

1 **HIGHER VEGETABLE PROTEIN CONSUMPTION, ASSESSED BY AN ISOENERGETIC**
2 **MACRONUTRIENT EXCHANGE MODEL, IS ASSOCIATED WITH A LOWER PRESENCE OF**
3 **OVERWEIGHT AND OBESITY IN THE WEB-BASED FOOD4ME EUROPEAN STUDY**

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38 **SHORT TITLE:** Vegetable protein intake and risk of obesity

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40

41 **Abstract**

42 The objective was to evaluate differences in macronutrient intake and to investigate the
43 possible association between consumption of vegetable protein and the risk of

44 overweight/obesity, within the Food4Me randomised, online intervention. Differences
45 in macronutrient consumption among the participating countries grouped by EU
46 Regions (Western Europe, British Isles, Eastern Europe and Southern Europe) were
47 assessed. Relation of protein intake, within isoenergetic exchange patterns, from
48 vegetable or animal sources with risk of overweight/obesity was assessed through the
49 multivariate nutrient density model and a multivariate-adjusted logistic regression.

50 A total of 2413 subjects who completed the Food4Me screening were included, with
51 self-reported data on age, weight, height, physical activity and dietary intake.

52 As success rates on reducing overweight/obesity are very low, from a public health
53 perspective, the elaboration of policies for increasing intakes of vegetable protein and
54 reducing animal protein and sugars, may be a method of combating overweight/obesity
55 at a population level.

56 **Trial registration:** The Food4Me trial was registered as a RCT (NCT01530139) at
57 [clinicaltrials.gov \(http://clinicaltrials.gov/show/NCT01530139\)](http://clinicaltrials.gov/show/NCT01530139).

58 **Keywords**

59 Food4Me Study; Macronutrient intake; Overweight and Obesity; Protein quality;
60 Vegetable protein.

61 **Introduction**

62 The current worldwide increase in overweight and obesity prevalence represents a
63 serious threat to health and quality of life in most societies (Ng et al., 2014). The
64 growing concern for being healthy is taking a lead role in the understanding of social
65 culture and population welfare (Kumanyika et al., 2008). This issue is supported by
66 research evidence, in which according to the recent report of GBD Risk Factors, dietary
67 factors are one of the leading risk factors of non-communicable diseases, and
68 importantly, are high preventable (Phillips et al., 2014, Cecchini et al., 2010, G. B. D.
69 Risk Factors Collaborators 2016).

70 Lifestyle choices, mainly dietary and physical activity patterns, are key factors for
71 preventing the onset of obesity features, type 2 diabetes, cardiovascular diseases,
72 accompanying comorbidities and cancer (Mathers 2015, Raguso et al., 2006, Milte and
73 McNaughton 2015, Grosso et al., 2017). Recent studies on the relationship between

74 protein consumption and prevention/management of obesity, as well as interactions
75 between macronutrient intake and age, sex and physical activity, have revealed
76 controversial or inconsistent results (Riddle et al., 2016, Levine et al., 2014, Hernandez-
77 Alonso et al., 2016, Larsen et al., 2010, Navas-Carretero et al., 2016).

78 In this context, the development of new epidemiological concepts and tools may
79 contribute to envisage public policies and to help health professionals modify risk
80 factors of disease onset to implement adequate therapeutic approaches during all life
81 stages (Srikanthan and Karlamangla 2014, Stenholm, Rantanen, et al., 2007, Stenholm,
82 Sainio, et al., 2007, Woods et al., 2016). Precision nutrition data, based on genetics,
83 clinical history, likes/dislikes, lifestyles, perinatal nutrition, social/cultural constraints,
84 etc., tries to harmonize accurate prediction equations and algorithms with sensitive
85 procedures to give more individualised dietary advice for health management (Forster et
86 al., 2016, Bauer et al., 2014). Furthermore, the increasing use of internet, as well as the
87 reduced timetables of working families to attend to the health professional practice,
88 creates a necessity to develop procedures that help professionals to acquire and provide
89 valid information from users, in order to prescribe personalised and valuable nutritional
90 advice (San-Cristobal et al., 2013, Gibney and Walsh 2013, Fallaize et al., 2015).
91 Moreover, in research and primary care there is a growing concern about the relative
92 lack of success of public health policies in developed as well as developing countries,
93 and the necessity to combine personalised with public health nutrition advices (Hafekost
94 et al., 2013, Kumanyika et al., 2008), where the role of energy-yielding macronutrients
95 on the obesity epidemic needs to be ascertained, although the intake of micronutrients
96 and other food derived compounds will receive attention in the future, when more
97 precise information about micronutrients, food processing effects, etc., is available.

98 To address such issues, the current analysis used data from the Food4Me study
99 (www.food4me.org), which is an European, randomised controlled trial, designed to
100 investigate the effect of different types of personalised nutrition advice using a web-
101 based intervention platform (Celis-Morales, Livingstone, Marsaux, et al., 2015).

102 In this context, the authors hypothesized that an increased consumption of protein from
103 vegetable origin instead of protein from animal origin, using models of isocaloric
104 nutrient exchange, would be associated with a reduction in overweight/obesity.
105 Therefore, the aim of the present study was to evaluate the differences in macronutrient

106 intake among participating centres, with populations presenting different features, in the
107 Food4Me study, and to assess the role of the substitution of animal and vegetable
108 protein sources by other macronutrients, on the prevalence of overweight or obesity.

109 **Subjects and methods**

110 **Study design**

111 The current investigation is an ancillary cross-sectional analysis from the Food4Me
112 randomised controlled trial (Food4Me 2011), including data from 2413 participants.
113 Food4Me was a Pan-European project designed for evaluating the opportunities and
114 challenges of personalised nutrition (Food4Me 2011). The Food4Me study included
115 four arms, conducted in 7 European Countries. The intervention was designed to
116 emulate a real-life web-based personalised nutrition service. The extended protocol of
117 the present intervention has been described elsewhere (Celis-Morales, Livingstone,
118 Marsaux, et al., 2015).

119 **Ethical approval and participant recruitment**

120 Ethical approval for the study was obtained from all the local research ethics
121 committees at each participating centre. All participants interested in the study were
122 required to sign online consent forms at two stages in the screening process: before
123 sending the first data and before completing the screening food frequency questionnaire
124 (FFQ).

125 Recruitment for the study was conducted between August 2012 and August 2013, in 7
126 European centres, as an internet-based personalised nutrition intervention. The
127 recruitment centres for the Food4Me study were as follows: University College Dublin
128 (Ireland); Maastricht University (The Netherlands); University of Navarra (Spain);
129 Harokopio University (Greece); University of Reading (United Kingdom, UK);
130 National Food and Nutrition Institute (Poland); and Technical University of Munich
131 (Germany). To facilitate recruitment, each centre used one or more of the following
132 strategies: Local and National advertising of the study, via newspapers, radio, the
133 internet, posters, flyers or social media; press releases through the internet (online news
134 media), radio, newspaper; and word of mouth (Livingstone et al., 2016). Participants
135 had to voluntarily register their details on the Food4Me website, participant section
136 (Food4Me 2011), which was designed for the purposes of the study.

137 **Inclusion and exclusion criteria**

138 The Food4Me inclusion criteria were set as wide as possible to include the most
139 representative populations excluding known diseases or prescribed diets. Inclusion
140 criteria were: age > 18 years; to have internet access at home or easily accessible; to be
141 healthy (self-perceived) and without any known food allergy/intolerance.

142 The exclusion criteria were: pregnancy or planning to be pregnant the next 6 months;
143 following a prescribed diet, including for weight loss, in the last 3 months; to have very
144 limited or no access to the internet; suffering from diabetes, coeliac disease, Crohn's
145 disease, or any other metabolic conditions implying an alteration of nutritional
146 requirements such as known non-controlled thyroid disorders or food allergies and
147 intolerances.

148 Additionally, for the specific analysis in the current study, all those participants who
149 reported energy intakes lower than 1.1-fold of the calculated basal metabolic rate
150 ($1.1 \times \text{BMR}$), or higher than 5000 kcal/day as well as those who provided unrealistic
151 data on height or weight were excluded.

152 **Data collection**

153 Once the interested individuals had registered on the Food4me website, and signed the
154 informed consent forms, they were then asked to fill in online-based questionnaires.

155 Participants were requested to provide age and sex, ease of internet access, pregnancy,
156 food intolerances and/or allergies, in order to automatically proceed to the
157 inclusion/exclusion of the participants. In addition, self-reported socio-demographic
158 information, health-related issues, anthropometrics data and dietary intakes were
159 collected.

160 **Dietary intake evaluation**

161 An online food frequency questionnaire (FFQ) was completed, where participants
162 provided details of the frequency and portion size of 157 commonly-used food items
163 they had consumed within the previous month, as described elsewhere (Forster et al.,
164 2014).

165 This questionnaire provided the list of food items, categorised in food groups, and for
166 each item, the participants had to mark the frequency they had consumed it, expressed
167 as times per month/week/day. In relation to the estimated portion size, for each item,
168 appropriate photographs were shown, in order to help the participant to fill in the most
169 realistic weight of the portion, according to these pictures.

