

How reliable is internet-based self-reported identity, socio-demographic and obesity measures in European adults?

Article

Accepted Version

Celis-Morales, C., Livingstone, K. M., Woolhead, C., Forster, H., O'Donovan, C. B., Macready, A., Fallaize, R., Marsaux, C. F. M., Tsirigoti, L., Efstathopoulou, E., Moschonis, G., Navas-Carretero, S., San-Cristobal, R., Kolossa, S., Klein, U. L., Hallmann, J., Godlewska, M., Surwiłło, A., Drevon, C. A., Bouwman, J., Grimaldi, K., Parnell, L. D., Manios, Y., Traczyk, I., Gibney, E. R., Brennan, L., Walsh, M. C., Lovegrove, J., Martinez, J. A., Daniel, H., Saris, W. H. M., Gibney, M. and Mathers, J. C. (2015) How reliable is internet-based self-reported identity, socio-demographic and obesity measures in European adults? *Genes and Nutrition*, 10 (5). pp. 476-487. ISSN 1555-8932 doi: <https://doi.org/10.1007/s12263-015-0476-0> Available at <http://centaur.reading.ac.uk/40725/>

It is advisable to refer to the publisher's version if you intend to cite from the work. See [Guidance on citing](#).

Published version at: <http://link.springer.com/article/10.1007%2Fs12263-015-0476-0>

To link to this article DOI: <http://dx.doi.org/10.1007/s12263-015-0476-0>

Publisher: Springer

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the [End User Agreement](#).

www.reading.ac.uk/centaur

CentAUR

Central Archive at the University of Reading

Reading's research outputs online

How reliable is internet-based self-reported identity, socio-demographic and obesity measures in European adults?

Article

Accepted Version

Celis-Morales, C., Livingstone, K., Woolhead, C., Forster, H., O'Donovan, C., Mcready, A., Fallaize, R., Marsaux, C., Tsirigoti, L., Efstathopoulou, E., Moschonis, G., Navas-Carretero, S., San-Cristobal, R., Kolossa, S., Klein, U., Hallmann, J., Godlewska, M., Surwiłło, A., Drevon, C., Bouwman, J., Grimaldi, K., Parnell, L., Manios, Y., Traczyk, I., Gibney, E., Brennan, L., Walsh, M., Lovegrove, J., Martinez, J., Daniel, H., Saris, W., Gibney, M. and Mathers, J. (2015) How reliable is internet-based self-reported identity, socio-demographic and obesity measures in European adults? *Genes and Nutrition*, 10 (5). p. 476. ISSN 1555-8932 doi: 10.1007/s12263-015-0476-0 Available at <http://centaur.reading.ac.uk/40786/>

It is advisable to refer to the publisher's version if you intend to cite from the work.

To link to this article DOI: <http://dx.doi.org/10.1007/s12263-015-0476-0>

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the [End User Agreement](#).

www.reading.ac.uk/centaur

CentAUR

Central Archive at the University of Reading

Reading's research outputs online

1 **VALIDATION OF INTERNET-BASED SELF-REPORTED ANTHROPOMETRIC, DEMOGRAPHIC**
2 **DATA AND PARTICIPANT IDENTITY IN THE FOOD4ME PAN-EUROPEAN STUDY**

3

4 **RUNING TITLE** – Validation of internet –based self-reported data

5

6 **AUTHOR NAMES**

7 Carlos Celis-Morales^{1*}, Katherine M Livingstone^{1*}, Clara Woolhead², Hannah Forster², Clare B O'Donovan²,
8 Anna L Macready³, Rosalind Fallaize³, Cyril F M Marsaux⁴, Lydia Tsirigoti⁵, Eirini Efstathopoulou⁵, George
9 Moschonis⁵, Santiago Navas-Carretero⁶, Rodrigo San-Cristobal⁶, Silvia Kolossa⁷, Ulla L Klein⁷, Jacqueline
10 Hallmann⁷, Magdalena Godlewska⁸, Agnieszka Surwiłło⁸, Christian A Drevon⁹, Jildau Bouwman¹⁰, Keith
11 Grimaldi¹¹, Laurence D Parnell¹², Yannis Manios⁵, Iwona Traczyk⁸, Eileen R Gibney², Lorraine Brennan²,
12 Marianne C Walsh², Julie A Lovegrove³, J Alfredo Martinez⁶, Hannelore Daniel⁷, Wim H M Saris⁴, Mike
13 Gibney², John C Mathers¹, on behalf of the Food4Me Study.

14

15 **AUTHOR AFFILIATIONS**

16 ¹ Human Nutrition Research Centre, Institute of Cellular Medicine, Newcastle University, Newcastle upon
17 Tyne, UK.

18 ² UCD Institute of Food and Health, University College Dublin, Belfield, Dublin 4, Republic of Ireland.

19 ³ Hugh Sinclair Unit of Human Nutrition and Institute for Cardiovascular and Metabolic Research, University of
20 Reading, Reading, UK.

21 ⁴ Department of Human Biology, NUTRIM School for Nutrition, Toxicology and Metabolism, Maastricht
22 University Medical Centre, Maastricht, The Netherlands

23 ⁵ Department of Nutrition and Dietetics, Harokopio University, Athens, Greece.

24 ⁶ Department of Nutrition, Food Science and Physiology, University of Navarra; CIBER Fisiopatología
25 Obesidad y Nutrición (CIBERObn), Instituto de Salud Carlos III, Spain (SN-C & JAM)

26 ⁷ ZIEL Research Center of Nutrition and Food Sciences, Biochemistry Unit, Technische Universität München,
27 Germany.

28 ⁸ National Food & Nutrition Institute (IZZ), Poland.

29 ⁹ Department of Nutrition, Faculty of Medicine, Institute of Basic Medical Sciences, University of Oslo, Oslo,
30 Norway.

- 31 ¹⁰ TNO, Microbiology and Systems Biology Group, Zeist, the Netherlands.
- 32 ¹¹ Eurogenetica Ltd, 7 Salisbury Road, Burnham-on-Sea, UK
- 33 ¹² Nutrition and Genomics Laboratory, Jean Mayer US Department of Agriculture Human Nutrition Research
- 34 Center on Aging at Tufts University, Boston, Massachusetts, USA
- 35 * These authors contributed equally to this work.

36 **CORRESPONDING AUTHOR**

37 Professor John C. Mathers

38 Human Nutrition Research Centre

39 Institute of Cellular Medicine

40 Newcastle University

41 Biomedical Research Building,

42 Campus for Ageing and Vitality

43 Newcastle upon Tyne

44 NE4 5PL

45 UK

46 john.mathers@newcastle.ac.uk

47 Tel: +44 (0) 1912081133

48 Fax: +44 (0) 1912081101

49 **ABSTRACT**

50 **Purpose**

51 In e-health intervention studies, there are concerns about the reliability of internet-based, self-reported (SR) data
52 and about the potential for identity fraud. This study introduced and tested a novel procedure for assessing the
53 validity of internet-based, SR identity and validated anthropometric and demographic data via measurements
54 performed face-to-face in a validation study (VS).

