments of physically attractive students: a review. *Review of Educational Research*. 1992.

18. Praino R, Stockemer D, Ratis J. Looking good or looking competent? Physical appearance and electoral success in the 2008 congressional elections. *American Politics Research*. 2014.
19. Van Den Abbeele J, Penton-Voak IS, Attwood AS, Stephen ID, Munafò MR. Increased facial attractiveness following moderate, but not high, alcohol consumption. *Alcohol and Alcoholism*. 2015;50(3):296-301.
20. Bellisle F. Meals and snacking, diet quality and energy balance. *Physiology & Behavior*. 2014;134:38-43.
21. Kanarek RB, Swinney D. Effects of food snacks on cognitive performance in male college students. *Appetite*. 1990;14(1):15-27.
22. Hätönen KA, Virtamo J, Eriksson JG, Sinkko HK, Sundvall JE, Valsta LM. Protein and fat modify the glycaemic and insulinaemic responses to a mashed potato-based meal. *British Journal of Nutrition*. 2011;106(2):248-53.
23. Sun L, Goh HJ, Govindharajulu P, Leow MKS, Henry CJ. Postprandial glucose, insulin and incretin responses differ by test meal macronutrient ingestion sequence (PATTERN study). *Clinical Nutrition*. 2020;39(3):950-7.
24. Bellisle F, Dalix AM, Mennen L, Galan P, Hercberg S, de Castro JM, et al. Contribution of snacks and meals in the diet of French adults: a diet-diary study. *Physiology & Behavior*. 2003;79(2):183-9.
25. Bellisle F, Hébel P, Salmon-Legagneur A, Vieux F. Breakfast consumption in French children, adolescents, and adults: a nationally representative cross-sectional survey examined in the context of the international breakfast research initiative. *Nutrients*. 2018;10(8):1056.
26. Guillou L, Durand V, Raymond M, Berticat C. Chronic refined carbohydrate consumption measured by glycemic load and variation in cognitive performance in healthy people. *Personality and Individual Differences*. 2023;206:112138.
27. Slimani N, Ferrari P, Ocke M, Welch A, Boeing H, Van Liere M, et al. Standardization of the 24-hour diet recall calibration method used in the European Prospective Investigation into Cancer and Nutrition (EPIC): general concepts and preliminary results. *European Journal of Clinical Nutrition*. 2000;54(12):900.
28. Hercberg S, Galan P, Preziosi P, Bertrais S, Mennen L, Malvy D, et al. The SU. VI. MAX Study: a randomized, placebo-controlled trial of the health effects of antioxidant vitamins and minerals. *Archives of internal medicine*. 2004;164(21):2335-42.
29. Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values: 2002. *The American Journal of Clinical Nutrition*. 2002;76(1):5-56.
30. Monro JA, Shaw M. Glycemic impact, glycemic glucose equivalents, glycemic index, and glycemic load: definitions, distinctions, and implications. *The American Journal of Clinical Nutrition*. 2008;87(1):237S-243S.
31. Eleazu CO. The concept of low glycemic index and glycemic load foods as panacea for type 2 diabetes mellitus; prospects, challenges and solutions. *African Health Sciences*. 2016;16(2):468-79.
32. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. *The American Journal of Clinical Nutrition*. 1997;65(4):1220S-1228S.
33. Dixson BJW, Lee AJ, Sherlock JM, Talamas SN. Beneath the beard: do facial morphometrics influence the strength of judgments of men's beardedness? *Evolution and Human Behavior*. 2017;38(2):164-74.