170 Intakes of foods and nutrients were then computed in real time, using a common food
171 composition database, with a small number of local food-item differences (McCance et
172 al., 2002). Both the online FFQ and the food database were developed and validated
173 specifically for the Food4Me trial (Forster et al., 2014, Fallaize et al., 2014, Marshall et
174 al., 2016). In the current analyses, the focus was specifically set on macronutrient and
175 energy intakes of the participants, and the percentual exchange of one macronutrient by
176 another.

177 **Anthropometric and physical activity assessment**

178 Body weight and height were self-measured and self-reported via internet following the
179 online instructions available at the website. These self-reported data evidenced good
180 agreement with standard methods, as it was demonstrated in a face-to-face validation of
181 a sample of the Food4Me participants (Celis-Morales, Livingstone, Woolhead, et al.,
182 2015). Physical activity was assessed with the self-reported occupational and non-
183 occupational activities using the Baecke questionnaire (Marsaux et al., 2016).
184 Participants were asked to categorise their occupational activity as light (e.g.
185 administrative and managerial), moderate (e.g. sales worker) or heavy (e.g. equipment
186 operator) and their non-occupational activity as sedentary (no activity or little
187 walking/cycling/exercise), moderately active (intense exercise 20-45 minutes, at least
188 twice per week) or very active (intense exercise during at least one hour daily) as
189 published (Marsaux et al., 2016).

190 **Statistical analyses**

191 Results from descriptive analyses are presented as means and Standard Deviation (SD)
192 for continuous variables or as percentages for categorical variables. Data were analysed
193 using Stata (version 12; Statacorp LP, College Station, TX, USA).

194 To facilitate the analytical process, participating centres were grouped according to the
195 United Nations Composition of geographical regions, geographical sub-regions, and

196 selected economic and other groupings (Nations). Thus, Ireland and the United
197 Kingdom were analysed together as “British Isles”, Germany and The Netherlands were
198 grouped as “Western Europe”, Poland was representative of “Eastern Europe”, and
199 finally Spain and Greece were grouped as “Southern Europe”.

200 To assess the influence of specific variables and to minimize biases, subjects were
201 dichotomised. Thus, participants were categorised by the median age in those below 40
202 years old and those who were 40 years or older. To study the influence of BMI and sex,
203 dichotomised categorical variables were used (under or above 25 kg/m², and
204 men/women, respectively).

205 To detect differences between regions, as well as between categorized variables, one
206 factor ANOVA and multivariate linear regression analyses were performed. Results
207 were considered statistically significant for p values <0.05.

208 The multivariate nutrient density model developed by Hu et al (Hu et al., 1999) was
209 performed to evaluate the influence of protein intake and the isoenergetic substitution of
210 protein sources on the risk of being overweight/obese. In this study, presence or absence
211 of overweight/obesity was considered the event outcome and dependent variable. A
212 multivariate-adjusted logistic regression was performed to calculate the Prevalence Risk
213 Ratio (PRR) of being overweight, using as independent variables the macronutrient
214 proportions (% of total energy intake), excluding protein for which the isoenergetic
215 exchange was analysed, and adjusting for total energy intake, geographical region, age,
216 sex and physical activity level (Moslehi et al., 2015). This approach allowed assessment
217 of the effect (risk) of the exchange of 1% (total energy intake) of protein by 1% (total
218 energy intake) of other macronutrients on being overweight or obese.

219 Sensitivity analysis for over and under estimation of food intake was performed, using
220 the cut-offs proposed by Goldberg and Black (Black 2000) based on the ratio of
221 reported energy intake/estimated energy requirements, to prevent biases in the risk
222 estimation model.

223 **Results**

224 A total of 5562 subjects across Europe were interested in receiving personalized
225 nutrition advice and registered on the Food4Me website (Figure 1), while 2402 did not
226 complete the whole screening process. Subsequently, these 3160 individuals signed the

227 two informed consents, filled in the two screening questionnaires and the food
228 frequency questionnaire. Finally, 2413 participants were considered eligible as they
229 provided valid data and fulfilled inclusion criteria.

230 **Participant characteristics**

231 Women represented the 64.69% of the total sample, with the biggest difference in
232 Eastern Europe, where 75% of registered participants were women (Table 1). Therefore,
233 data analyses were adjusted for sex. Anthropometric measures showed slight, but
234 significant differences between regions ($p < 0.001$). Notably, height was significantly
235 greater in Western Europe compared with the other regions by 4cm on average.
236 Differences in BMI were also statistically significant, with participants in Western and
237 Eastern Europe presenting the lowest BMI, whereas overweight/obesity was more
238 prevalent in the British Isles and Southern Europe.

239 In relation to food intake, no differences in energy consumption (kcal/day) were
240 observed, with mean energy intake ranging from 2558 to 2608 kcal/day across regions.
241 However, macronutrient distribution was significantly different ($p < 0.001$) across
242 European regions (Table 1). Southern European participants consumed the highest fat
243 content in their diet ($p < 0.001$), mainly attributable to olive oil, as MUFA intake was
244 higher (15.2 ± 3.8 %E, $p < 0.001$) and SFA intake was lower (13.5 ± 3.1 %E) in southern
245 European participants compared with other EU Regions. Protein intake was
246 significantly higher in Southern Europe (18.6 ± 4.1 %E) compared with Western Europe
247 (16.0 ± 2.9 %E), Eastern Europe (16.8 ± 3.3 %E) and the British Isles (16.3 ± 3.1 %E).
248 Southern Europeans consumed the largest proportion of animal protein (12.2%E) and
249 the lowest percentage of vegetable protein (4.7%), compared with other regions.
250 Western Europe and British Isles participants consumed more dietary fibre (33 g/day),
251 while Eastern Europeans showed the highest intake of carbohydrates (49.2 ± 7.1 %E) and
252 simple sugars (22.0 ± 6.6 %E) compared to the other regions.

253 When participants were grouped according to age (Table 2), the youngest participants
254 were lighter and had lower BMI (70.6 kg and 24.1 kg/m^2 vs 76.9 kg and 26.4 kg/m^2 ;
255 $p < 0.001$ in both measures), as well as higher physical activity level (1.53 vs 1.50
256 arbitrary units, $p < 0.001$). Dietary intake was similar between age groups, and there were
257 only very highly significant differences ($p < 0.001$) for intake of PUFA and dietary fibre,
258 which was higher in the group > 40 years-old (Table 2). Also, a significant difference

259 (p=0.02) in protein intake was observed, as younger participants consumed more than
260 older subjects.

261 As expected, when men were compared with women, significant differences (p<0.001)
262 were found in all the analysed outcomes, concerning anthropometry, physical activity
263 level and dietary intake (table 2), except for protein and carbohydrates intake.

264 Finally, regression analysis of BMI as dependent variable and protein intake (%E) as
265 the independent variable, adjusted for age, sex, country of origin, total energy intake
266 and physical activity level, showed a weak but significant positive association ($\beta= 0.12$;
267 $p < 0.001$). Comparing participants with BMI below 25 kg/m² (n=1322) with those
268 presenting overweight or obesity (BMI \geq 25 kg/m²; n=1091), this second group were
269 significantly older and practised significantly less physical activity (table 2). In relation
270 to nutrient intake, those presenting overweight reported higher energy intakes
271 (p<0.001). In addition, the overweight group showed a slight but significantly higher
272 proportion of total fat (p=0.046) and lower carbohydrates (p<0.001) in their diets. Also,
273 those subjects with overweight reported significantly higher intakes of total protein
274 (p<0.001).

275 **Contribution of food groups to reported protein intakes**

276 When the sources of protein were evaluated separately (Figure 2a), animal products
277 were the major contributors to dietary protein intake in all regions, although differences
278 between regions were highly significant (p<0.001) for the main protein sources: meat,
279 fish and eggs (33.5% Western Europe, 37.4% Eastern Europe; 39.5% British Isles; and
280 46.7% Southern Europe); dairy products (19.4% Western Europe; 19.9% Eastern
281 Europe; 17.1% British Isles; 16.6% Southern Europe); bread, grains, pasta and rice
282 (27.8% Western Europe; 25.7% Eastern Europe; 22.8% British Isles; 18.8% Southern
283 Europe) or vegetables (7.6% Western Europe; 5.9% Eastern Europe; 9.1% British Isles;
284 7.8% Southern Europe).

285 Moreover, protein sources in overweight/obese subjects, differed significantly from
286 those reported by participants with BMI < 25 kg/m² (Figure 2b). Although meat, fish
287 and eggs were the major contributors for protein in both groups, subjects with lower
288 BMI consumed less animal products than overweight/obese subjects (37.9% vs 42.9%,
289 p<0.001, respectively), while the percentages of cereals, grains, pasta and rice (24.0%),

290 and fruits and vegetables (8.3%) were significantly higher among normal weight
291 subjects than in overweight participants (22% of protein from cereals and 7.1% from
292 fruits and vegetables, $p < 0.001$).

293 **Influence of isoenergetic protein exchange on the risk of overweight/obesity**

294 No relevant changes in relative risks were found within the sensitivity analyses
295 performed according to available cut-offs.

296 When the isocaloric nutrient exchange analysis was performed, according to the method
297 described in the statistics section, the focus was set on evaluating the effect of
298 increasing vegetable protein consumption in isolation from other macronutrients.