55

56 **Methods**

57 Participants (n=140) from seven European countries, participating in the Food4Me intervention study which
58 aimed to test the efficacy of personalised nutrition approaches delivered via the internet, were invited to take
59 part in the VS. Participants visited a research centre in each country within two weeks of providing SR data via
60 the internet. Participants received detailed instructions on how to perform each measurement. Individual's
61 identity was checked visually and by repeated collection and analysis of buccal cell DNA for 33 genetic
62 variants.

63

64 **Results**

65 Validation of identity using genomic information showed perfect concordance between SR and VS. Similar
66 results were found for demographic data (age and sex verification). We observed strong Intra Class Correlation
67 coefficients between SR and VS for anthropometric data (height 0.990, weight 0.994 and BMI 0.983). However,
68 internet-based SR weight was under-reported (Δ -0.70 kg [-3.6 to 2.1], $p < 0.0001$) and, therefore, BMI was lower
69 for SR data (Δ -0.29 kg.m² [-1.5 to 1.0], $p < 0.0001$). BMI classification was correct in 93% of cases.

70

71 **CONCLUSION**

72 We demonstrate the utility of genotype information for detection of possible identity fraud in e-health studies
73 and confirm the reliability of internet-based, SR anthropometric and demographic data collected in the Food4Me
74 study.

75

76 **KEY WORDS** – Internet-based, validation, identity, anthropometrics, personalised nutrition and randomized
77 controlled trial.

78 TRIAL REGISTRATION - NCT01530139 (<http://clinicaltrials.gov/show/NCT01530139>)

79 **INTRODUCTION**

80 Non-communicable diseases (NCD) account for over half of global deaths [30], with 4 million deaths annually
81 attributed to cardiovascular diseases (CVD) alone [19]. Because modifiable risk factors, notably diet, smoking
82 and physical activity (PA), account for more than 80% of deaths from CVD and cerebrovascular diseases [30],
83 effective lifestyle-based interventions are important for minimising NCD burden. However, current strategies to
84 improve diet and PA result in relatively modest behavioural changes [9, 15] and may have limited ability to
85 reduce NCD-related mortality. Traditionally, face-to-face interventions have been used to promote behavioural
86 changes. By 2015, 85% of the EU population are predicted to be internet users [6] and internet-based
87 interventions are increasing. The degree of behavioural change achievable via internet-based interventions is
88 similar to [26, 29], or potentially greater than [28], those conducted face-to-face.

89 The advantages of administrating nutritional interventions via the internet include scalability, efficient and cost-
90 effective collection of data, and lower respondent and researcher burden[5]. On the other hand, intervention
91 studies conducted remotely via the internet may incur problems of fidelity in the self-reported (SR) data and in
92 the collection of biological samples, the provenance of which may be uncertain or unreliable. Furthermore, SR
93 anthropometric data may be prone to respondent biases and measurement errors. Validation studies (VS) in
94 which trained researchers repeat measurements in a sub-sample of the population are integral to ensure the
95 quality of data collected in internet-based interventions and provide some reassurance [27]. However,
96 verification of participant identity appears to have been neglected in previous validation studies [1, 3, 17, 22].
97 Using the internet to recruit participants into intervention studies delivered remotely provides opportunities for
98 participant mis-representation (identity fraud i.e. pretending to be who they are not) which may undermine the
99 objectives and findings of the study.

100 The Food4Me study, an internet-based randomized controlled trial (RCT) conducted across seven European
101 countries, was designed to test the efficacy of personalised nutrition (PN) approaches on health-related
102 outcomes [4]. Using data from the Food4Me study, the present paper introduces a novel approach for validating
103 participant identity and describes outcomes from a VS to assess the validity of internet-based, SR
104 anthropometric, demographic and identity data, compared with standardized measurements performed face-to-
105 face.

106

107 **METHODS**

108 The present VS was performed in a subsample of the Food4Me PoP study, a four-arm, internet-based RCT
109 conducted across seven European countries on the efficacy of PN approaches on health-related outcomes[4].

110

111 **Design of the Proof of Principle study**

112 The Food4Me PoP study protocol has been described in detail [4]. In brief, participants across seven European
113 countries were recruited via the internet to emulate an internet-based PN service. Recruitment was aided by
114 local and national advertising via the internet, radio advertisements, posters, e-flyers, the use of social media and
115 word of mouth. Identical standardised protocols for recruitment were used in the seven European countries,
116 aiming for 1540 participants (i.e. 220 participants per country). The PoP study recruitment sites were:
117 University College Dublin, (Ireland); Maastricht University, (The Netherlands); University of Navarra, (Spain);
118 Harokopio University, (Greece); University of Reading, (United Kingdom); National Food and Nutrition
119 Institute, (Poland); Technische Universität München, (Germany).

120

121 **Eligibility criteria**

122 Participants aged ≥ 18 years were included in the study. To keep the cohort representative of the adult
123 population, a minimal set of exclusion criteria were applied: a) pregnancy or lactation; b) no or limited access to
124 the internet; c) following a prescribed diet for any reason, including weight loss, in the last 3 months; d) insulin
125 dependent diabetes, celiac disease, Crohn's disease, or any metabolic disease or condition that alters nutritional
126 requirements e.g. food intolerances or allergies.

127

128 **PoP study measures**

129 Participants consented to report their measurements via the internet and to return self-collected biological
130 samples (Dried Blood Spot Cards and Buccal swabs) by post, using pre-paid stamped addressed envelopes. To
131 ensure that procedures were similar in all recruiting centres, standardised operating procedures were prepared
132 for all measurements, and researchers underwent centralised training. In addition, to enable participants to
133 collect and report the required information and to collect, process and dispatch the biological samples correctly,

134 participants were given printed detailed instructions, and video demonstrations of key procedures were available
135 online. All instructions were provided in the local language.

136

137 **Collection of demographic and anthropometric data**

138 An online screening questionnaire collected detailed SR information about demographic, food choices, health
139 and anthropometric data. Body weight, height and upper thigh, waist and hip circumferences were self-measured
140 and reported by participants via the internet. Participants were instructed to measure body weight after an
141 overnight fast, without shoes and wearing light clothing using a home or commercial scale, and to measure
142 height, barefoot, using a standardised measuring tape provided by Food4Me[4].