34. Lee AJ, Mitchem DG, Wright MJ, Martin NG, Keller MC, Zietsch BP. Genetic factors that increase male facial masculinity decrease facial attractiveness of female relatives. *Psychological Science*. 2014;25(2):476-84.
35. Scott IML, Pound N, Stephen ID, Clark AP, Penton-Voak IS. Does masculinity matter? The contribution of masculine face shape to male attractiveness in humans. *Vitzthum VJ, éditeur. PLOS One*. 2010;5(10):e13585.
36. Tiddeman BP, Stirrat MR, Perrett DI. Towards realism in facial image transformation: results of a wavelet MRF method. *Computer Graphics Forum*. 2005;24(3):449-56.
37. Zelditch ML, Swiderski DL, Sheets HD. *Geometric morphometrics for biologists: a primer*. Academic Press; 2012.
38. Chung Y, Rabe-Hesketh S, Dorie V, Gelman A, Liu J. A Nondegenerate penalized likelihood estimator for variance parameters in multilevel models. *Psychometrika*. 2013;78(4):685-709.
39. Rosseel Y. lavaan: An R package for structural equation modeling. *Journal of Statistical Software*. 2012;48(1):1-36.
40. Harrell FE. *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*. Springer International Publishing; 2015.
41. Zuur AF, Ieno EN, Elphick CS. A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution*. 2010;1(1):3-14.
42. Barr DJ, Levy R, Scheepers C, Tily HJ. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*. 2013;68(3):255-78.
43. Hume DK, Montgomerie R. Facial attractiveness signals different aspects of “quality” in women and men. *Evolution and human behavior*. 2001; 22(2), 93-112.)
44. Jenkins DJ, Wolever TM, Taylor RH, Ghafari H, Jenkins AL, Barker H, et al. Rate of digestion of foods and postprandial glycaemia in normal and diabetic subjects. *British Medical Journal*.1980;281(6232):14-7.
45. Allwood MJ, Hensel H, Papenberg J. Muscle and skin blood flow in the human forearm during insulin hypoglycaemia. *The Journal of Physiology*. 1959;147(2):269-73.
46. Pundyk KJ, Marks SD. Hypoglycemia. In: Stanley T, Misra M, editors. *Endocrine conditions in pediatrics: a practical guide*. Springer International Publishing; 2021;p. 53-55.
47. Tronstad C, Elvebakk O, Staal OM, Kalvøy H, Høgetveit JO, Jenssen TG, et al. Non-invasive prediction of blood glucose trends during hypoglycemia. *Analytica Chimica Acta*. 2019;1052:37-48.
48. Kennedy A, Martinez K, Chuang CC, LaPoint K, McIntosh M. Saturated fatty acid-mediated inflammation and insulin resistance in adipose tissue: mechanisms of action and implications. *The Journal of Nutrition*. 2009;139(1):1-4.
49. Lutz SZ, Wagner R, Fritsche L, Peter A, Rettig I, Willmann C, et al. Sex-specific associations of testosterone with metabolic traits. *Frontiers in Endocrinology*. 2019;10.
50. Danby FW. Nutrition and aging skin: sugar and glycation. *Clinical Dermatology*. 2010;28(4):409-11.
51. Jencks C, And Others. *Who gets ahead? The determinants of economic success in America*. New York: Basic Books;1979.

52. Nkengne A, Bertin C, Stamatas GN, Giron A, Rossi A, Issachar N, et al. Influence of facial skin attributes on the perceived age of Caucasian women. *Journal of the European Academy of Dermatology and Venereology*. 2008;22(8):982-91.
53. Samson N, Fink B, Matts PJ. Visible skin condition and perception of human facial appearance. *International Journal of Cosmetic Science*. 2010;32(3):167-84.
54. Escasa M, Gray PB, Patton JQ. Male traits associated with attractiveness in Conambo, Ecuador. *Evolution and Human Behavior*. 2010;31(3):193-200.
55. Mathes EW, Brennan SM, Haugen PM, Rice HB. Ratings of physical attractiveness as a function of age. *The Journal of Social Psychology*. 1985;125(2):157-68.
56. McLellan B, McKelvie SJ. Effects of age and gender on perceived facial attractiveness. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement*. 1993;25(1):135-42.
57. Magkos F, Wang X, Mittendorfer B. Metabolic actions of insulin in men and women. *Nutrition*. 2010;26(7):686-93.
58. Varlamov O, Bethea CL, Roberts CT. Sex-specific differences in lipid and glucose metabolism. *Frontiers in Endocrinology*. 2015;5:241.
59. Mauvais-Jarvis F. Gender differences in glucose homeostasis and diabetes. *Physiology & Behavior*. 2018;187:20-3.
60. Pasquali R. Obesity and androgens: facts and perspectives. *Fertility and Sterility*. 2006;85(5):1319-40.
61. Ma L, Wang J, Li Y. Insulin resistance and cognitive dysfunction. *Clinica Chimica Acta*. 2015;444:18-23.
62. Mekary RA, Giovannucci E, Willett WC, van Dam RM, Hu FB. Eating patterns and type 2 diabetes risk in men: breakfast omission, eating frequency, and snacking. *The American Journal of Clinical Nutrition*. 2012;95(5):1182-9.
63. Song WO, Chun OK, Obayashi S, Cho S, Chung CE. Is consumption of breakfast associated with body mass index in US adults? *Journal of the American Dietetic Association*. 2005;105(9):1373-82.
64. Yoshimura E, Hatamoto Y, Yonekura S, Tanaka H. Skipping breakfast reduces energy intake and physical activity in healthy women who are habitual breakfast eaters: A randomized crossover trial. *Physiology & Behavior*. 2017;174:89-94.
65. Brewer G, Howarth S. Sport, attractiveness and aggression. *Personality and Individual Differences*. 2012;53(5):640-3.
66. Shackelford TK, Larsen RJ. Facial attractiveness and physical health. *Evolution and Human Behavior*. 1999;20(1):71-6.
67. Chapelot D, Marmonier C, Aubert R, Gausseres N, Louis-Sylvestre J. A role for glucose and insulin preprandial profiles to differentiate meals and snacks. *Physiology & Behavior*. 2004;80(5):721-31.
68. Jones AL, Porcheron A, Sweda JR, Morizot F, Russell R. Coloration in different areas of facial skin is a cue to health: The role of cheek redness and periorbital luminance in health perception. *Body Image*. 2016;17:57-66.
69. Fink B, Grammer K, Matts PJ. Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evolution and Human Behavior*. 2006;27(6):433-42.