299 Therefore, the Prevalence Risk Ratio of increasing 1% of total energy from vegetable
300 protein, and the reduction in 1% of total energy of other nutrients is given (Figure 3).

301 The risk of overweight/obesity was reduced if vegetable protein replaced animal protein
302 ($p = 0.012$), also observed in relation to sugar consumption ($p = 0.006$). The calculated
303 Prevalence Risk Ratio of replacing 1%E of sugar by 1%E of vegetable protein was of
304 0.940 (95% CI: 0.900-0.982), i.e. a reduction of about 6% in the risk of being
305 overweight/obese. With regards to total fat exchange, although not significant, the
306 substitution of total fat by vegetable protein showed a marginal trend to clearly protect
307 against obesity ($p = 0.079$).

308 The comparison of subjects categorised by tertiles for animal and vegetable protein
309 consumption showed significant differences in BMI (Figure 4), with the highest animal
310 protein consumption (above 11.4% of total energy consumption), associated to the
311 highest BMI, and those participants consuming less vegetable protein had BMI > 25
312 kg/m².

313 **Discussion**

314 A major finding was that a higher vegetable protein intake is associated with reduced
315 risk of developing overweight or obesity, whereas a positive association was found for
316 animal protein consumption and the risk of overweight/obesity. Moreover, the current
317 results revealed that self-reported data, collected via the Internet may be useful for
318 acquiring nutritional and socio-demographic information in large cohorts. Although it
319 cannot be completely confirmed whether this is an accurate reflection of the real food
320 intake, this knowledge will enable the future elaboration of a more accurate and directed

321 personalised advice. It must be drawn to one's attention that the FFQ used within the
322 present study had already been validated (Fallaize et al., 2014, Forster et al., 2014,
323 Marshall et al., 2016), with respect to the accuracy in estimating changes in dietary
324 habits, being this feasible and simple tool to estimate nutrient intake for screening,
325 which may be considered more a strength than a limitation (Forster et al., 2016).

326 In agreement with previous studies on dietary habits, Food4Me online participants from
327 Western Europe, Eastern Europe and the British Isles, reported a larger consumption of
328 saturated fats, whereas Greece and Spain presented the largest intakes of MUFA,
329 possibly because their main fat staple source is traditionally olive oil (Osler and Schroll
330 1997, Lasheras et al., 2000, Trichopoulou et al., 2003). Furthermore, differences in meat
331 and fish consumption were reflected in protein intake (larger in southern countries), and
332 in agreement with other studies, reduced intake of grain and potatoes was associated
333 with lower carbohydrates intake in Southern European countries (Naska et al., 2006,
334 Trichopoulou et al., 2007). However, it should be noted that dietary patterns are
335 changing in Mediterranean and other countries towards more westernized patterns (San-
336 Cristobal et al., 2015, da Silva et al., 2009, Vardavas et al., 2010).

337 In relation to differences found between men and women in nutrients intake, it is
338 interesting to highlight that women in the Food4Me study seemed to present "a priori" a
339 less favourable macronutrient profile, according to their reported total fat, saturated fat
340 and sugars consumption, with a lower intake of dietary fibre. These differences seemed
341 inconsistent given that women had a lower BMI and a significantly higher percentage of
342 men were overweight or obese. In this context, the misreporting of overweight/obese
343 subjects may have played a role (Jessri et al., 2016). When normal weight subjects were
344 compared to overweight/obese participants, differences in sugar consumption were
345 observed, being higher in the normal weight group, which may be the result of an
346 inverse causality phenomena, indicating that the expected cause-effect response has not
347 been observed due to a bias in reporting, as previously noted in other studies (Santiago
348 et al., 2015, Santiago et al., 2013). Also, it must be pointed out that a previous analysis
349 of dietary patterns in the Spanish Food4Me participants identified four dietary patterns,
350 which were consistently associated with subjects' weight-status (San-Cristobal et al.,
351 2015). In the Spanish cohort, the "compensatory" pattern, characterised by an
352 overconsumption of both beneficial and detrimental food items, was related to the

353 highest BMI, and a similar association might occur in this larger sample (San-Cristobal
354 et al., 2015).

355 The association observed between protein consumption and BMI has also been reported
356 in several life-stages in previous studies (Alkerwi et al., 2015, Hernandez-Alonso et al.,
357 2016, Lin et al., 2015). The PREDIMED trial (Hernandez-Alonso et al., 2016) as well
358 as the ORISCAV-LUX study (Alkerwi et al., 2015) showed an association between
359 higher risk of obesity and death with higher total and animal protein consumption, but
360 apparently did not report data on protein intake from vegetable sources. With a similar
361 approach, the HELENA study reported an association between total and animal protein
362 consumption and higher risk of obesity in European adolescents (Lin et al., 2015).
363 Interestingly, the HELENA study evidenced a protective effect of vegetable protein
364 consumption in the development of obesity among young Europeans, which is in
365 agreement with our data.

366 In other studies, the dietary intake of protein is positively associated with percent body
367 fat in middle-aged and older adults (Vinknes et al., 2011), and that cysteine intake may
368 be the causal factor (Elshorbagy et al., 2012). Thus, it would be of interest to examine
369 the amino acid pattern of the protein sources of our European populations to achieve
370 new insights. Nevertheless, and taking into account the origin of protein, vegetable
371 protein is accompanied by many other micronutrients and compounds which may play a
372 role in metabolism, and these effects must not be disregarded, given the possibility of
373 interaction of phytochemical activity with energy metabolism [50].

374 In another trial carried out with patients presenting features of the metabolic syndrome,
375 within the RESMENA study (Zulet et al., 2011, de la Iglesia et al., 2014), it was
376 observed that protein quality may have an important impact in overweight/obesity, but
377 also in related diseases (Lopez-Legarrea et al., 2014). In this context, consuming
378 vegetable protein sources under energy restriction was specifically associated to a
379 reduction of inflammatory markers, which allowed to hypothesize that obesity could
380 also be tackled through this anti-inflammatory process. The positive effect of diets
381 differing in macronutrient composition on weight loss has also been previously shown
382 by this research group (Abete et al., 2009). In a study with hypoenergetic diets,
383 additional benefits in consuming high- legumes or high-protein (30%E), were observed
384 (7% and 8% weight loss, respectively, compared to 5% weight loss with a control diet)

385 and mitochondrial oxidation, which led the authors to conclude that an increase in
386 energy expenditure led to a higher basal metabolic rate in the volunteers (Abete et al.,
387 2009). These researchers also observed how inflammatory and lipid markers, and blood
388 pressure improved after the nutritional intervention enriched in protein (Hermsdorff et
389 al., 2011).

390 Focusing on weight maintenance, some nutritional interventions revealed better or
391 similar responses to weight control with diets containing higher protein proportions
392 (Larsen et al., 2010, Navas-Carretero et al., 2016, Keogh et al., 2007, Brinkworth et al.,
393 2004, Clifton et al., 2014). In this context, nutritional interventions such as the
394 DIOGENES study (Larsen et al., 2010) have shown that diets with higher protein
395 content (30%E) and lower glycemic index may have a marginal effect on maintaining
396 the weight loss at 6 months (Larsen et al., 2010) and at 12 months (Aller et al., 2014).
397 Indeed, a more thorough analysis of these results led to the conclusion that gender may
398 also need to be considered as another factor to integrate in the complex process leading
399 to precision nutrition, in order to prescribe the best possible dietary patterns for each
400 subject (Navas-Carretero et al., 2016).

401 Other studies have reported similar positive results, when analysing weight loss and
402 maintenance on higher protein diets compared with control diets as well as on
403 cardiovascular risk markers (Keogh et al., 2007, Brinkworth et al., 2004). In any case,
404 it must be considered that in most of these trials and nutritional interventions, the
405 effectiveness of good adherence to the prescribed diet is essential to achieve successful
406 and sustainable weight loss and maintenance results (Clifton et al., 2014).

407 Different sources of protein have been investigated through intervention studies and
408 epidemiological cohorts showing distinct health responses depending on the animal and
409 vegetable protein intake, where animal protein sources are associated with increased
410 risk of developing obesity-related diseases (Lin et al., 2015). However, white meats or
411 fish products have not been often related to these outcomes (Battaglia Richi et al.,
412 2015), or as in RESMENA study, fish-protein has been correlated, as well as vegetable
413 protein, with positive effects on inflammation (Lopez-Legarrea et al., 2014). The results
414 of the present analysis, suggest that the risk of overweight or obesity was lower when
415 higher amounts of protein from vegetable origin are consumed, whereas animal protein
416 (in general) has been associated with an increased risk for overweight or obesity.

417 Interestingly, substitution of 1% E from sugars by vegetable protein demonstrated a
418 lower prevalence of obesity, in agreement with studies reporting that refined
419 carbohydrates may be implicated in the obesity epidemics (Stanhope 2016). The same
420 trend, although with a marginal statistical evidence, was found with the exchange of
421 1%E from fat by vegetable protein confirming the benefit of vegetable protein increase
422 in the diet (Lopez-Legarrea et al., 2014, Feskens et al., 2014).