143

144 **Genotypic analyses**

145 Buccal cell samples were collected from participants at baseline using Isohelix SK-1 DNA buccal swabs and
146 Isohelix dried-capsules and posted to each recruiting centre for shipment to LCG Genomics (Hertfordshire,
147 United Kingdom). LCG Genomics extracted DNA and genotyped 33 loci using KASPTM genotyping assays to
148 provide bi-allelic scoring of single nucleotide polymorphisms (SNP) and insertions and deletions at specific
149 loci[8].

150

151 **Validation study design**

152 To validate the SR demographic (identity, age and sex) and anthropometric (height, weight and estimated BMI)
153 data, an intervention arm-balanced sub-sample of 140 participants (approximately 20 participants per country)
154 from the PoP intervention study were randomly selected and invited to take part in the VS. Whereas participants
155 for the intervention study were recruited nationally, for logistic reasons, participants living near research centres
156 participated in the VS. Upon completion of the PoP online survey and measurements, participants attended a
157 measurement session at their national research centre. To minimize variations in body mass due to time lags
158 between the completion of SR measures online and the appointment at the research centre, participants were
159 instructed to visit the centre within 2 weeks of their last completed online measurements.

160

161 At the research centre, researchers measured height and weight, assessed sex visually, confirmed participant's
162 age and collected buccal cell samples which were sent to LGC Genomics to replicate genotyping of the 33 loci
163 previously genotyped in baseline samples of the PoP study. Concordance between both sets of genotypic data
164 was used to confirm participant identity.

165

166 **Ethical approval and participant consent**

167 The Research Ethics Committees at each centre administering the intervention granted ethical approval for the
168 VS. Before participation, all participants signed two online consent forms, which were automatically directed to
169 study investigators to be counter-signed and archived. All Ethical Committees accepted an online informed
170 consent procedure, with the exception of The Netherlands and Germany whose ethics committees requested
171 additional hard copy consent forms, which were posted to the respective recruitment centres. The Maastricht
172 University Ethics Committee specified that an extra 10% of the participants should be invited to participate to
173 confirm their demographic SR data (age and sex). This check was performed by teleconference.

174

175 **Data analysis**

176 SR and VS data are presented as means \pm SD for continuous variables and as percentages for categorical
177 variables. Kolmogorov-Smirnov tests for normal distribution were used for continuous variables. Differences
178 between SR and measured height, weight and calculated BMI were assessed using paired t tests. Simple and
179 multiple regression analyses were used to investigate determinants of differences between SR and measured
180 values. General Linear Models were used to investigate differences between SR and measured values by age
181 group, sex and country.

182 Intra-class Correlation Coefficients (ICC) were used to quantify associations and Bland Altman analyses to
183 investigate the degree of agreement between SR and measured height, weight and BMI [2]. Cohen's kappa
184 statistics and the corresponding 95% confidence interval (CI) for classification were used to assess the
185 concordance of sex, age group and BMI status (underweight, normal weight, overweight and obesity) derived
186 from SR and measured values. The degree of agreement between measured and SR overweight and obesity was
187 assessed as follows: $\kappa < 0$ was none/poor; $0 \leq \kappa \leq 0.20$ was slight; $0.21 \leq \kappa \leq 0.40$ was fair; $0.41 \leq \kappa \leq 0.60$ was
188 moderate; $0.61 \leq \kappa \leq 0.80$ was substantial; and $0.81 \leq \kappa \leq 1.0$ was almost perfect [14]. The sensitivity and

189 specificity of correctly classified BMI based on the SR data were assessed by ROC analysis. Data analyses were
190 performed using STATA/SE v.13 (StataCorp. College Station, TX, USA) and MedCalc v.12 (Ostend, Belgium)

191

192 **RESULTS**

193 **Participant characteristics**

194 Table 1 summarises characteristics of the 1607 Food4Me participants, and the sub-sample in the VS (n=140). Of
195 194 participants invited to take part in the VS, 43 were unable to visit the research centre because of location,
196 time constraints or personal reasons and 11 invitees did not respond. The baseline characteristic of these
197 participants who did not take part in the VS were similar to those who accepted to take part in the VS (age 41.3
198 \pm 13.9; weight 72.8 \pm 15.6; BMI 25.3 \pm 4.7). Demographic and anthropometric characteristics of VS
199 participants were similar to those of the Food4Me PoP Study participants (Table 1).

200

201 **Validity and reliability of self-reported data**

202 SR weight was slightly lower than measured weight (Δ -0.70 kg SD 1.5, range -6.0 to 5.9, P <0.0001) but there
203 was no significant difference between SR and measured height (Δ 0.19 cm SD 1.2, range -3 to 5, P =0.066).
204 Thus, BMI calculated from SR height and weight was slightly lower (Δ -0.29 kg.m⁻² SD 0.6, range -2.2 to 1.7,
205 P <0.0001) than measured values. There were no significant differences between SR and measured values by age
206 group (<45 and \geq 45 years) but men overestimated whereas women underestimated height (Table 2). Overweight
207 and obese participants showed higher levels of under-reporting of body mass compared with normal weight
208 participants (P <0.0005). Results stratified by country are presented in supplementary material (Table S1).

209 Strong correlations (ICC) were observed between SR and measured values for height (0.990 [95%CI: 0.987 to
210 0.993], P <0.0001), weight (0.994 [0.991 to 0.995], P <0.0001) and BMI (0.983 [0.977 to 0.988], P <0.0001)
211 (Table 2).

212

213 **Self-reported and measured values**

214 Outcomes of Bland-Altman analyses of SR v. measured values for height, weight and BMI with the
215 corresponding lower and higher level of agreement (LOA) showed a small systematic under-reporting bias for
216 SR weight (Δ -0.70kg [LOA: -3.6 to 2.1], $P < 0.0001$) and BMI (Δ -0.29 kg.m² [LOA: -1.5 to 1.0], $P < 0.0001$)
217 compared with the measured values (Figure 1, Table 3). We noted trends for greater under-reporting with
218 increasing body weight and BMI. Bland-Altman results stratified by country are presented in supplementary
219 material (Table S2).

220

221 **Concordance of demographic and BMI classification**

222 There was a strong concordance for BMI classification (underweight, normal, overweight and obese), estimated
223 from SR and measured height and weight, weighted kappa 0.94 (95% CI 0.89 to 0.99). Five overweight
224 participants (3.5%) were incorrectly classified as being normal weight by the SR method. Of those who were
225 obese, just one participant (0.7%) was incorrectly classified as overweight using SR values, leading to a
226 sensitivity of 94.1% and a specificity of 87.8% (Table 4).

