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## **Predictive formulas for estimation of height in sub-Saharan African older people: A new formula (EPIDEMCA study)**

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1 Predictive formulas for estimation of height in sub-Saharan African older people: a new  
2 formula (EPIDEMCA study)

3

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25 **Short running head:** Estimation of height in sub-Saharan African elderly.

26 **Conflict of interest:** none

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35 Gautier for proofreading the manuscript.

36

37 **Abstract**

38 *Background:* Chumlea's formulas are means of predicting height from knee height (KHt),  
39 including among people aged over 60 years who cannot get upright. However, they were  
40 developed in Caucasian and African-American people and have not yet been validated in  
41 older native Africans. **The aims of the study were** (i) to assess Chumlea's formulas in older  
42 people in Central Africa and (ii) to propose a new validated formula in the same population.

43 *Methods:* Height (MHt) and KHt were measured in a population of people over 65 years old  
44 from the Republic of Congo and the Central African Republic. Predicted height (PHt) was  
45 calculated using Chumlea's formulas for the American black population (CBP) and for  
46 Caucasian (CC). The percentages of accurate predictions ( $\pm 5$  cm) were compared between  
47 MHt and PHt. A new formula was estimated after randomization in a derivation sample  
48 (n=877) and assessed for accuracy in a validation sample (n=877).

49 *Results:* A total of 1754 individuals were included. Prediction was accurate ( $\pm 5$ cm) in 66.8%  
50 and 63.2% of CBP and CC, respectively. Overestimation was as high as 24.1% and 29.0%,  
51 respectively. As such an overestimation is unacceptable in clinical practice and population  
52 surveys, **a new formula was proposed:**  $\text{height(cm)} = 72.75 + (1.86 * \text{KHt[cm]}) - (0.13 * \text{age[years]}) + 3.41 * \text{sex}$  (0: **women**; 1: **men**). This new formula significantly increases  
53 accuracy (71.3%) and decreases overestimation (14.7%). The nutritional status based on body  
54 mass index was not different with the **MHt and the PHt** by the new formula.

56 *Conclusion:* Chumlea's formulas provided a poor estimate of height in this population  
57 sample. **The proposed formula** more accurately estimates height in older native Africans. This  
58 formula should be tested in other sub-Saharan African countries in order to extend its use in  
59 clinical practice and in future studies.

60 **Key words:** norms, reference equation, anthropometric data, ageing, body mass index,

61 ethnicity

62

63 **Abbreviation list**

64 BMI: body mass index

65 CAR: Central African Republic

66 CBP: Chumlea's formula for non-hispanic black people

67 CC: Chumlea's formula for Caucasian people

68 ICC: intraclass correlation coefficients

69 IQR: interquartile range

70 Mht: Measured height

71 n: number

72 PHt: predicted height

73 P-M: predicted height minus measured height

74 ROC: Republic of Congo

75 **R<sup>2</sup>: coefficient of determination**

76 SD: standard deviation

77

## 78 **Introduction**

79 Nutritional status is often assessed using body mass index (BMI), which requires height for its  
80 calculation [1]. In epidemiological studies and clinical practice, height may be difficult to  
81 measure in older adults because of an inability to stand upright (due to physical disability or  
82 spinal distortion). In those instances, an alternative way of estimating height in older adults is  
83 essential in order to accurately assess nutritional status. Chumlea et al. [2–4] proposed several  
84 formulas with which to estimate height using knee height (KHt) in different populations  
85 including African Americans. To the best of the authors' knowledge, these formulas have not  
86 been validated in older native central Africans. Despite, the lack of validation of these  
87 formulas in sub-Saharan populations, some studies conducted in Africa used different formula  
88 to predict height of older people [5–7]. Numerous recent studies have looked at nutritional  
89 status in older adults from sub-Saharan Africa [5,6,8–18]. Due to a lack of data on height,  
90 BMI could not be calculated in 2.5 to 6.5% of the populations in several studies in Africa  
91 [5,8,19,20]. Recently, our research team studied these formulas in Benin and found an  
92 accurate prediction of height ( $\pm 5$  cm) close to 80% [21]. The aims of this study were: i) to  
93 assess the validity of three Chumlea's formulas to provide predicted height (PHt) in older  
94 people from central Africa; ii) if validation failed, to propose a new formula for estimation of  
95 height for this population; and iii) to compare BMI and nutritional status according to  
96 measured height (MHt) and PHt.