423 Current data point to the differential effect and potential interactions of isolated
424 nutrients. Moreover, it shows the importance of the nutrient sources and provides an
425 opportunity for further investigation of dietary patterns. This strategy would take into
426 account the combination of nutrients in a food matrix, behavioural influences, and
427 interaction between different genes (Bauer et al., 2014, Fallaize et al., 2013, Kelly et al.,
428 2016, San-Cristobal et al., 2015), leading personalised nutrition to the next step of
429 precision nutrition, by considering lifestyle, social environment, and clinical features
430 among others (Ferguson et al., 2016).

431 Data collection may be considered a weak point in the present study, given that all
432 measurements were self-reported. However, as mentioned previously, the FFQ used to
433 obtain the analysed data have been validated to ensure the accuracy of measurements
434 (Fallaize et al., 2014, Forster et al., 2014, Marshall et al., 2016). In addition, checking of
435 anthropometrical and genetic markers as proxy for identity was carried out at each
436 intervention centre in a random subsample of the volunteers enrolled in the intervention
437 study (Celis-Morales, Livingstone, Woolhead, et al., 2015). These results showed a
438 strong validity and agreement between the self-reported data and data collected by
439 trained researchers (Celis-Morales, Livingstone, Woolhead, et al., 2015). It is also worth
440 mentioning as a strength of the study, the nutrient substitution model used in the
441 analyses, which has been widely used since it was developed (Hu et al., 1999) and
442 allows to study the association of the substitution of isolated nutrients, as well as some
443 interactions, while energy intake is kept constant, as previously reported (Moslehi et al.,
444 2015, Skilton et al., 2008, Vergnaud et al., 2013).

445 Nevertheless, some limitations that the current analysis might present must also be
446 mentioned. In this sense, the consideration of “crude” isolated macronutrients on
447 overweight or obesity might disregard some synergistic effects of micronutrients
448 contained in foods that are source of vegetable or animal protein, such as

449 phytochemicals, vitamins or fibre, and minerals, respectively. It must also be noted that
450 the use of BMI as a marker of adiposity, may underestimate cases of high adipose tissue
451 within a normal weight. However, and acknowledging the limitations, the measure of
452 BMI is still widely used as a proxy screening tool in population studies [10, 47, 48].

453 The need of developing valid, feasible, effective and economic personalised medicine
454 strategies will also have an impact on precision nutrition, with individual and public
455 health perspectives. In this context, the Food4Me study hypothesized that web-based
456 contact with subjects interested in improving their nutritional status is feasible, and
457 internet-based personalised nutritional advice (Celis-Morales, Livingstone, Marsaux, et
458 al., 2015) may be a future tool for preventing and managing non-communicable
459 diseases, although the impact of these type of interventions in subjects suffering from
460 specific diseases needs to be assessed. Taking into account differences in macronutrient
461 intakes among countries, a “One size fits all” strategy may be inappropriate, while more
462 specific messages, such as increasing vegetable protein consumption, may be easier to
463 deliver. Indeed, personalising nutritional advice based on the phenotype of individuals,
464 as well as their previous dietary habits may advance our understanding of precision
465 nutrition, because dietary habits differ substantially in European regions (Livingstone et
466 al., 2016). Although from a public health nutrition point of view, general
467 recommendations are advisable, the need for combining general messages with nutrient-
468 specific targets depending on the region is becoming urgent to reduce the epidemic of
469 obesity and accompanying diseases, such as diabetes, hypertension and dislipemia
470 (Pavlovic et al., 2007, Jankovic et al., 2015, Kirwan et al., 2016), and messages
471 stressing the role of protein and the possible effects depending on the protein quality
472 and sources may be beneficial in this public health actions.

473 **Conclusion**

474 In conclusion, the present results shed light on the differential role of protein quality in
475 the occurrence of overweight/obesity, stressing the importance of increasing vegetable
476 protein sources in our diet, in substitution of animal protein and simple sugars.
477 Differences found in macronutrient intakes depending on region of origin, sex, age and
478 physical activity also point to the importance of personalised nutrition in targeting
479 successful messages for a healthier lifestyles.

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489 **Competing interests**

490 The authors declare that they have no conflict of interest concerning this research

491 **Authorship**

492 Author responsibilities were as follows: SNC and RSC drafted the paper and performed
493 the statistical analysis for the manuscript. SNC and RSC are joint first authors. JAM was
494 the responsible of Spanish centre of intervention. MG, JCM, JAM, CCM, MCW, ERG, LB,
495 WHMS, HD, CAD, JAL, YM and IT, contributed to the research design. SNC, RSC, KML,
496 CFM, CO'D, HF, CW, ALM, RF, GM, CPL, MJ, and AS conducted the intervention. All
497 authors contributed to a critical review of the manuscript during the writing process.
498 All authors approved the final version to be published.

499 **Ethical Standards Disclosure**

500 All procedures performed in the study were in accordance with the ethical standards
501 of the corresponding research committees of each of the seven participating centres,
502 and with the 1964 Helsinki declaration and its later amendments or comparable ethical
503 standards. Written informed consent was obtained from all individual participants
504 included in the study.

505 The Research Ethics Committees evaluating the study protocol were those with the
506 appropriate authority in each study site: University College Dublin, Ireland; University
507 of Maastricht, Netherlands; Universidad de Navarra, Spain; Harokopio University,
508 Greece; The University of Reading, United Kingdom; National Food and Nutrition
509 Institute, Poland; Technische Universitaet Muenchen, German.

510 Being the study coordinator Ireland, the relevant Health Authority in Food4Me study
511 was the Research Ethics Committee of Ireland.

512 The Food4Me trial was registered as a RCT (NCT01530139) at clinicaltrials.gov
513 (<http://clinicaltrials.gov/show/NCT01530139>).

514

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516 **References**

- 517 Abete, I., Parra, D. & Martinez, J. A. (2009). Legume-, fish-, or high-protein-based hypocaloric
518 diets: effects on weight loss and mitochondrial oxidation in obese men. *J Med Food*,
519 **12**, 100-8.
- 520 Alkerwi, A., Sauvageot, N., Buckley, J. D., Donneau, A. F., Albert, A., Guillaume, M. & Crichton,
521 G. E. (2015). The potential impact of animal protein intake on global and abdominal
522 obesity: evidence from the Observation of Cardiovascular Risk Factors in Luxembourg
523 (ORISCAV-LUX) study. *Public Health Nutr*, **18**, 1831-8.
- 524 Aller, E. E., Larsen, T. M., Claus, H., Lindroos, A. K., Kafatos, A., Pfeiffer, A., Martinez, J. A.,
525 Handjieva-Darlenska, T., Kunesova, M., Stender, S., Saris, W. H., Astrup, A. & van Baak,
526 M. A. (2014). Weight loss maintenance in overweight subjects on ad libitum diets with
527 high or low protein content and glycemic index: the DIOGENES trial 12-month results.
528 *Int J Obes (Lond)*, **38**, 1511-7.

529 Battaglia Richi, E., Baumer, B., Conrad, B., Darioli, R., Schmid, A. & Keller, U. (2015). Health
530 Risks Associated with Meat Consumption: A Review of Epidemiological Studies. *Int J*
531 *Vitam Nutr Res*, **85**, 70-8.

532 Bauer, D. C., Gaff, C., Dinger, M. E., Caramins, M., Buske, F. A., Fenech, M., Hansen, D. &
533 Cobiac, L. (2014). Genomics and personalised whole-of-life healthcare. *Trends Mol*
534 *Med*, **20**, 479-86.

535 Black, A. E. (2000). Critical evaluation of energy intake using the Goldberg cut-off for energy
536 intake: basal metabolic rate. A practical guide to its calculation, use and limitations. *Int*
537 *J Obes Relat Metab Disord*, **24**, 1119-30.

538 Brinkworth, G. D., Noakes, M., Keogh, J. B., Luscombe, N. D., Wittert, G. A. & Clifton, P. M.
539 (2004). Long-term effects of a high-protein, low-carbohydrate diet on weight control
540 and cardiovascular risk markers in obese hyperinsulinemic subjects. *Int J Obes Relat*
541 *Metab Disord*, **28**, 661-70.

542 Cecchini, M., Sassi, F., Lauer, J. A., Lee, Y. Y., Guajardo-Barron, V. & Chisholm, D. (2010).
543 Tackling of unhealthy diets, physical inactivity, and obesity: health effects and cost-
544 effectiveness. *Lancet*, **376**, 1775-84.

545 Celis-Morales, C., Livingstone, K. M., Marsaux, C. F., Forster, H., O'Donovan, C. B., Woolhead,
546 C., Macready, A. L., Fallaize, R., Navas-Carretero, S., San-Cristobal, R., Kolossa, S.,
547 Hartwig, K., Tsirigoti, L., Lambrinou, C. P., Moschonis, G., Godlewska, M., Surwillo, A.,
548 Grimaldi, K., Bouwman, J., Daly, E. J., Akujobi, V., O'Riordan, R., Hoonhout, J., Claassen,
549 A., Hoeller, U., Gundersen, T. E., Kaland, S. E., Matthews, J. N., Manios, Y., Traczyk, I.,
550 Drevon, C. A., Gibney, E. R., Brennan, L., Walsh, M. C., Lovegrove, J. A., Alfredo
551 Martinez, J., Saris, W. H., Daniel, H., Gibney, M. & Mathers, J. C. (2015). Design and
552 baseline characteristics of the Food4Me study: a web-based randomised controlled
553 trial of personalised nutrition in seven European countries. *Genes Nutr*, **10**, 450.