70. Fink B, Matts PJ, D'Emiliano D, Bunse L, Weege B, Röder S. Colour homogeneity and visual perception of age, health and attractiveness of male facial skin. *Journal of the European Academy of Dermatology and Venereology*. 2012;26(12):1486-92.
71. Ashton LM, Pezdirc KB, Hutchesson MJ, Rollo ME, Collins CE. Is Skin Coloration Measured by Reflectance Spectroscopy Related to Intake of Nutrient-Dense Foods? A Cross-Sectional Evaluation in Australian Young Adults. *Nutrients*. 2018;10(1):11.
72. Coyle DH, Pezdirc K, Hutchesson MJ, Collins CE. Intake of specific types of fruit and vegetables is associated with higher levels of skin yellowness in young women: A cross-sectional study. *Nutrition research*. 2018;56:23-31.
73. Gupta MA, Gupta AK. Dissatisfaction with skin appearance among patients with eating disorders and non-clinical controls. *British Journal of Dermatology*. 2001;145(1):110-3.
74. Perrett DI, Talamas SN, Cairns P, Henderson AJ. Skin color cues to human health: carotenoids, aerobic fitness, and body fat. *Frontiers in Psychology*. 2020;11:392.
75. Appleton KM, McGrath AJ, McKinley MC, Draffin CR, Hamill LL, Young IS, et al. The value of facial attractiveness for encouraging fruit and vegetable consumption: analyses from a randomized controlled trial. *BMC Public Health*. 2018;18(1):298.
76. Zuniga A, Stevenson RJ, Mahmut MK, Stephen ID. Diet quality and the attractiveness of male body odor. *Evolution and Human Behavior*. 2017;38(1):136-43.
77. Azadbakht L, Mohammadifard N, Akhavanzanjani M, Taheri M, Golshahi J, Haghighatdoost F. The association between dietary glycemic index, glycemic load and diet quality indices in Iranian adults: results from Isfahan Healthy Heart Program. *International Journal of Food Sciences and Nutrition*. 2016;67(2):161-9.
78. Jones M, Barclay AW, Brand-Miller JC, Louie JCY. Dietary glycaemic index and glycaemic load among Australian children and adolescents: results from the 2011–2012 Australian Health Survey. *British Journal of Nutrition*. 2016;116(1):178-87.
79. Roberts SC, Havlicek J, Flegr J, Hruskova M, Little AC, Jones BC, et al. Female facial attractiveness increases during the fertile phase of the menstrual cycle. *Proceedings of the Royal Society of London Series B*. 2004;271(Suppl 5):S270-2.
80. Penton-Voak IS, Perrett DI, Castles DL, Kobayashi T, Burt DM, Murray LK, et al. Menstrual cycle alters face preference. *Nature*. 1999;399(6738):741-2.
81. Sundelin T, Lekander M, Sorjonen K and [Axelsson J](#). Negative effects of restricted sleep on facial appearance and social appeal. *Royal Society Open Science*. 2017;4160918160918.

Supporting information

595

596 **Table S1.** Exhaustive list of the different food items of the diet questionnaire in French and translated.

597

598 **Table S2.** Effects of rater characteristics and subject age and sex on the subject age perception by raters.
599 Raters were instructed to ascribe an age for the photographs they were viewing. The estimate (β), standard
600 error of the mean (se), χ^2 statistic, and corresponding p-value are given. Bold characters indicate significant
601 ($p < 0.05$) effects.

602

603 **Table S3.** Effects of rater characteristics on the subjects' masculinity/femininity perception by raters. The
604 Wilcoxon test statistic (V), Friedman chi-squared (F) and corresponding p-value are given. Bold characters
605 indicate significant ($p < 0.05$) effects. Median and terciles of age and study level were used for the Wilcoxon
606 signed-rank test and Friedman two-way analysis of variance, respectively.