227

228 **Validation of identity**

229 To validate the identity of the participants, the 33 SNPs genotyped previously for the intervention study were re-
230 genotyped and the two datasets were compared. At the VS visit, we collected new buccal cell samples (n=140)
231 from which we obtained reliable genotypes for 135 (33 SNP x 135 individuals = 4455 genotypes). For the
232 remaining five samples, the poor DNA quality precluded informative analysis. There was perfect genotype
233 concordance between original and repeat samples for all but 4 participants, who had a total of four instances at
234 two distinct SNPs (rs2282679, rs4680) where genotypes did not agree. This mismatch incidence is very low,
235 $4/4455 = 0.09\%$ and falls within accepted values for this technology [24]. To explore possible reasons for the
236 apparent genotype mismatches, DNA sequences in the neighbourhoods of these two SNPs were examined for
237 possible copy number variants (CNVs). This analysis revealed that the two SNPs mapped to known CNVs.
238 Participant sex and age showed perfect concordance between SR data and researcher assessed data.

239

240 **DISCUSSION**

241 **Main findings**

242 A novel aspect of this study was the application of genotype analysis using DNA from buccal cell samples to
243 validate the identity of participants recruited via the internet. By replicating the analysis of 33 genetic variants,
244 we showed 99.9% concordance between patterns of genotypic variants in DNA collected in the VS and those
245 observed in DNA obtained from previous, self-collected buccal cell samples. This demonstrates the utility of
246 this novel approach for identity checking - a potentially sensitive aspect of internet-based interventions
247 delivered remotely which has not been investigated in earlier studies. In addition, our findings provide further
248 evidence that SR data via internet for height, weight and BMI showed a high degree of reliability compared with
249 face-to-face measurements made by experienced researchers using standard protocols. Concordance for BMI
250 classification between SR and measured data was strong and we observed perfect agreement for SR sex and age
251 with that assessed in the VS.

252

253 **Validation of participant identity**

254 Administrating lifestyle-based interventions via the internet offers advantages of scale, efficiency and cost-
255 effective data collection [5, 31]. Nevertheless, internet-based intervention studies conducted remotely may result
256 in problems of reliability in the recruitment of participants and in the collection of biological samples. To the
257 best of our knowledge, the issue of validation of participant identity appears to have been overlooked in
258 previous validation studies. Inevitably, the use of internet to recruit participants to intervention studies provides
259 undesirable opportunities for participant mis-representation, which may undermine the study objectives. In the
260 current VS, we replicated the analysis of 33 genetic variants as a proxy of validation of identity. We found
261 strong agreement for over 99.9% of participant genotypes, with just four examples showing disagreement. As
262 our results showed a perfect concordance for age and sex verification, these minor mismatches represent
263 technical errors during genotyping or may reflect the presence of copy number variants (CNVs), which
264 complicate genotyping. LGC Genomics reports that the average genotyping error in positive control DNA
265 samples using Kompetitive Allele Specific PCR, or KASP™ is between 0.7 to 1.6% and the assay design
266 success rate is between 98 to 100% [23]. We conclude that it is likely that we had perfect agreement in
267 participant identity between samples collected remotely during the Food4Me study and those collected in the
268 VS. Furthermore, we suggest that this novel genotype-based approach to validation of participant identity may
269 be used in many internet-based observational and intervention studies.

270

271 **Comparison with other studies**

272 The magnitude of differences between SR and measured height (0.19 cm SD 1.2), weight (-0.70 kg SD1.5), and
273 BMI (-0.29 kg.m⁻² SD 0.6) observed here is similar to findings from previous internet-based studies in adult
274 populations. NutriNet-Sante,[17] a French internet-based prospective cohort study including a VS in a sub-
275 sample of 815 adults, found that height was over-reported by 0.56 cm (SD 2.4) and that weight and BMI were
276 under-reported by 0.49 kg (SD 1.4) and 0.34 kg.m⁻² (SD 1.5), respectively. A study conducted in 177 adults
277 (aged 18-35 years) in Australia [22] observed a larger over-reporting bias for height (1.36 cm SD 1.9), and a
278 similar under-reporting bias for weight (-0.55 kg SD 2.0) and BMI (-0.56 kg.m⁻² SD 0.08) compared with the
279 present study. In contrast, an internet-based study conducted in 149 adults in Sweden[3], reported larger
280 differences between SR and measured weight (1.2 kg SD 2.6) compared with our results. A systematic review
281 [7] of validation of SR anthropometric data found that height was over-reported by 0.6 to 7.5 cm whereas
282 weight and BMI were under-reported by -0.1 to 6.5 kg and 0 to -2.2 kg.m⁻² respectively. It should be noted that
283 under-reporting of body weight is quite common particularly among overweight and obese subjects [11, 17, 18,
284 25].

285 In agreement with some [18, 20, 25] but not all previous studies [3, 17], men in the Food4Me study were more
286 likely to over-report height. Although women appeared more likely to under-report weight than men, this
287 difference was not significant in our study. Previous studies have observed that women were significantly more
288 likely to under-report their weight compared with men [17, 18, 25]. Whilst height was more likely to be over-
289 reported with increasing age in previous studies [1, 13, 17], we did not find any effect of age on differences
290 between SR and measured height.

291 In addition to sex and age, BMI was a strong predictor of differences between SR and measured methods. As a
292 consequence of mis-reporting of the primary measurements of height and weight, differences in under-reporting
293 of calculated BMI was 4.8 times higher in both overweight and obese individuals compared with normal weight
294 participants (Δ -0.12, -0.54 and -0.53 kg.m⁻² for normal, overweight and obese participants respectively). Our
295 results confirm previous findings of under-reporting of BMI by 0.16, 0.36 and 0.63 kg.m⁻² for normal weight,
296 overweight and obese participants respectively [17]. However, we found smaller differences in weight mis-
297 reporting between BMI categories than those observed by another internet-based study [22] in which under-
298 reporting among overweight and obese participants was -1.36 kg compared with -0.31 kg in those of normal

299 BMI. A possible explanation for the greater degree of mis-reporting of body weight by overweight and obese
300 individuals lies in the social desirability concept, which argues that perceptions are influenced by desires to
301 conform to perceived societal norms and that, with respect to body weight, such pressures apply more strongly
302 in obese participants [16]. However, the estimated proportion of subjects for whom SR height, weight and
303 calculated BMI was within 5% of the measured values were 100% (n=140) for height, 96% (n=135) for weight,
304 and 92% (n=129) for estimated BMI, respectively. This suggests that most Food4Me participants provided
305 reliable measures of their anthropometrics.