554 Celis-Morales, C., Livingstone, K. M., Woolhead, C., Forster, H., O'Donovan, C. B., Macready, A.
555 L., Fallaize, R., Marsaux, C. F., Tsirigoti, L., Efstathopoulou, E., Moschonis, G., Navas-
556 Carretero, S., San-Cristobal, R., Kolossa, S., Klein, U. L., Hallmann, J., Godlewska, M.,
557 Surwillo, A., Drevon, C. A., Bouwman, J., Grimaldi, K., Parnell, L. D., Manios, Y., Traczyk,
558 I., Gibney, E. R., Brennan, L., Walsh, M. C., Lovegrove, J. A., Martinez, J. A., Daniel, H.,
559 Saris, W. H., Gibney, M. & Mathers, J. C. (2015). How reliable is internet-based self-
560 reported identity, socio-demographic and obesity measures in European adults? *Genes*
561 *Nutr*, **10**, 476.

562 Clifton, P. M., Condo, D. & Keogh, J. B. (2014). Long term weight maintenance after advice to
563 consume low carbohydrate, higher protein diets--a systematic review and meta
564 analysis. *Nutr Metab Cardiovasc Dis*, **24**, 224-35.

565 Collaborators, G. B. D. R. F. (2016). Global, regional, and national comparative risk assessment
566 of 79 behavioural, environmental and occupational, and metabolic risks or clusters of
567 risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015.
568 *Lancet*, **388**, 1659-1724.

569 da Silva, R., Bach-Faig, A., Raimo Quintana, B., Buckland, G., Vaz de Almeida, M. D. & Serra-
570 Majem, L. (2009). Worldwide variation of adherence to the Mediterranean diet, in
571 1961-1965 and 2000-2003. *Public Health Nutr*, **12**, 1676-84.

572 de la Iglesia, R., Lopez-Legarrea, P., Abete, I., Bondia-Pons, I., Navas-Carretero, S., Forga, L.,
573 Martinez, J. A. & Zulet, M. A. (2014). A new dietary strategy for long-term treatment of
574 the metabolic syndrome is compared with the American Heart Association (AHA)
575 guidelines: the MEtabolic Syndrome REduction in NAvarra (RESMENA) project. *Br J*
576 *Nutr*, **111**, 643-52.

577 Elshorbagy, A. K., Kozich, V., Smith, A. D. & Refsum, H. (2012). Cysteine and obesity:
578 consistency of the evidence across epidemiologic, animal and cellular studies. *Curr*
579 *Opin Clin Nutr Metab Care*, **15**, 49-57.

580 Fallaize, R., Forster, H., Macready, A. L., Walsh, M. C., Mathers, J. C., Brennan, L., Gibney, E. R.,
581 Gibney, M. J. & Lovegrove, J. A. (2014). Online dietary intake estimation:
582 reproducibility and validity of the Food4Me food frequency questionnaire against a 4-
583 day weighed food record. *J Med Internet Res*, **16**, e190.

584 Fallaize, R., Macready, A. L., Butler, L. T., Ellis, J. A., Berezowska, A., Fischer, A. R., Walsh, M. C.,
585 Gallagher, C., Stewart-Knox, B. J., Kuznesof, S., Frewer, L. J., Gibney, M. J. & Lovegrove,
586 J. A. (2015). The perceived impact of the National Health Service on personalised
587 nutrition service delivery among the UK public. *Br J Nutr*, **113**, 1271-9.

588 Fallaize, R., Macready, A. L., Butler, L. T., Ellis, J. A. & Lovegrove, J. A. (2013). An insight into the
589 public acceptance of nutrigenomic-based personalised nutrition. *Nutr Res Rev*, **26**, 39-
590 48.

591 Ferguson, L. R., De Caterina, R., Gorman, U., Allayee, H., Kohlmeier, M., Prasad, C., Choi, M. S.,
592 Curi, R., de Luis, D. A., Gil, A., Kang, J. X., Martin, R. L., Milagro, F. I., Nicoletti, C. F.,
593 Nonino, C. B., Ordovas, J. M., Parslow, V. R., Portillo, M. P., Santos, J. L., Serhan, C. N.,
594 Simopoulos, A. P., Velazquez-Arellano, A., Zulet, M. A. & Martinez, J. A. (2016). Guide
595 and Position of the International Society of Nutrigenetics/Nutrigenomics on
596 Personalised Nutrition: Part 1 - Fields of Precision Nutrition. *J Nutrigenet*
597 *Nutrigenomics*, **9**, 12-27.

598 Feskens, E. J., Sluik, D. & Du, H. (2014). The Association Between Diet and Obesity in Specific
599 European Cohorts: DiOGenes and EPIC-PANACEA. *Curr Obes Rep*, **3**, 67-78.

600 Food4Me [internet]. 2011. [cited 15/02/2016]. Available from: <http://www.food4me.org/>

601 Forster, H., Fallaize, R., Gallagher, C., O'Donovan, C. B., Woolhead, C., Walsh, M. C., Macready,
602 A. L., Lovegrove, J. A., Mathers, J. C., Gibney, M. J., Brennan, L. & Gibney, E. R. (2014).
603 Online dietary intake estimation: the Food4Me food frequency questionnaire. *J Med*
604 *Internet Res*, **16**, e150.

605 Forster, H., Walsh, M. C., Gibney, M. J., Brennan, L. & Gibney, E. R. (2016). Personalised
606 nutrition: the role of new dietary assessment methods. *Proc Nutr Soc*, **75**, 96-105.

607 Gibney, M. J. & Walsh, M. C. (2013). The future direction of personalised nutrition: my diet, my
608 phenotype, my genes. *Proc Nutr Soc*, **72**, 219-25.

609 Grosso, G., Bella, F., Godos, J., Sciacca, S., Del Rio, D., Ray, S., Galvano, F. & Giovannucci, E. L.
610 (2017). Possible role of diet in cancer: systematic review and multiple meta-analyses of
611 dietary patterns, lifestyle factors, and cancer risk. *Nutr Rev*, **75**, 405-419.

612 Hafekost, K., Lawrence, D., Mitrou, F., O'Sullivan, T. A. & Zubrick, S. R. (2013). Tackling
613 overweight and obesity: does the public health message match the science? *BMC Med*,
614 **11**, 41.

615 Hermsdorff, H. H., Zulet, M. A., Abete, I. & Martinez, J. A. (2011). A legume-based hypocaloric
616 diet reduces proinflammatory status and improves metabolic features in
617 overweight/obese subjects. *Eur J Nutr*, **50**, 61-9.

618 Hernandez-Alonso, P., Salas-Salvado, J., Ruiz-Canela, M., Corella, D., Estruch, R., Fito, M., Aros,
619 F., Gomez-Gracia, E., Fiol, M., Lapetra, J., Basora, J., Serra-Majem, L., Munoz, M. A.,
620 Buil-Cosiales, P., Saiz, C. & Bullo, M. (2016). High dietary protein intake is associated
621 with an increased body weight and total death risk. *Clin Nutr*, **35**, 496-506.

622 Hu, F. B., Stampfer, M. J., Rimm, E., Ascherio, A., Rosner, B. A., Spiegelman, D. & Willett, W. C.
623 (1999). Dietary fat and coronary heart disease: a comparison of approaches for
624 adjusting for total energy intake and modeling repeated dietary measurements. *Am J*
625 *Epidemiol*, **149**, 531-40.

626 Jankovic, N., Geelen, A., Streppel, M. T., de Groot, L. C., Kieft-de Jong, J. C., Orfanos, P.,
627 Bamia, C., Trichopoulou, A., Boffetta, P., Bobak, M., Pikhart, H., Kee, F., O'Doherty, M.
628 G., Buckland, G., Woodside, J., Franco, O. H., Ikram, M. A., Struijk, E. A., Pajak, A.,
629 Maljutina, S., Kubinova, R., Wennberg, M., Park, Y., Bueno-de-Mesquita, H. B.,
630 Kampman, E. & Feskens, E. J. (2015). WHO guidelines for a healthy diet and mortality

631 from cardiovascular disease in European and American elderly: the CHANCES project.
632 *Am J Clin Nutr*, **102**, 745-56.

633 Jessri, M., Lou, W. Y. & L'Abbe, M. R. (2016). Evaluation of different methods to handle
634 misreporting in obesity research: evidence from the Canadian national nutrition
635 survey. *Br J Nutr*, **115**, 147-59.

636 Kelly, S., Martin, S., Kuhn, I., Cowan, A., Brayne, C. & LaFortune, L. (2016). Barriers and
637 Facilitators to the Uptake and Maintenance of Healthy Behaviours by People at Mid-
638 Life: A Rapid Systematic Review. *PLoS One*, **11**, e0145074.

639 Keogh, J. B., Luscombe-Marsh, N. D., Noakes, M., Wittert, G. A. & Clifton, P. M. (2007). Long-
640 term weight maintenance and cardiovascular risk factors are not different following
641 weight loss on carbohydrate-restricted diets high in either monounsaturated fat or
642 protein in obese hyperinsulinaemic men and women. *Br J Nutr*, **97**, 405-10.