607

608 **Table S4.** Effects of rater characteristics on the subjects' attractiveness perception by raters. The Wilcoxon test
609 statistic (V), Friedman chi-squared (F) and corresponding p-value are given. Bold characters indicate significant
610 ($p < 0.05$) effects. Median and terciles of age and study level were used for the Wilcoxon signed-rank test and
611 Friedman two-way analysis of variance, respectively.

612

613 **Table S5.** Structural equation analysis. The results based on Figures 2 and 3. RC1, RC2 and RC3 are the
614 three variables representing refined carbohydrate consumption. The standardized estimate (β), standard error
615 of the mean (se), z-value, and corresponding p-value are given. Bold characters indicate significant ($p <$
616 0.05) effects. For each sex, only variables with a p-value < 0.01 were integrated into the model.

617

618 **Table S6.** Sensitivity analysis for the test of attractiveness for male or female faces. After a random 10% data
619 reduction, p-values are computed and this process is repeated 1000 times, providing a p-value distribution for each
620 variable. RGL1, RGL2 and RGL3 are the three variables representing refined carbohydrate consumption. The
621 mean p-value (mean p), standard deviation (sd), minimum p-value (min) and maximum p-value (max) are given.

622

623

624

625

626

627

628

629

630

631

632

633

634

635

636

637



638 **Figure 1. Example of a pair of faces used during the evaluation of women's facial attractiveness by male**
639 **raters.** For each pair of women, the rater was instructed to click on the photograph of the woman that he found
640 the most attractive. Faces were anonymized for publication.

641

642

643

644

645

646

647

648

649

650

651

652

653

654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681

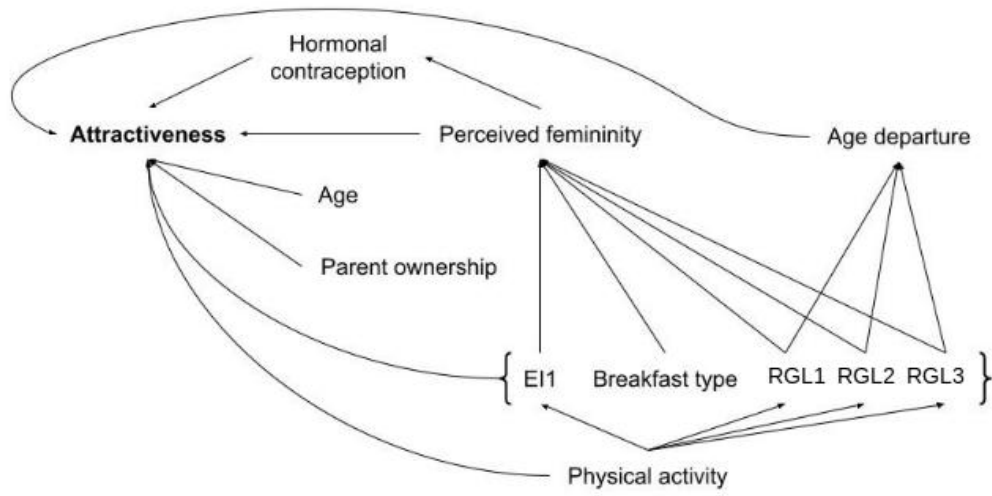


Figure 2. Hypothesized path model for women’s attractiveness with the variables of the generalized linear mixed model.

682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708

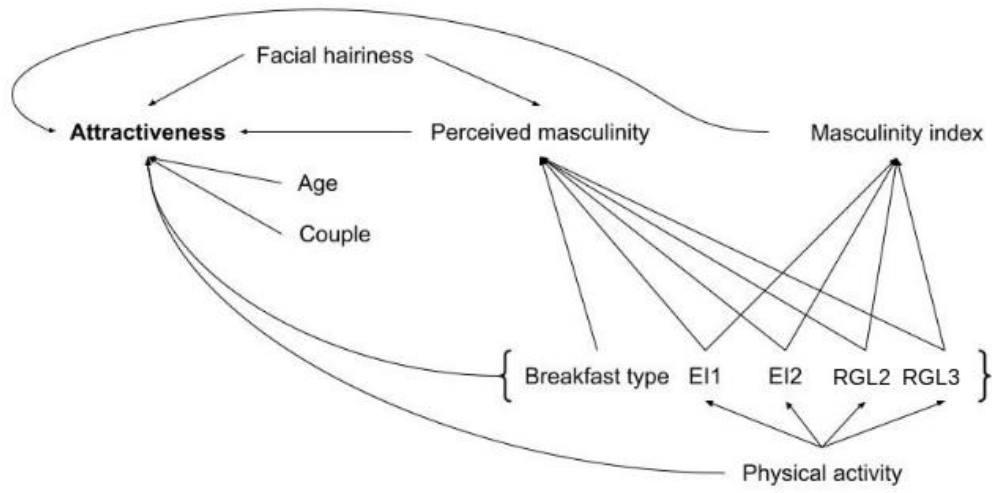


Figure 3. Hypothesized path model for men's attractiveness with the variables of the generalized linear mixed model.