97

## 98 **Population and Methods**

### 99 **Study Design**

100 The EPIDEMCA study is a multicenter population-based cross-sectional survey in rural and  
101 urban areas in the Central African Republic (CAR - Bangui and Nola) and in the Republic of  
102 Congo (ROC - Brazzaville and Gamboma). Conducted between November 2011 and  
103 December 2012, its main objective was to assess the prevalence of dementia and to  
104 investigate its risk factors. The sample size was estimated *a priori* at 500 in each study site. In  
105 urban areas, participant selection was carried out stratified by city subdivision, with random  
106 sampling proportional to the size of each subdivision. In rural areas, exhaustive sampling  
107 using a door-to-door approach was adopted for logistic and financial reasons. The detailed  
108 methodology is described in an open-access publication [22].

### 109 **Inclusion criteria**

110 Individuals 65 years of age and older who lived in the study areas at the time were included.  
111 Those who declined to participate or presented severe comorbidities (cancers, bedridden  
112 condition,) carrying a high risk of death, which did not allow longitudinal follow-up for future  
113 studies were excluded.

### 114 **Ethics**

115 Approval was obtained from the ethical committees supervised by the Ministry of Public  
116 Health in CAR, the *Comité d'Éthique de la Recherche en Sciences de Santé* in ROC, and the  
117 *Comité de Protection des Personnes du Sud-Ouest et d'Outre-Mer 4* in France. All  
118 participants and/or their families gave informed consent prior to inclusion in the study.  
119 Written consent was obtained where feasible. For illiterate people, the study's objectives were  
120 verbally explained and consent was obtained by thumbprint.

### 121 **Anthropometric measurements**



122 Anthropometric measurements were performed by 10 medical students (at least in their 6<sup>th</sup>  
123 year), from Bangui and Brazzaville Universities. All students were specifically trained in  
124 order to limit the inter-measurer bias. Weight (kg) was measured in an upright position to the  
125 nearest 100g using a portable mechanical balance with a weighing capacity of 10 to 150 kg  
126 (Seca™ Hamburg, Germany). **MHt (cm) was determined at** the nearest centimeter using a  
127 carpenter's measure along as flat a surface as possible, such as a door or a wall. **KHt (cm)** was  
128 measured in all participants with a paediatric height scale to the nearest centimeter on the  
129 right leg with an angle of 90° between the thigh and the leg in a supine position according to  
130 Chumlea et al. [2]. The paediatric height scale was placed in line with the lateral malleolus  
131 and the head of the fibula; with the soft tissue compressed, the distance from the sole of the  
132 foot to the top of the thigh immediately above the condyles of the femur was measured. BMI  
133 was calculated by dividing the weight in kilograms by the height in meters squared and  
134 rounded to 1 decimal place [1]. Undernutrition was defined as BMI < 18.5 kg/m<sup>2</sup>, normal  
135 status as BMI between 18.5 and 24.9 kg/m<sup>2</sup>, overweight as BMI between 25 and 29.9 kg/m<sup>2</sup>  
136 and obesity as BMI ≥ 30 kg/m<sup>2</sup> [1].

### 137 **Estimation of height using Chumlea's formulas**

138 Chumlea et al. developed several formulas for estimation of height according to the  
139 population. In this study, two Chumlea's formulas were used, one for non-Hispanic American  
140 black people (CBP) and one for Caucasian (CC) as used in the study of Marais et al. in a  
141 mixed population in South Africa (black African and Caucasian people) [4,7].

142 CBP [2]:

143 height (cm) = 79.69 + (1.85 \* KHt[cm]) - (0.14 \* age[years]) for **men** (**coefficient of**  
144 **determination [R<sup>2</sup>]: 70.0%**)

145 height (cm) = 89.58 + (1.61 \* KHt[cm]) - (0.17 \* age[years]) for **women** (R<sup>2</sup>: 63.0%)

146 CC [4,7]:

147  $\text{height(cm)} = 59.01 + (2.08 * \text{KHt[cm]})$  for **men** ( $R^2$ : 68.0%)

148  $\text{height(cm)} = 75.00 + (1.91 * \text{KHt[cm]}) - (0.17 * \text{age[years]})$  for **women** ( $R^2$ : 59.0%).

#### 149 **Other data**

150 Age was ascertained from official documents, by using historical events [23], or from an  
151 informant. **Sex** and country of residence were also recorded.