643 Kirwan, L., Walsh, M. C., Brennan, L., Gibney, E. R., Drevon, C. A., Daniel, H., Lovegrove, J. A.,
644 Manios, Y., Martinez, J. A., Saris, W. H., Traczyk, I., Mathers, J. C. & Gibney, M. (2016).
645 Comparison of the portion size and frequency of consumption of 156 foods across
646 seven European countries: insights from the Food4ME study. *Eur J Clin Nutr*, **70**, 642-4.

647 Kumanyika, S. K., Obarzanek, E., Stettler, N., Bell, R., Field, A. E., Fortmann, S. P., Franklin, B. A.,
648 Gillman, M. W., Lewis, C. E., Poston, W. C., 2nd, Stevens, J. & Hong, Y. (2008).
649 Population-based prevention of obesity: the need for comprehensive promotion of
650 healthful eating, physical activity, and energy balance: a scientific statement from
651 American Heart Association Council on Epidemiology and Prevention, Interdisciplinary
652 Committee for Prevention (formerly the expert panel on population and prevention
653 science). *Circulation*, **118**, 428-64.

654 Larsen, T. M., Dalskov, S. M., van Baak, M., Jebb, S. A., Papadaki, A., Pfeiffer, A. F., Martinez, J.
655 A., Handjieva-Darlenska, T., Kunesova, M., Pihlsgard, M., Stender, S., Holst, C., Saris, W.
656 H. & Astrup, A. (2010). Diets with high or low protein content and glycemic index for
657 weight-loss maintenance. *N Engl J Med*, **363**, 2102-13.

658 Lasheras, C., Fernandez, S. & Patterson, A. M. (2000). Mediterranean diet and age with respect
659 to overall survival in institutionalized, nonsmoking elderly people. *Am J Clin Nutr*, **71**,
660 987-92.

661 Levine, M. E., Suarez, J. A., Brandhorst, S., Balasubramanian, P., Cheng, C. W., Madia, F.,
662 Fontana, L., Mirisola, M. G., Guevara-Aguirre, J., Wan, J., Passarino, G., Kennedy, B. K.,
663 Wei, M., Cohen, P., Crimmins, E. M. & Longo, V. D. (2014). Low protein intake is
664 associated with a major reduction in IGF-1, cancer, and overall mortality in the 65 and
665 younger but not older population. *Cell Metab*, **19**, 407-17.

666 Lin, Y., Mouratidou, T., Vereecken, C., Kersting, M., Bolca, S., de Moraes, A. C., Cuenca-Garcia,
667 M., Moreno, L. A., Gonzalez-Gross, M., Valtuena, J., Labayen, I., Grammatikaki, E.,
668 Hallstrom, L., Leclercq, C., Ferrari, M., Gottrand, F., Beghin, L., Manios, Y., Ottevaere,
669 C., Van Oyen, H., Molnar, D., Kafatos, A., Widhalm, K., Gomez-Martinez, S., Prieto, L. E.,
670 De Henauw, S. & Huybrechts, I. (2015). Dietary animal and plant protein intakes and
671 their associations with obesity and cardio-metabolic indicators in European
672 adolescents: the HELENA cross-sectional study. *Nutr J*, **14**, 10.

673 Livingstone, K. M., Celis-Morales, C., Navas-Carretero, S., San-Cristobal, R., O'Donovan, C. B.,
674 Forster, H., Woolhead, C., Marsaux, C. F., Macready, A. L., Fallaize, R., Kolossa, S.,
675 Tsigirioti, L., Lambrinou, C. P., Moschonis, G., Godlewska, M., Surwillo, A., Drevon, C. A.,
676 Manios, Y., Traczyk, I., Gibney, E. R., Brennan, L., Walsh, M. C., Lovegrove, J. A., Alfredo
677 Martinez, J., Saris, W. H., Daniel, H., Gibney, M. & Mathers, J. C. (2016). Profile of
678 European adults interested in internet-based personalised nutrition: the Food4Me
679 study. *Eur J Nutr*, **55**, 759-69.

680 Lopez-Legarrea, P., de la Iglesia, R., Abete, I., Navas-Carretero, S., Martinez, J. A. & Zulet, M. A.
681 (2014). The protein type within a hypocaloric diet affects obesity-related
682 inflammation: the RESMENA project. *Nutrition*, **30**, 424-9.

683 Marsaux, C. F., Celis-Morales, C., Hoonhout, J., Claassen, A., Goris, A., Forster, H., Fallaize, R.,
684 Macready, A. L., Navas-Carretero, S., Kolossa, S., Walsh, M. C., Lambrinou, C. P.,
685 Manios, Y., Godlewska, M., Traczyk, I., Lovegrove, J. A., Martinez, J. A., Daniel, H.,
686 Gibney, M., Mathers, J. C. & Saris, W. H. (2016). Objectively Measured Physical Activity
687 in European Adults: Cross-Sectional Findings from the Food4Me Study. *PLoS One*, **11**,
688 e0150902.

689 Marshall, S. J., Livingstone, K. M., Celis-Morales, C., Forster, H., Fallaize, R., O'Donovan, C. B.,
690 Woolhead, C., Marsaux, C. F., Macready, A. L., Navas-Carretero, S., San-Cristobal, R.,
691 Kolossa, S., Tsigoti, L., Lambrinou, C. P., Moschonis, G., Godlewska, M., Surwillo, A.,
692 Drevon, C. A., Manios, Y., Traczyk, I., Martinez, J. A., Saris, W. H., Daniel, H., Gibney, E.
693 R., Brennan, L., Walsh, M. C., Lovegrove, J. A., Gibney, M. & Mathers, J. C. (2016).
694 Reproducibility of the Online Food4Me Food-Frequency Questionnaire for Estimating
695 Dietary Intakes across Europe. *J Nutr*, **146**, 1068-75.

696 Mathers, J. C. (2015). Impact of nutrition on the ageing process. *Br J Nutr*, **113 Suppl**, S18-22.

697 McCance, R. A., Widdowson, E. M., Royal Society of Chemistry (Great Britain), Food Standards
698 Agency (Great Britain) & AFRC Institute of Food Research (2002). The composition of
699 foods. Pp. XV, 537 p. Cambridge (UK) London, Royal Society of Chemistry ;

700 Milte, C. M. & McNaughton, S. A. (2015). Dietary patterns and successful ageing: a systematic
701 review. *Eur J Nutr*.

702 Moslehi, N., Ehsani, B., Mirmiran, P., Hojjat, P. & Azizi, F. (2015). Association of Dietary
703 Proportions of Macronutrients with Visceral Adiposity Index: Non-Substitution and Iso-
704 Energetic Substitution Models in a Prospective Study. *Nutrients*, **7**, 8859-70.

705 Naska, A., Fouskakis, D., Oikonomou, E., Almeida, M. D., Berg, M. A., Gedrich, K., Moreiras, O.,
706 Nelson, M., Trygg, K., Turrini, A., Remaut, A. M., Volatier, J. L. & Trichopoulou, A.
707 (2006). Dietary patterns and their socio-demographic determinants in 10 European
708 countries: data from the DAFNE databank. *Eur J Clin Nutr*, **60**, 181-90.

709 Nations, U. U. [internet]. [cited 05/11/2015]. Available from:
710 <http://millenniumindicators.un.org/unsd/methods/m49/m49regin.htm>

711 Navas-Carretero, S., Holst, C., Saris, W. H., van Baak, M. A., Jebb, S. A., Kafatos, A., Papadaki,
712 A., Pfeiffer, A. F., Handjieva-Darlenska, T., Hlavaty, P., Stender, S., Larsen, T. M., Astrup,
713 A. & Martinez, J. A. (2016). The Impact of Gender and Protein Intake on the Success of
714 Weight Maintenance and Associated Cardiovascular Risk Benefits, Independent of the
715 Mode of Food Provision: The DiOGenes Randomized Trial. *J Am Coll Nutr*, **35**, 20-30.