709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735



Figure 4. Graphical representation of the adjusted odd ratios with their 95% confidence intervals from the model studying the probability of being chosen in the attractiveness test for male or female faces. Raters were instructed to choose the individual found to be the most attractive between two facial photographs. RGL1, RGL2 and RGL3 are the three variables representing chronic refined carbohydrate consumption. For each variable, the difference between the two individuals (left minus right) presented was integrated into the model. For the immediate breakfast type variable, estimates are given for one category compared with the reference category corresponding to focal with B1 and non focal with B2 (underlined term). * P < 0.05 ** P < 0.01 *** P < 0.001.

736 **Table S1.** Exhaustive list of the different food items of the diet questionnaire in French and translated.

| French | English |
|---|--|
| Baguette (morceaux) | Baguette (pieces) |
| Pain (morceaux) | Bread (pieces) |
| Pain de campagne | Country bread |
| Pain complet | Whole wheat bread |
| Pain de mie | Soft bread |
| Pain de seigle | Rye bread |
| Pain poilane | Poilane bread |
| Pain découpé (restaurant-cantine) | Sliced bread (restaurant-canteen) |
| Couleur café au lait | Latte coffee color |
| Couleur chocolat au lait | Milk chocolate color |
| Blé soufflé | Puffed wheat |
| Müesli | Muesli |
| Pétales de maïs | Corn petals |
| Biscottes diverses | Various rusks |
| Brioche tranches ou individuelles | Sliced or individual brioche |
| Beurre | Butter |
| Epaisseur du beurre | Butter thickness |
| Confiture (consommation totale, e.g. tartine, boisson, laitage) | Jam (total consumption including for instance toast, drink, dairy) |
| Miel (consommation totale y compris tartine, boisson, laitage) | Honey (total consumption including toast, drink, dairy) |
| Nutella (consommation totale y compris tartine, boisson, laitage) | Nutella (total consumption including toast, drink, dairy) |
| Sucre morceaux (consommation totale y compris boisson, laitage) | Sugar cubes (total consumption including drink, dairy) |
| Sucre poudre (consommation totale y compris boisson, laitage) | Granulated sugar (total consumption including drink, dairy) |
| Chèvre crottin | Goat cheese |
| Bûche | Goat cheese |
| Pyramide | Goat cheese |
| Boursin | Boursin |
| Camembert | Camembert |
| Rouy | Rouy |
| Gruyère | Gruyere |
| Mimolette | Mimolette |
| Roquefort | Roquefort |
| Tomme | Cheese |
| Fromage blanc | White cheese |
| Nombre de yaourts déjà sucrés à l'achat (aromatisé, aux fruits) | Number of yogurts already sweetened (flavored, with fruits) |
| Nombre de yaourts naturels | Number of plain yogurts |
| Nombre de petits-suisse nature | Number of plain Petits-Suisse |
| Yaourt à boire: nombre de verres | Drinkable yogurt: number of glasses |
| Taille du verre pour le yaourt à boire | Glass size for yogurt drink |
| Chantilly | Sweet whipped cream |
| Entremet semoule et riz | Semolina and rice dessert |
| Flan | Blank |

| | |
|---|--|
| Mousse au chocolat | Chocolate mousse |
| Gâteau à la crème | Cream cake |
| Gâteau mousse aux fruits | Fruit mousse cake |
| Tarte aux fruits | Fruit tart |
| Gâteau au chocolat | Chocolate cake |
| Tourte aux amandes | Almond pie |
| Cake | Cake |
| Madeleines | Madeleines |
| Quatre-quarts | Pound cake |
| Type de biscuits consommés | Type of cookies eaten |
| Nombre de biscuits consommés | Number of cookies eaten |
| Nombre de viennoiseries consommées (croissant, pain au chocolat,...) | Number of pastries consumed (croissant, pain au chocolat, etc.) |
| Noix | Nut |
| Noisettes | Hazelnut |
| Pistaches | Pistachios |
| Cerises | Cherries |
| Fraises | Strawberries |
| Framboises | Raspberries |
| Banane | Banana |
| Pomme | Apple |
| Poire | Pear |
| Kiwi | Kiwi |
| Abricot | Apricot |
| Groseilles | Currants |
| Quetsches (prunes) | Quetsches (plums) |
| Raisins | Grapes |
| Orange | Orange |
| Pruneaux | Prunes |
| Ananas au sirop | Pineapple in syrup |
| Fruits au sirops divers | Fruits in various syrups |
| Bonbons divers | Various candies |
| Chocolat (carrés) | Chocolate (squares) |
| Barre chocolatée | Chocolate bar |
| Soda, jus de fruit: nombre de boissons individuelles consommées (canette-bouteille-brick) | Soda, fruit juice: number of individual drinks consumed (can-bottle-brick) |
| Type de contenant de boisson individuelle (canette-bouteille-brick) | Type of individual beverage container (can-bottle-brick) |
| Soda, jus de fruit: nombre de verres | Soda, fruit juice: number of glasses |
| Taille du verre (soda ou jus) | Glass size (soda or juice) |
| Taille de la tasse ou du bol (lait-café-chocolat) | Cup or bowl size (milk-coffee-chocolate) |