306

307 **Concordance of BMI classification**

308 One of the main concerns arising from data collection, either SR via the internet or with paper-based forms, is
309 the validity and accuracy of the data provided and its utility as a basis for provision of health-related advice.
310 Several studies have reported greater under-estimation of weight (and BMI) with remote SR collection methods
311 than with face-to-face interviews [10]. However, we observed a good agreement between the BMI
312 classifications derived from SR and measured height and weight (kappa 0.939), with just six participants being
313 wrongly classified when SR data were used. There were no differences in the proportions of those classified as
314 underweight, and only small differences in the proportions of normal weight (3.6%), overweight (-2.9%) and
315 obese participants (-0.7%). These results are comparable with previous findings reporting a kappa of 0.97 for
316 BMI classification and prevalence differences between SR and measured values of 0.6 and 0.7% for overweight
317 and obese participants, respectively [17]. Similarly, Pursey et al. reported that the prevalence of overweight was
318 2.6% lower when using SR compared with measured values, but there was no difference for obesity prevalence
319 [22].

320 Although social desirability may drive differences between SR and measured values [12], we found very good
321 agreement between the internet-based SR and validation measures for the key anthropometric variables height
322 and weight suggesting that, in an internet-based setting, participants may be less prone to social desirability bias.
323 This apparently enhanced truthfulness may result from the greater feeling of anonymity when using the web
324 rather than other media such as the telephone [12]. However, the reliability of more difficult self-measurements
325 such as waist and hip circumferences need to be explored in future studies.

326

327 **Strengths and limitations**

328 To our knowledge, this is the first internet-based study that has validated participant identity using genotypic
329 analysis. Our findings of the utility, and practicability, of this approach to validation of participant identity
330 provide proof of concept for remotely-conducted, e.g. internet-based, studies in which participant mis-
331 representation is a potentially major, and often ignored, concern. A particular strength of this study was the
332 collection of data via a novel internet-based server in European countries from a relatively large sample of the
333 adult population with a wide range of ages and BMIs. Our ability to obtain reliable SR anthropometric data was
334 enhanced by the use of standardized protocols by study participants. Protocols were provided in text format with
335 pictures, but also as a series of online videos. In addition, during the VS, trained researchers collected the
336 anthropometric data using the same standardised protocols. An additional strength of our study was the short
337 period of time (i.e. up to 2 weeks) between the collection of internet-based SR data and direct measurement by
338 the researchers. Furthermore, to ensure independence of measurements in the subsequent VS, subjects were
339 invited to participate in the VS only after they had completed their internet-based measures.

340 A potential limitation of our study is that the participants in the Food4Me study were recruited from those
341 showing interest in an intervention study on PN. As a result, we may have recruited those with a particular
342 interest in lifestyle-based interventions but we have no reason to believe that this interest influenced the
343 truthfulness of SR data. In addition, the BMI distribution among Food4Me participants was comparable with the
344 prevalence of normal weight, overweight and obesity in the adult European population [21].

345 In conclusion, we introduced and tested, a simple genotype-based approach for validation of the identity of
346 study participants recruited to internet-based studies. This approach is simple and robust and, given the low
347 costs of genotyping we envisage that it may have wide utility for identity validation in the many types of studies
348 (including internet-based studies) where participant recruitment and sample data collection are conducted
349 remotely. Although overall agreement between SR and measured values was excellent, under-reporting of
350 weight was more common among overweight and obese individuals, and such SR data should be interpreted
351 with caution when adiposity is an important outcome. Overall, our findings clearly demonstrate the reliability of
352 internet-based, SR anthropometric and demographic data collected in the Food4Me study.

353

354 **ACKNOWLEDGEMENTS**

355 The Food4Me study was supported by the European Commission under the Food, Agriculture, Fisheries and
356 Biotechnology Theme of the 7th Framework Programme for Research and Technological Development, grant
357 number 265494. We acknowledge the design contribution of Anette Karlsen and Ingrid Gjelstad at early stages
358 of the validation study.

359 Mention of trade names or commercial products in this publication is solely for the purpose of providing
360 specific information and does not imply recommendation or endorsement by the U.S. Department of
361 Agriculture. The USDA is an equal opportunity provider and employer.

362

363 **CONFLICT OF INTEREST**

364 The authors declare no conflict of interest.

365

366 **REFERENCES**

- 367 1. Bes-Rastrollo M, Sabate J, Jaceldo-Siegl K, Fraser GE (2011) Validation of self-reported
368 anthropometrics in the Adventist Health Study 2. *BMC Public Health* 11. doi 10.1186/1471-2458-11-
369 213.
- 370 2. Bland JM, Altman DG (2010) Statistical methods for assessing agreement between two methods of
371 clinical measurement. *International Journal of Nursing Studies* 47:931-936. doi
372 10.1016/j.ijnurstu.2009.10.001.
- 373 3. Bonn SE, Lagerros YT, Balter K (2013) How Valid are Web-Based Self-Reports of Weight? *Journal of*
374 *Medical Internet Research* 15. doi 10.2196/jmir.2393.
- 375 4. Celis-Morales C, Livingstone KM, Marsaux CFM, Forster H, O'Donovan CB, Woolhead C, Macready
376 AL, Fallaize R, Navas-Carretero S, San-Cristobal R, Kolossa S, Hartwig K, Tsirigoti L, Lambrinou CP,
377 Moschonis G, Godlewska M, Surwillo A, Grimaldi K, Bouwman J, Daly EJ, Akujobi V, O'Riordan R,
378 Hoonhout J, Claassen A, Hoeller U, Gundersen TE, Kaland SE, Matthews JNS, Manios Y, Traczyk I,
379 Drevon CA, Gibney ER, Brennan L, Walsh MC, Lovegrove JA, Alfredo Martinez J, Saris WHM,
380 Daniel H, Gibney M, Mathers JC (2014) Design and baseline characteristics of the Food4Me study: a
381 web-based randomised controlled trial of personalised nutrition in seven European countries. *Genes*
382 *Nutr* 10:1-13. doi 10.1007/s12263-014-0450-2.
- 383 5. Celis-Morales CL, J; Mathers, JC; (2014) Personalising nutritional guidance for more effective
384 behaviour change. *Proceedings of the Nutrition Society*:1-9. doi 10.1017/S0029665114001633
- 385 6. Eurostat (2012) Life Online In:
- 386 7. Gorber SC, Tremblay M, Moher D, Gorber B (2007) Diagnostic in obesity comorbidities - A
387 comparison of direct vs. self-report measures for assessing height, weight and body mass index: a
388 systematic review. *Obesity Reviews* 8:307-326. doi 10.1111/j.1467-789X.2007.00347.x.
- 389 8. He C, Holme J, Anthony J (2014) SNP genotyping: the KASP assay. *Methods in molecular biology*
390 (Clifton, N.J.) 1145:75-86. doi 10.1007/978-1-4939-0446-4_7.
- 391 9. Hobbs N, Godfrey A, Lara J, Errington L, Meyer TD, Rochester L, White M, Mathers JC, Sniehotta FF
392 (2013) Are behavioral interventions effective in increasing physical activity at 12 to 36 months in
393 adults aged 55 to 70 years? A systematic review and meta-analysis. *BMC Medicine* 11. doi
394 10.1186/1741-7015-11-75.
- 395 10. Hood K, Robling M, Ingledew D, Gillespie D, Greene G, Ivins R, Russell I, Sayers A, Shaw C,
396 Williams J (2012) Mode of data elicitation, acquisition and response to surveys: a systematic review.
397 *Health Technology Assessment* 16:1+-. doi 10.3310/hta16270.