716 Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E. C.,
717 Biryukov, S., Abbafati, C., Abera, S. F., Abraham, J. P., Abu-Rmeileh, N. M., Achoki, T.,
718 AlBuhairan, F. S., Alemu, Z. A., Alfonso, R., Ali, M. K., Ali, R., Guzman, N. A., Ammar, W.,
719 Anwari, P., Banerjee, A., Barquera, S., Basu, S., Bennett, D. A., Bhutta, Z., Blore, J.,
720 Cabral, N., Nonato, I. C., Chang, J. C., Chowdhury, R., Courville, K. J., Criqui, M. H.,
721 Cundiff, D. K., Dabhadkar, K. C., Dandona, L., Davis, A., Dayama, A., Dharmaratne, S. D.,
722 Ding, E. L., Durrani, A. M., Esteghamati, A., Farzadfar, F., Fay, D. F., Feigin, V. L.,
723 Flaxman, A., Forouzanfar, M. H., Goto, A., Green, M. A., Gupta, R., Hafezi-Nejad, N.,
724 Hankey, G. J., Harewood, H. C., Havmoeller, R., Hay, S., Hernandez, L., Husseini, A.,
725 Idrisov, B. T., Ikeda, N., Islami, F., Jahangir, E., Jassal, S. K., Jee, S. H., Jeffreys, M., Jonas,
726 J. B., Kabagambe, E. K., Khalifa, S. E., Kengne, A. P., Khader, Y. S., Khang, Y. H., Kim, D.,
727 Kimokoti, R. W., Kinge, J. M., Kokubo, Y., Kosen, S., Kwan, G., Lai, T., Leinsalu, M., Li, Y.,
728 Liang, X., Liu, S., Logroscino, G., Lotufo, P. A., Lu, Y., Ma, J., Mainoo, N. K., Mensah, G.
729 A., Merriman, T. R., Mokdad, A. H., Moschandreas, J., Naghavi, M., Naheed, A., Nand,
730 D., Narayan, K. M., Nelson, E. L., Neuhouser, M. L., Nisar, M. I., Ohkubo, T., Oti, S. O.,
731 Pedroza, A., et al. (2014). Global, regional, and national prevalence of overweight and
732 obesity in children and adults during 1980-2013: a systematic analysis for the Global
733 Burden of Disease Study 2013. *Lancet*, **384**, 766-81.

734 Osler, M. & Schroll, M. (1997). Diet and mortality in a cohort of elderly people in a north
735 European community. *Int J Epidemiol*, **26**, 155-9.

736 Pavlovic, M., Prentice, A., Thorsdottir, I., Wolfram, G. & Branca, F. (2007). Challenges in
737 harmonizing energy and nutrient recommendations in Europe. *Ann Nutr Metab*, **51**,
738 108-14.

739 Phillips, K., Wood, F. & Kinnersley, P. (2014). Tackling obesity: the challenge of obesity
740 management for practice nurses in primary care. *Fam Pract*, **31**, 51-9.

741 Raguso, C. A., Kyle, U., Kossovsky, M. P., Roynette, C., Paoloni-Giacobino, A., Hans, D., Genton,
742 L. & Pichard, C. (2006). A 3-year longitudinal study on body composition changes in the
743 elderly: role of physical exercise. *Clin Nutr*, **25**, 573-80.

744 Riddle, E. S., Stipanuk, M. H. & Thalacker-Mercer, A. E. (2016). Amino acids in healthy aging
745 skeletal muscle. *Front Biosci (Elite Ed)*, **8**, 326-50.

746 San-Cristobal, R., Milagro, F. I. & Martinez, J. A. (2013). Future challenges and present ethical
747 considerations in the use of personalized nutrition based on genetic advice. *J Acad
748 Nutr Diet*, **113**, 1447-54.

749 San-Cristobal, R., Navas-Carretero, S., Celis-Morales, C., Brennan, L., Walsh, M., Lovegrove, J.
750 A., Daniel, H., Saris, W. H., Traczyk, I., Manios, Y., Gibney, E. R., Gibney, M. J., Mathers,
751 J. C. & Martinez, J. A. (2015). Analysis of Dietary Pattern Impact on Weight Status for
752 Personalised Nutrition through On-Line Advice: The Food4Me Spanish Cohort.
753 *Nutrients*, **7**, 9523-37.

754 Santiago, S., Sayon-Orea, C., Babio, N., Ruiz-Canela, M., Marti, A., Corella, D., Estruch, R., Fito,
755 M., Aros, F., Ros, E., Gomez-Garcia, E., Fiol, M., Lapetra, J., Serra-Majem, L., Becerra-
756 Tomas, N., Salas-Salvado, J., Pinto, X., Schroder, H. & Martinez, J. A. (2015). Yogurt
757 consumption and abdominal obesity reversion in the PREDIMED study. *Nutr Metab
758 Cardiovasc Dis*.

759 Santiago, S., Zazpe, I., Marti, A., Cuervo, M. & Martinez, J. A. (2013). Gender differences in
760 lifestyle determinants of overweight prevalence in a sample of Southern European
761 children. *Obes Res Clin Pract*, **7**, e391-400.

762 Skilton, M. R., Laville, M., Cust, A. E., Moulin, P. & Bonnet, F. (2008). The association between
763 dietary macronutrient intake and the prevalence of the metabolic syndrome. *Br J Nutr*,
764 **100**, 400-7.

765 Srikanthan, P. & Karlamangla, A. S. (2014). Muscle mass index as a predictor of longevity in
766 older adults. *Am J Med*, **127**, 547-53.

767 Stanhope, K. L. (2016). Sugar consumption, metabolic disease and obesity: The state of the
768 controversy. *Crit Rev Clin Lab Sci*, **53**, 52-67.

769 Stenholm, S., Rantanen, T., Alanen, E., Reunanen, A., Sainio, P. & Koskinen, S. (2007). Obesity
770 history as a predictor of walking limitation at old age. *Obesity (Silver Spring)*, **15**, 929-
771 38.

772 Stenholm, S., Sainio, P., Rantanen, T., Koskinen, S., Jula, A., Heliövaara, M. & Aromaa, A.
773 (2007). High body mass index and physical impairments as predictors of walking
774 limitation 22 years later in adult Finns. *J Gerontol A Biol Sci Med Sci*, **62**, 859-65.

775 Trichopoulou, A., Bamia, C., Norat, T., Overvad, K., Schmidt, E. B., Tjønneland, A., Halkjaer, J.,
776 Clavel-Chapelon, F., Vercaembre, M. N., Boutron-Ruault, M. C., Linseisen, J., Rohrmann,
777 S., Boeing, H., Weikert, C., Benetou, V., Psaltopoulou, T., Orfanos, P., Boffetta, P.,
778 Masala, G., Pala, V., Panico, S., Tumino, R., Sacerdote, C., Bueno-de-Mesquita, H. B.,
779 Ocke, M. C., Peeters, P. H., Van der Schouw, Y. T., Gonzalez, C., Sanchez, M. J.,
780 Chirlaque, M. D., Moreno, C., Larranaga, N., Van Guelpen, B., Jansson, J. H., Bingham,
781 S., Khaw, K. T., Spencer, E. A., Key, T., Riboli, E. & Trichopoulos, D. (2007). Modified
782 Mediterranean diet and survival after myocardial infarction: the EPIC-Elderly study. *Eur
783 J Epidemiol*, **22**, 871-81.

784 Trichopoulou, A., Costacou, T., Bamia, C. & Trichopoulos, D. (2003). Adherence to a
785 Mediterranean diet and survival in a Greek population. *N Engl J Med*, **348**, 2599-608.

786 Vardavas, C. I., Linardakis, M. K., Hatzis, C. M., Saris, W. H. & Kafatos, A. G. (2010).
787 Cardiovascular disease risk factors and dietary habits of farmers from Crete 45 years
788 after the first description of the Mediterranean diet. *Eur J Cardiovasc Prev Rehabil*, **17**,
789 440-6.

790 Vergnaud, A. C., Norat, T., Mouw, T., Romaguera, D., May, A. M., Bueno-de-Mesquita, H. B.,
791 van der, A. D., Agudo, A., Wareham, N., Khaw, K. T., Romieu, I., Freisling, H., Slimani,
792 N., Perquier, F., Boutron-Ruault, M. C., Clavel-Chapelon, F., Palli, D., Berrino, F.,
793 Mattiello, A., Tumino, R., Ricceri, F., Rodriguez, L., Molina-Montes, E., Amiano, P.,
794 Barricarte, A., Chirlaque, M. D., Crowe, F. L., Orfanos, P., Naska, A., Trichopoulou, A.,
795 Teucher, B., Kaaks, R., Boeing, H., Buijsse, B., Johansson, I., Hallmans, G., Drake, I.,
796 Sonestedt, E., Jakobsen, M. U., Overvad, K., Tjonneland, A., Halkjaer, J., Skeie, G.,
797 Braaten, T., Lund, E., Riboli, E. & Peeters, P. H. (2013). Macronutrient composition of
798 the diet and prospective weight change in participants of the EPIC-PANACEA study.
799 *PLoS One*, **8**, e57300.

800 Vinknes, K. J., de Vogel, S., Elshorbagy, A. K., Nurk, E., Drevon, C. A., Gjesdal, C. G., Tell, G. S.,
801 Vollset, S. E. & Refsum, H. (2011). Dietary intake of protein is positively associated with
802 percent body fat in middle-aged and older adults. *J Nutr*, **141**, 440-6.

803 Woods, N. F., Rillamas-Sun, E., Cochrane, B. B., La Croix, A. Z., Seeman, T. E., Tindle, H. A.,
804 Zaslavsky, O., Bird, C. E., Johnson, K. C., Manson, J. E., Ockene, J. K., Seguin, R. A. &
805 Wallace, R. B. (2016). Aging Well: Observations From the Women's Health Initiative
806 Study. *J Gerontol A Biol Sci Med Sci*, **71 Suppl 1**, S3-S12.

807 Zulet, M. A., Bondia-Pons, I., Abete, I., de la Iglesia, R., Lopez-Legarrea, P., Forga, L., Navas-
808 Carretero, S. & Martinez, J. A. (2011). The reduction of the metabolic syndrome in
809 Navarra-Spain (RESMENA-S) study: a multidisciplinary strategy based on
810 chrononutrition and nutritional education, together with dietetic and psychological
811 control. *Nutr Hosp*, **26**, 16-26.