737

738

739

740

741

742 **Table S2.** Effects of rater characteristics and subject age and sex on the subject age perception by raters. Raters
 743 were instructed to ascribe an age for the photographs they were viewing. The estimate (β), standard error of the
 744 mean (se), χ^2 statistic, and corresponding p-value are given. Bold characters indicate significant ($p < 0.05$) effects.

| | Male faces (N = 52) | | | | Female faces (N = 52) | | | |
|-------------------|---------------------|------|----------|------------------------|-----------------------|------|----------|------------------------|
| | β | se | χ^2 | p | β | se | χ^2 | p |
| Intercept | 25.5 | 0.41 | | | 24.6 | 0.38 | | |
| Subject age | 1.36 | 0.28 | 22.6 | 10⁻⁶ | 0.95 | 0.24 | 15.8 | 10⁻⁵ |
| Rater age | -0.26 | 0.26 | 0.95 | 0.32 | -0.36 | 0.24 | 2.26 | 0.13 |
| Rater sex | -0.04 | 0.45 | 0.01 | 0.93 | 0.21 | 0.44 | 0.23 | 0.62 |
| Rater study level | -0.25 | 0.26 | 0.94 | 0.33 | 0.21 | 0.25 | 0.71 | 0.39 |

745

746

747

748

preprint

749 **Table S3.** Effects of rater characteristics on the subjects' masculinity/femininity perception by raters. The
 750 Wilcoxon test statistic (V), Friedman chi-squared (F) and corresponding p-value are given. Bold characters
 751 indicate significant ($p < 0.05$) effects. Median and terciles of age and study level were used for the Wilcoxon
 752 signed-rank test and Friedman two-way analysis of variance, respectively.

| | | Men faces (N = 52) | | Women faces (N = 52) | |
|--|-------------------|--------------------|---------|----------------------|---------|
| | | V | p-value | V | p-value |
| Wilcoxon signed-rank test | Rater age | 593 | 0.963 | 582 | 0.332 |
| | Rater study level | 671 | 0.944 | 507 | 0.294 |
| | | F(χ^2) | p-value | F(χ^2) | p-value |
| Friedman two-way analysis of variance | Rater age | 4.657 | 0.097 | 2.261 | 0.323 |
| | Rater study level | 1.107 | 0.575 | 0.131 | 0.937 |

753

754

755

756 **Table S4.** Effects of rater characteristics on the subjects' attractiveness perception by raters. The Wilcoxon test
 757 statistic (V), Friedman chi-squared (F) and corresponding p- value are given. Bold characters indicate significant
 758 ($p < 0.05$) effects. Median and terciles of age and study level were used for the Wilcoxon signed-rank test and
 759 Friedman two-way analysis of variance, respectively.

| | | Men faces (N = 52) | | Women faces (N = 52) | |
|--|-------------------|--------------------|---------|----------------------|---------|
| | | V | p-value | V | p-value |
| Wilcoxon signed-rank test | Rater age | 588 | 0.360 | 650 | 0.712 |
| | Rater study level | 697 | 0.945 | 735.5 | 0.675 |
| | | F(χ^2) | p-value | F(χ^2) | p-value |
| Friedman two-way analysis of variance | Rater age | 1.459 | 0.482 | 0.907 | 0.635 |
| | Rater study level | 0.269 | 0.874 | 0.299 | 0.860 |

760

761

762

763

764

765

766

767

768

769

770

771

772

773

774

775

776 **Table S5.** Structural equation analysis. The results based on Figures 2 and 3. RGL1, RGL2 and RGL3 are the
 777 three variables representing refined carbohydrate consumption. The standardized estimate (β), standard error of
 778 the mean (se), z-value, and corresponding p-value are given. Bold characters indicate significant ($p < 0.05$)
 779 effects. For each sex, only variables with a p-value < 0.01 were integrated into the model.