- 398 11. Johansson L, Solvoll K, Bjorneboe GEA, Drevon CA (1998) Under- and overreporting of energy
399 intake related to weight status and lifestyle in a nationwide sample. *American Journal of Clinical*
400 *Nutrition* 68:266-274.
- 401 12. Joinson A (1999) Social desirability, anonymity, and Internet-based questionnaires. *Behavior Research*
402 *Methods Instruments & Computers* 31:433-438. doi 10.3758/bf03200723.
- 403 13. Kuczmarski MF, Kuczmarski RJ, Najjar M (2001) Effects of age on validity of self-reported height,
404 weight, and body mass index: Findings from the third National Health and Nutrition Examination
405 Survey, 1988-1994. *Journal of the American Dietetic Association* 101:28-34. doi 10.1016/s0002-
406 8223(01)00008-6.
- 407 14. Landis JR, Koch GG (1977) Measurement of observer agreement for categorical data. *Biometrics*
408 33:159-174. doi 10.2307/2529310.
- 409 15. Lara J, Hobbs N, Moynihan PJ, Meyer TD, Adamson AJ, Errington L, Rochester L, Sniehotta FF,
410 White M, Mathers JC (2014) Effectiveness of dietary interventions among adults of retirement age: a
411 systematic review and meta-analysis of randomized controlled trials. *BMC Medicine* 12. doi
412 10.1186/1741-7015-12-60.
- 413 16. Larson MR (2000) Social desirability and self-reported weight and height. *International Journal of*
414 *Obesity* 24:663-665. doi 10.1038/sj.ijo.0801233.
- 415 17. Lassale C, Peneau S, Touvier M, Julia C, Galan P, Herczeg S, Kesse-Guyot E (2013) Validity of Web-
416 Based Self-Reported Weight and Height: Results of the Nutrinet-Sante Study. *Journal of Medical*
417 *Internet Research* 15. doi 10.2196/jmir.2575.
- 418 18. Merrill RM, Richardson JS (2009) Validity of self-reported height, weight, and body mass index:
419 findings from the National Health and Nutrition Examination Survey, 2001-2006. *Preventing Chronic*
420 *Disease* 6.
- 421 19. Nichols M, Townsend N, Scarborough P, Rayner M (2013) *European Cardiovascular Disease Statistics*
422 4th edition 2012: EuroHeart II. *European Heart Journal* 34:3007-3007. doi 10.1093/eurheartj/ehs379.
- 423 20. Niedhammer I, Bugel I, Bonenfant S, Goldberg M, Leclerc A (2000) Validity of self-reported weight
424 and height in the French GAZEL cohort. *International Journal of Obesity* 24:1111-1118. doi
425 10.1038/sj.ijo.0801375.
- 426 21. OECD (2012) *Health at a Glance: Europe 2012*. In: Publishing. O (ed)OECD
- 427 22. Pursey K, Burrows TL, Stanwell P, Collins CE (2014) How Accurate is Web-Based Self-Reported
428 Height, Weight, and Body Mass Index in Young Adults? *Journal of Medical Internet Research* 16. doi
429 10.2196/jmir.2909.
- 430 23. Semagn K, Babu R, Hearne S, Olsen M (2014) Single nucleotide polymorphism genotyping using
431 Kompetitive Allele Specific PCR (KASP): overview of the technology and its application in crop
432 improvement. *Molecular Breeding* 33:1-14. doi 10.1007/s11032-013-9917-x.
- 433 24. Smith CE, Arnett DK, Corella D, Tsai MY, Lai CQ, Parnell LD, Lee YC, Ordovas JM (2012) Perilipin
434 polymorphism interacts with saturated fat and carbohydrates to modulate insulin resistance. *Nutrition*
435 *Metabolism and Cardiovascular Diseases* 22:449-455. doi 10.1016/j.numecd.2010.09.003.
- 436 25. Spencer EA, Appleby PN, Davey GK, Key TJ (2002) Validity of self-reported height and weight in
437 4808 EPIC-Oxford participants. *Public Health Nutrition* 5:561-565. doi 10.1079/phn2001322.
- 438 26. Steele RM, Mummery WK, Dwyer T (2009) A Comparison of Face-to-Face or Internet-Delivered
439 Physical Activity Intervention on Targeted Determinants. *Health Education & Behavior* 36:1051-1064.
440 doi 10.1177/1090198109335802.
- 441 27. Thorndike FP, Ritterband LM, Saylor DK, Magee JC, Gonder-Frederick LA, Morin CM (2011)
442 Validation of the Insomnia Severity Index as a Web-Based Measure. *Behavioral Sleep Medicine* 9:216-
443 223. doi 10.1080/15402002.2011.606766.
- 444 28. Wantland DJ, Portillo CJ, Holzemer WL, Slaughter R, McGhee EM (2004) The effectiveness of Web-
445 based vs. non-Web-based interventions: A meta-analysis of behavioral change outcomes. *Journal of*
446 *Medical Internet Research* 6:67-84.
- 447 29. Weigold A, Weigold IK, Russell EJ (2013) Examination of the Equivalence of Self-Report Survey-
448 Based Paper-and-Pencil and Internet Data Collection Methods. *Psychological Methods* 18:53-70. doi
449 10.1037/a0031607.
- 450 30. WHO (2010) *Global status report on noncommunicable diseases 2010*. In: World Health Organization
- 451 31. Wright KB (2005) Researching Internet-based populations: Advantages and disadvantages of online
452 survey research, online questionnaire authoring software packages, and Web survey services. *Journal*
453 *of Computer-Mediated Communication* 10.

455 **Table 1.** Demographic and anthropometric characteristics of the Food4Me Proof of Principle (PoP) Study and
 456 Validation Study participants.