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Table 1. Demographic anthropometric and dietary characteristics of subjects in the Food4Me study by European Regions at screening.

	Total		Western Europe		British Isles		Southern Europe		Eastern Europe		p ¹
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
n (n females)	2413 (1561)		742 (462)		518 (341)		900 (568)		253 (190)		
Age (years)	40.2	13.0	46.0	14.1 ^c	37.8	13.1 ^{a,b}	38.1	10.3 ^b	35.7	12.7 ^a	<0.001
Height (m)	1.71	0.09	1.74	0.09 ^b	1.70	0.09 ^a	1.69	0.09 ^a	1.69	0.08 ^a	<0.001
Weight (kg)	73.6	15.5	74.8	14.5 ^a	72.9	15.7 ^{a,b}	74.0	16.1 ^a	70.4	15.7 ^b	<0.001
BMI (kg/m ²)	25.2	4.7	24.7	4.0 ^a	25.2	4.7 ^a	25.9	5.0 ^b	24.6	4.9 ^a	<0.001
BMI status											
Underweight (< 18.5 kg/m ²)	2.3%		2.4%		2.1%		1.8%		4.3%		
Normal weight (18.5 – 24.99 kg/m ²)	52.5%		56.6%		55.0%		46.9%		54.9%		<0.001 ²
Overweight (25 – 29.9 kg/m ²)	31.1%		30.5%		28.6%		34.2%		26.9%		
Obesity (> 30 kg/m ²)	14.1%		10.5%		14.3%		17.1%		13.8%		
Physical activity factor (AU)	1.51	0.10	1.52	0.10 ^b	1.53	0.10 ^b	1.50	0.10 ^a	1.50	0.11 ^a	<0.001
Energy (kcal/d)	2602	797	2609	744	2632	823	2592	823	2558	802	0.641
Total fat (% E)	35.7	6.4	35.4	6.5 ^a	35.6	6.2 ^{a,b}	36.4	6.6 ^b	34.5	5.7 ^a	<0.001
SFA (% E)	14.0	3.4	14.2	3.6 ^b	14.2	3.4 ^b	13.5	3.1 ^a	14.5	3.6 ^b	<0.001
MUFA (% E)	13.8	3.4	13.0	2.9 ^b	13.2	3.0 ^b	15.2	3.8 ^c	11.9	2.2 ^a	<0.001
PUFA (% E)	5.6	1.4	5.9	1.4 ^b	5.8	1.5 ^b	5.2	1.3 ^a	5.8	1.6 ^b	<0.001
Protein (% E)	17.1	3.6	16.0	2.9 ^a	16.3	3.1 ^{a,b}	18.6	4.1 ^c	16.8	3.3 ^c	<0.001
Animal Protein (%E)	10.3	4.3	8.7	3.6 ^a	9.5	3.6 ^b	12.2	4.7 ^c	9.9	3.8 ^b	<0.001
Vegetable Protein (%E)	5.1	1.7	5.5	1.7 ^c	5.0	1.5 ^b	4.7	1.7 ^a	5.1	1.7 ^b	<0.001
Total carbohydrates (% E)	46.4	8.2	46.9	8.0 ^b	47.1	8.1 ^b	44.7	8.5 ^a	49.2	7.1 ^c	<0.001
Simple sugars (% E)	21.3	6.4	20.8	5.9 ^a	22.0	6.2 ^b	21.1	6.7 ^{a,b}	22.0	6.6 ^b	0.002
Dietary fibre (g)	30.8	13.3	33.4	14.2 ^b	33.1	13.6 ^b	27.3	11.8 ^a	30.8	12.6 ^b	<0.001

Values are expressed as mean and SD (Standard Deviation) or percentages. Western = Netherlands and Germany; British isles = United Kingdom and Ireland; BMI: Body Mass Index; AU = Arbitrary Units; SFA = Saturated fatty acids; MUFA = Monounsaturated fatty acids; PUFA = Polyunsaturated fatty acids; %E = % of total energy intake. ¹Differences between European Regions analysed by one way ANOVA. ²Chi-square p-value for distribution. Different superscript letters mean significant differences among regions (p<0.05) in Tukey post-hoc analysis.

Table 2. Differences among Food4Me screenees according to age, sex and BMI.

	<40 years		≥40 years		p ¹	Male		Female		p ¹	BMI<25 kg/m ²		BMI>25kg/m ²		p ¹
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
n (n females)	1236 (826)		1177 (735)			852		1561			1322 (958)		1091 (603)		
Age (years)	29.4	5.7	51.5	8.0	<0.001	42.0	13.6	39.2	12.6	<0.001	37.4	13.0	43.5	12.3	<0.001
Height (m)	1.71	0.09	1.70	0.09	0.602	1.79	0.07	1.66	0.07	<0.001	1.70	0.09	1.71	0.09	0.118
Weight (kg)	70.6	14.9	76.8	15.6	<0.001	83.8	13.4	68.1	13.7	<0.001	64.0	9.2	85.3	13.5	<0.001
BMI (kg/m ²)	24.1	4.3	26.4	4.7	<0.001	26.3	4.0	24.7	4.9	<0.001	22.0	1.89	29.2	3.9	<0.001
BMI status*															
Under-weight	3.2%		1.4%			0.5%		3.3%							
Normal Weight	62.8%		41.6%		<0.001 ²	42.3%		58.0%		<0.001 ²	NA				
Overweight	25.2%		37.2%			41.5%		25.4%							
Obesity	8.7%		19.8%			15.7%		13.3%							
Physical activity factor (AU)*	1.53	0.11	1.50	0.09		<0.001	1.54	0.12	1.50				0.08	<0.001	1.53
Energy (kcal/d)	2599	808	2606	785	0.617	2888	758	2446	774	<0.001	2481	774	2750	800	<0.001
Total fat (% E)	35.6	6.1	35.7	6.7	0.702	34.8	6.5	36.2	6.3	<0.001	35.4	6.3	36.1	6.5	0.046
SFA (% E)	13.9	3.2	14.0	3.5	0.8019	13.5	3.4	14.2	3.4	<0.001	13.8	3.3	14.1	3.4	0.0168
MUFA (% E)	13.8	3.3	13.7	3.5	0.4697	13.4	3.3	14.0	3.5	<0.001	13.5	3.4	14.0	3.4	0.001
PUFA (% E)	5.5	1.3	5.8	1.5	<0.001	5.5	1.4	5.7	1.4	0.001	5.6	1.4	5.6	1.4	0.5703
Protein (% E)	17.3	3.7	16.9	3.5	0.0205	17.2	3.6	17.1	3.7	0.572	16.9	3.5	17.4	3.7	<0.001
Animal Protein (%E)	10.5	4.3	10.1	4.3	0.010	10.4	4.3	10.3	4.3	0.553	9.9	4.2	10.8	4.4	<0.001
Vegetable Protein (%E)	5.0	1.6	5.1	1.7	0.616	5.1	1.8	5.0	1.6	0.098	5.2	1.7	4.9	1.7	<0.001
Total carbohydrates (% E)	46.7	7.9	46.1	8.6	0.0531	46.1	8.4	46.5	8.1	0.359	47.1	8.1	45.5	8.3	<0.001
Simple sugars (% E)	21.5	6.1	21.1	6.6	0.1457	20.2	5.9	21.9	6.5	<0.001	21.8	6.2	20.7	6.5	<0.001
Dietary fibre (g/day)	29.7	13.1	32.0	13.5	<0.001	32.5	13.9	29.9	12.9	<0.001	31.1	13.8	30.5	12.8	0.300

Values are expressed as mean and SD (Standard Deviation).

BMI = Body Mass Index; AU = Arbitrary Units; SFA = Saturated fatty acids; MUFA = Monounsaturated fatty acids; PUFA = Polyunsaturated fatty acids; % E = % of total energy intake; NA=Not applicable. ¹Differences between groups analysed by one way ANOVA. ²Chi-square p-value for distribution.

* BMI Categories: Underweight (< 18.5 kg/m²); Normal weight (18.5 – 24.99 kg/m²); Overweight (25 – 29.9 kg/m²); Obesity (> 30 kg/m²).

FIGURE TITLES AND FOOTNOTES

Figure 1. Flow-chart for the participants in the online Food4Me screening included in the present study.

Figure 2. Contribution of different Food Groups to protein intake in each EU Region (a), and divided by BMI (<25 kg/m² vs >25 kg/m²) (b).

[Footnote] Protein intake differed between regions and BMI in meat, fish and eggs (p<0.001); cereal, grain, pasta and rice (p<0.001), as well as in dairy products and fruits and vegetables (p<0.001 in both comparisons).

Figure 3. Prevalence Risk Ratio (PRR) of overweight or obesity in Food4Me screenees.

[Footnote] Calculation of PRR was performed according to the isoenergetic substitution (1 %E) of macronutrients by vegetable protein, following the nutrient-density model (n=2413).

Figure 4. Differences in BMI by tertiles of animal protein and vegetable protein intake, in the Food4Me Screenees

[Footnote] Different superscript letters represent significant mean differences between tertiles (p<0.05) in Tukey post-hoc analysis.