| Regressions~ | | Male faces evaluated by women | | | | Female faces evaluated by men | | | |
|------------------|----------------------------------|-------------------------------|---------|---------|-------|-------------------------------|-------|---------|-----------------------------|
| | | β | se | z-value | p | β | se | z-value | p |
| Attractiveness | RGL1 | | | | | - 0.127 | 0.104 | - 1.228 | 0.220 |
| | RGL2 | 0.077 | 0.119 | 0.644 | 0.519 | - 0.101 | 0.110 | - 0.921 | 0.357 |
| | RGL3 | - 0.011 | 0.130 | - 0.088 | 0.930 | - 0.047 | 0.105 | - 0.452 | 0.651 |
| | EI1 | 0.108 | 0.123 | 0.880 | 0.379 | 0.161 | 0.105 | 1.531 | 0.126 |
| | EI2 | 0.064 | 0.130 | 0.491 | 0.623 | | | | |
| | Breakfast type | - 0.204 | 0.122 | - 1.675 | 0.094 | 0.092 | 0.105 | 0.875 | 0.382 |
| | Age | 0.081 | 0.130 | 0.618 | 0.537 | - 0.175 | 0.105 | - 1.668 | 0.095 |
| | Age departure | | | | | - 0.102 | 0.110 | - 0.924 | 0.356 |
| | Fem/Masc Index | - 0.137 | 0.121 | - 1.134 | 0.257 | | | | |
| | Perceived masculinity/femininity | 0.268 | 0.139 | 1.933 | 0.053 | 0.414 | 0.103 | 4.021 | < 10⁻³ |
| | Physical activity | 0.214 | 0.134 | 1.599 | 0.110 | 0.277 | 0.107 | 2.597 | 0.009 |
| | Parental ownership home | | | | | 0.216 | 0.105 | 2.056 | 0.040 |
| | Contraceptive | | | | | - 0.186 | 0.106 | - 1.758 | 0.079 |
| | Couple status | 0.099 | 0.131 | 0.754 | 0.451 | | | | |
| Facial hairiness | - 0.159 | 0.128 | - 1.242 | 0.214 | | | | | |
| Age departure | RGL1 | | | | | - 0.081 | 0.129 | - 0.625 | 0.532 |
| | RGL2 | | | | | 0.306 | 0.124 | 2.475 | 0.013 |
| | RGL3 | | | | | - 0.165 | 0.128 | - 1.286 | 0.198 |

| | | | | | | | | | |
|----------------------------------|----------------------|---------|-------|---------|--------------|---------|-------|---------|-------|
| Perceived masculinity/femininity | RGL1 | | | | | - 0.007 | 0.136 | - 0.052 | 0.959 |
| | RGL2 | - 0.029 | 0.115 | - 0.249 | 0.803 | - 0.054 | 0.136 | - 0.396 | 0.692 |
| | RGL3 | - 0.275 | 0.113 | - 2.441 | 0.015 | - 0.055 | 0.135 | - 0.408 | 0.683 |
| | EI1 | 0.216 | 0.114 | 1.904 | 0.057 | 0.013 | 0.136 | 0.097 | 0.923 |
| | EI2 | - 0.366 | 0.109 | - 3.357 | 0.001 | | | | |
| | Breakfast type | - 0.130 | 0.115 | - 1.132 | 0.258 | - 0.195 | 0.132 | - 1.479 | 0.139 |
| | Facial hairiness | 0.185 | 0.113 | 1.633 | 0.102 | | | | |
| Contraceptive | Perceived femininity | | | | | - 0.247 | 0.130 | - 1.896 | 0.058 |
| RGL1 | Physical activity | | | | | 0.063 | 0.138 | 0.458 | 0.647 |
| RGL2 | Physical activity | - 0.009 | 0.139 | - 0.065 | 0.948 | - 0.179 | 0.133 | - 1.343 | 0.179 |
| RGL3 | Physical activity | - 0.304 | 0.123 | - 2.470 | 0.014 | - 0.027 | 0.139 | - 0.195 | 0.845 |
| EI1 | Physical activity | 0.100 | 0.137 | 0.727 | 0.467 | 0.227 | 0.130 | 1.749 | 0.080 |
| EI2 | Physical activity | - 0.049 | 0.138 | - 0.356 | 0.722 | | | | |
| Fem/Masc Index | RGL2 | 0.157 | 0.133 | 1.179 | 0.238 | | | | |
| | RGL3 | - 0.061 | 0.135 | - 0.453 | 0.651 | | | | |
| | EI1 | - 0.107 | 0.134 | - 0.798 | 0.425 | | | | |
| | EI2 | 0.122 | 0.134 | 0.908 | 0.364 | | | | |

780

781

782

783

784

785

786

787

788

789 **Table S6.** Sensitivity analysis for the test of attractiveness for male or female faces. After a random 10% data
 790 reduction, p-values are computed and this process is repeated 1000 times, providing a p-value distribution for each
 791 variable. RGL1, RGL2 and RGL3 are the three variables representing refined carbohydrate consumption. The
 792 mean p-value (mean p), standard deviation (sd), minimum p-value (min) and maximum p-value (max) are given.