	Food4Me PoP Study participants	Validation Study participants	P-value
Demographic			
Total (n)*	1607	140	-
Sex - female (%)	60.9	56.4	0.719
Age (years)	39.8 ± 13.1	42.6 ± 13.6	0.018
Age range (years)	18 to 79	18 to 68	-
Anthropometrics			
Height (cm)	171.1 ± 9.4	170.1 ± 9.1	0.227
Weight (kg)	74.6 ± 15.8	72.3 ± 14.2	0.089
BMI (kg.m ⁻²)	25.5 ± 5.2	24.9 ± 3.9	0.173
Weight status categories (%)			
Underweight: BMI <18.5	2.7	0.7	0.171
Normal weight: BMI ≥18.5 to ≤24.9	51.2	56.4	0.244
Overweight: BMI ≥25 to ≤29.9	30.3	30.7	0.926
Obese: BMI ≥30.0	15.8	12.2	0.252

457 Data represent means ± SD for continuous variables and percentages for categorical variables. Differences for

458 continuous variables were analysed using independent t-test and Chi-square for categorical variables.

459 *Sex and age were verified by teleconference in an additional 21 participants in The Netherlands.

460 **Table 2.** Summary statistics and correlation coefficients for self-reported and measured height, weight and BMI.

Variables	Collection method		P-value ^a	Correlation coefficient
	Self-reported	Measured		ICC (95%CI) ^b
All (n=140)				
Height (cm)	170.3± 9.4	170.1 ± 9.1	0.066	0.990 (0.986 to 0.993)*
Weight (kg)	71.6 ± 13.9	72.3 ± 14.3	<0.0001	0.993 (0.991 to 0.995)*
BMI (kg.m ⁻²)	24.6 ± 3.8	24.9 ± 3.9	<0.0001	0.983 (0.977 to 0.988)*
By sex:				
Women(n=79)				
Height (cm)	164.2 ± 6.4	164.3 ± 6.1	0.084	0.974 (0.960 to 0.983)*
Weight (kg)	64.8 ± 10.7	65.5 ± 11.1	0.0004	0.987 (0.981 to 0.992)*
BMI (kg.m ⁻²)	24.1 ± 3.9	24.3 ± 4.1	0.005	0.982 (0.972 to 0.988)*
Men (n=61)				
Height (cm)	178.1 ± 6.4	177.6 ± 6.3	0.0002	0.985 (0.975 to 0.981)*
Weight (kg)	80.4 ± 12.6	81.2 ± 13.0	<0.0001	0.993 (0.988 to 0.995)*
BMI (kg.m ⁻²)	25.3 ± 3.5	25.7 ± 3.6	<0.0001	0.983 (0.973 to 0.990)*
By age group				
<45 years (n=71)				
Height (cm)	171.2± 8.9	171.2 ± 8.4	0.136	0.990 (0.985 to 0.994)*
Weight (kg)	70.0 ± 13.6	70.5 ± 13.8	0.009	0.992 (0.988 to 0.996)*
BMI (kg.m ⁻²)	23.7 ± 3.6	23.9 ± 3.7	0.005	0.981 (0.970 to 0.988)*
≥45 years (n=69)				
Height (cm)	169.3± 9.8	169.1 ± 9.7	0.236	0.990 (0.984 to 0.993)*
Weight (kg)	73.3 ± 14.1	74.2 ± 14.5	<0.0001	0.994 (0.990 to 0.996)*
BMI (kg.m ⁻²)	25.4 ± 3.7	25.8 ± 3.9	<0.0001	0.983 (0.973 to 0.989)*
By BMI categories				
Normal weight (n=80)				
Height (cm)	169.6 ± 9.0	169.5 ± 8.7	0.719	0.992 (0.987 to 0.994)*
Weight (kg)	63.1 ± 8.5	63.4 ± 8.4	0.053	0.984 (0.976 to 0.990)*
BMI (kg.m ⁻²)	21.9 ± 1.7	22.0 ± 1.7	0.071	0.937 (0.903 to 0.959)*
Overweight (n=43)				
Height (cm)	171.1± 9.5	170.6 ± 10.0	0.017	0.987 (0.977 to 0.993)*
Weight (kg)	78.8 ± 9.2	79.9 ± 9.3	<0.0001	0.986 (0.975 to 0.992)*
BMI (kg.m ⁻²)	26.8 ± 1.5	27.40 ± 1.3	<0.0001	0.839 (0.722 to 0.909)*
Obese (n=17)				
Height (cm)	171.8 ± 9.0	171.8 ± 9.0	0.984	0.991 (0.970 to 0.997)*
Weight (kg)	93.3 ± 10.4	94.8 ± 10.3	0.002	0.974 (0.934 to 0.990)*
BMI (kg.m ⁻²)	31.5 ± 1.7	32.1 ± 1.6	0.006	0.864 (0.672 to 0.948)*

461 Data represent means ± SD for self-reported and measured values. ^a Paired t-test was used for assessing
462 differences between means of both methods. ^b Intraclass correlation coefficient (ICC) and ^c Pearson Product
463 correlation coefficient (r) and their corresponding 95% confident intervals were used to assess the level of
464 reliability between methods. *All P-values for ICC and Pearson correlation were significant at <0.0001.

465 **Table 3.** Bland-Altman analyses for self-reported and measured height, weight and BMI.

Variables	Bland-Altman		P-value*
	Absolute mean differences (LOA)	(%) Relative mean differences (LOA)	
All (n=140)			
Height (cm)	0.19 (-2.3 to 2.7)	0.11 (-1.4 to 1.6)	0.066
Weight (kg)	-0.70 (-3.6 to 2.1)	-0.93 (-4.9 to 3.1)	<0.0001
BMI (kg.m ⁻²)	-0.29 (-1.5 to 1.0)	-1.14 (-6.2 to 4.0)	<0.0001
By sex:			
Women(n=79)			
Height (cm)	0.03 (-2.8 to 2.7)	0.02 (-1.7 to 1.7)	0.084
Weight (kg)	-0.65 (-3.7 to 2.4)	-0.94 (-5.6 to 3.7)	0.0004
BMI (kg.m ⁻²)	-0.23 (-1.6 to 1.2)	-0.89 (-6.7 to 4.9)	0.005
Men (n=61)			
Height (cm)	0.49 (-1.4 to 2.4)	0.28 (-0.8 to 1.4)	0.0002
Weight (kg)	-0.81 (-3.3 to 1.8)	-0.90 (-3.9 to 2.1)	<0.0001
BMI (kg.m ⁻²)	-0.38 (-1.4 to 0.6)	-1.45 (-5.3 to 2.4)	<0.0001
By age group:			
<45 years (n=71)			
Height (cm)	0.21 (-2.1 to 2.5)	0.11 (-1.3 to 1.5)	0.136
Weight (kg)	-0.50 (-3.6 to 2.6)	-0.69 (-5.3 to 3.9)	0.009
BMI (kg.m ⁻²)	-0.23 (-1.5 to 1.1)	-0.91 (-6.6 to 4.8)	0.005
>45 years (n=69)			
Height (cm)	0.18 (-2.1 to 2.5)	0.10 (-1.5 to 1.7)	0.236
Weight (kg)	-0.91 (-3.5 to 1.6)	-1.16 (-4.4 to 2.0)	<0.0001
BMI (kg.m ⁻²)	-0.37 (-1.5 to 0.8)	-1.37 (-5.7 to 3.0)	<0.0001
By BMI categories			
Normal weight (n=80)			
Height (cm)	0.04 (-2.1 to 2.2)	0.02 (-1.3 to 1.3)	0.719
Weight (kg)	-0.32 (-3.1 to 2.5)	-0.52 (-5.0 to 4.0)	0.053
BMI (kg.m ⁻²)	-0.12 (-1.3 to 1.0)	-0.56 (-5.9 to 4.7)	0.071
Overweight (n=43)			
Height (cm)	0.56 (-2.4 to 3.5)	0.32 (-1.5 to 2.1)	0.017
Weight (kg)	-1.08 (-3.2 to 1.0)	-1.37 (-3.9 to 1.2)	<0.0001
BMI (kg.m ⁻²)	-0.54 (-1.7 to 0.7)	-2.01 (-6.4 to 2.4)	<0.0001
Obese (n=17)			
Height (cm)	0.01 (-2.4 to 3.2)	0.01 (-1.4 to 1.4)	0.984
Weight (kg)	-1.56 (-3.8 to 1.4)	-1.70 (-5.6 to 2.2)	0.002
BMI (kg.m ⁻²)	-0.53 (-1.8 to 0.7)	-1.68 (-6.1 to 2.8)	0.006

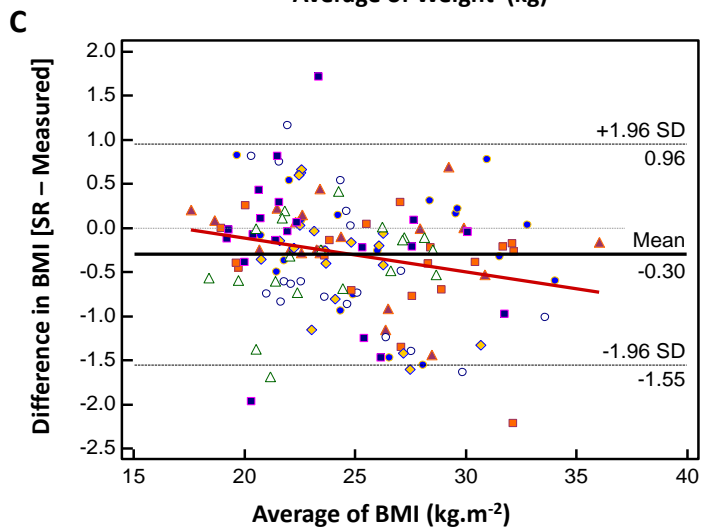
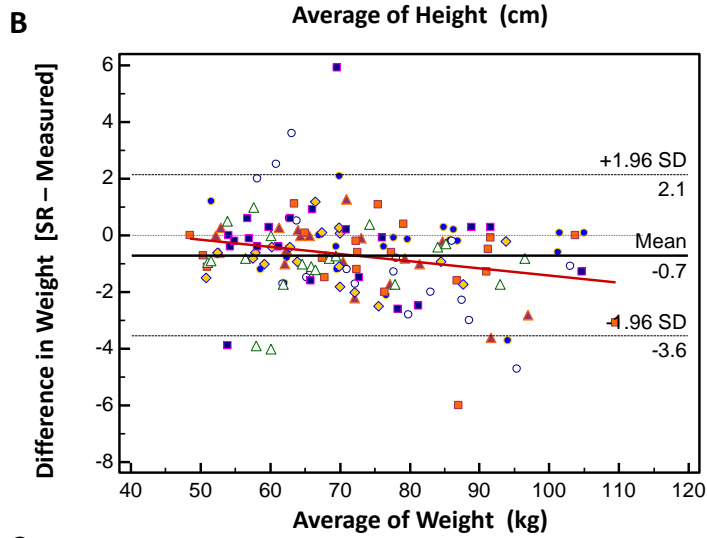
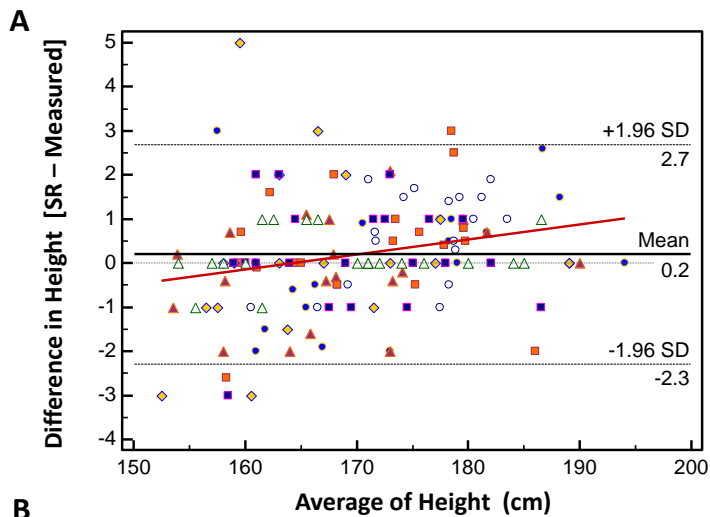
466 Data represent absolute and relative mean differences [SR - measured values] with their corresponding limits of
 467 agreements (LOA \pm 1.96 SD). * Paired t-test was used for assessing absolute differences between means of SR
 468 and measured values.

469 **Table 4.** Validity and concordance of weight classification estimated from self-reported and measured values.

BMI categories	SR	Measured	Number misclassified
Underweight	1 (0.7%)	1 (0.7%)	0
Normal	84 (60.0%)	79 (56.4%)	5 (3.5%)
Overweight	39 (27.9%)	43 (30.7%)	4 (2.9%)
Obese	16 (11.4%)	17 (12.1%)	1 (0.7%)
*Kappa	0.939 (0.891 to 0.988)		

470 Data represent count (and percentages) for measured and self-reported (SR) values. *A weighted Kappa value

471 and its corresponding 95% CI were estimated to measure the level of concordance between both methods.



472

○ Germany ● Ireland ■ Spain ◆ UK
 ■ Greece ▲ Poland ▲ NL

473

474 Figure 1. Bland-Altman plots illustrating the agreement between self-reported (SR) and measured (a) height, (b)

475 weight, (c) BMI, and the corresponding means estimated by the two methods across all countries. Solid lines are

476 mean differences and dotted lines are the lower and upper 95% limits of agreements; red lines illustrate the
477 regression line for differences in measurements against the mean of both SR and VS measurements.