793

| | Male faces evaluated by women | | | | Female faces evaluated by men | | | |
|----------------------------------|-------------------------------|-------------------|--------------------|-------------------|-------------------------------|-------------------|--------------------|-------------------|
| | mean p | sd | min | max | mean p | sd | min | max |
| RGL1 | 0.789 | 0.151 | 0.276 | 0.999 | 0.037 | 0.037 | $6 \cdot 10^{-4}$ | 0.363 |
| RGL2 | $6 \cdot 10^{-6}$ | 10^{-5} | $2 \cdot 10^{-8}$ | 10^{-4} | 0.058 | 0.047 | 0.002 | 0.460 |
| RGL3 | 10^{-6} | $4 \cdot 10^{-6}$ | $2 \cdot 10^{-11}$ | $5 \cdot 10^{-5}$ | 0.139 | 0.097 | 0.004 | 0.547 |
| EI1 | $3 \cdot 10^{-5}$ | $8 \cdot 10^{-5}$ | $2 \cdot 10^{-8}$ | 0.001 | $3 \cdot 10^{-4}$ | $4 \cdot 10^{-4}$ | $8 \cdot 10^{-6}$ | 0.006 |
| EI2 | $6 \cdot 10^{-4}$ | $8 \cdot 10^{-4}$ | $3 \cdot 10^{-6}$ | 0.010 | 0.783 | 0.152 | 0.270 | 0.999 |
| EI3 | 0.688 | 0.179 | 0.187 | 0.999 | 0.394 | 0.166 | 0.057 | 0.999 |
| Breakfast type | 10^{-5} | $2 \cdot 10^{-5}$ | $4 \cdot 10^{-9}$ | $2 \cdot 10^{-4}$ | 10^{-8} | $8 \cdot 10^{-8}$ | $2 \cdot 10^{-12}$ | $2 \cdot 10^{-6}$ |
| Age | 0.001 | $2 \cdot 10^{-3}$ | $5 \cdot 10^{-6}$ | 0.039 | $5 \cdot 10^{-4}$ | 0.001 | $4 \cdot 10^{-7}$ | 0.014 |
| Age departure from actual age | 0.212 | 0.152 | 0.011 | 0.970 | $2 \cdot 10^{-4}$ | $6 \cdot 10^{-4}$ | $3 \cdot 10^{-8}$ | 0.008 |
| Fem/Masc Index | 0.139 | 0.106 | 0.003 | 0.719 | 0.731 | 0.186 | 0.162 | 0.999 |
| Perceived masculinity/femininity | 0.095 | 0.060 | 0.011 | 0.492 | 0.007 | 0.007 | $2 \cdot 10^{-4}$ | 0.056 |
| BMI | 0.604 | 0.197 | 0.144 | 0.999 | 0.638 | 0.208 | 0.107 | 0.999 |
| Physical activity | 0.095 | 0.070 | 0.004 | 0.438 | 0.002 | 0.003 | $4 \cdot 10^{-5}$ | 0.029 |
| Smoker | 0.643 | 0.199 | 0.107 | 0.999 | 0.640 | 0.197 | 0.123 | 0.998 |
| Parental home ownership | 0.455 | 0.206 | 0.055 | 0.999 | 0.027 | 0.027 | $2 \cdot 10^{-4}$ | 0.195 |

| | | | | | | | | |
|------------------|-----------|-------------------|-------------------|-------|-------------------|-------------------|-------------------|-------|
| Contraceptive | - | - | - | - | $3 \cdot 10^{-5}$ | $7 \cdot 10^{-5}$ | $6 \cdot 10^{-9}$ | 0.001 |
| Couple status | 0.008 | 0.011 | $5 \cdot 10^{-5}$ | 0.137 | 0.289 | 0.146 | 0.023 | 0.812 |
| Facial hairiness | 10^{-4} | $2 \cdot 10^{-4}$ | $4 \cdot 10^{-7}$ | 0.002 | - | - | - | - |

794

795

preprint