152

#### 153 **Data analysis**

##### 154 *Population description*

155 Percentages and median with interquartile range (IQR) were used to describe the study  
156 sample.

##### 157 *Validation of Chumlea's formulas*

158 The degree of agreement between PHt and MHt was assessed using Bland and Altman plots  
159 and intraclass correlation coefficients (ICC) [24]. The percentage of difference and the 95%  
160 limit of agreement were also computed. The mean percentage of difference between PHt and  
161 MHt was calculated [21]. Based on clinical and epidemiological experience, a threshold of  $\pm$   
162 5 cm (**3% of the MHt**) was considered as an acceptable threshold for the difference between  
163 the predicted and measured heights [21]. This threshold of  $\pm$  5 cm was used in a previous  
164 study in Benin [21]. The percentage of accurate prediction (between - 5 cm and + 5 cm) was  
165 accordingly calculated. A prediction over 5 cm was considered as an overestimation and  
166 under 5 cm as an underestimation.

##### 167 *Creation of a new formula*

168 After randomization, two subsamples were created: a derivation subsample (n = 877) to  
169 construct the new formula, and a validation subscale (n = 877) to test it. Mann-Whitney and  
170 Chi square tests were used to compare the two subsamples. The new formula was created  
171 based on a linear multiple regression according to sex, age and KHt in the derivation  
172 subsample. The coefficient of determination ( $R^2$ ) of the linear regression was calculated.  
173 Accuracy of this new formula was tested on the validation subsample with Bland and Altman  
174 plots and ICC [24]. The percentage of accurate predictions was also calculated with the  
175 above-mentioned strategy and compared it to CBP.

#### 176 *BMI and nutritional status assessment*

177 Mann-Whitney test was used to compare BMI calculated with MHt and with all PHt  
178 formulas. Chi square test was used to compare nutritional status (undernutrition, normal,  
179 overweight and obesity) with MHt and with all PHt formulas.

180

181 Data were analysed using GraphPad Prism 6.0 (GraphPad Software Inc, La Jolla, CA, USA)  
182 and SAS<sup>®</sup> software v9.3 (SAS Institute, Cary, North Carolina, USA). A p-value <0.05 was  
183 the limit of significance. STROBE statement was complied with [25].

184

185 **Results**

186 *Characteristics of the participants*

187 A total of 2,002 individuals 65 years of age and older were included in the EPIDEMCA  
188 survey. Height was missing for 167 participants, KHt for 144 and weight for 94. In this study,  
189 1,754 individuals (n=880 in ROC; n=874 in CAR) were analysed.

190

191 Table 1 shows the characteristics of the participants. **Women** accounted for 61.5%, with no  
192 significant differences between countries. ROC participants were significantly older than  
193 those from CAR (72.0 [68.0 – 78.0] vs. 71.0 [67.0 – 76.0] years, respectively - p= 0.004). The  
194 median MHt was 157.0 cm [150.5 – 164.0]; participants were significantly shorter in ROC  
195 than in CAR (156.0 [149.9 – 162.0] vs. 158.0 [153.0 – 165.0] cm, respectively - p < 0.001).  
196 Mean height was 164.0 cm [158.0 – 170.0] among **men** and 153.0 cm [148.0 – 158.4] among  
197 **women** (p < 0.001).

198 *Validity of Chumlea's formulas in older adults from Central Africa*

199 Table 2 presents the accuracy of the **PHt** calculated using the two Chumlea formulas. Figure 1  
200 shows the Bland and Altman plots for the total sample, ROC and CAR. The ICC was 0.77  
201 (95% confidence interval [95%CI]: 0.71 – 0.82) and 0.78 (95%CI: 0.68 – 0.84) between MHt  
202 and CBP and CC, respectively.

203 The percentages of accurate estimation by the two Chumlea formulas are shown by **sex**, age  
204 and country in Figure 2. The percentage of accurate prediction was higher using CBP (66.8%)  
205 compared to CC (63.2%, p =0.028). The agreement was lower among **men** 75 years of age  
206 and older than in younger ones in both countries but not among **women**.

207 The CBP and CC overestimated height in 24.2% and 29.0% of cases, respectively.

208 *New formulas for estimation of height for older central Africans*

209 The deviation subsample and validation subsample were not significantly different (Table -1).

210 Using the derivation subsample, a new **sex**-adjusted formula was obtained:

211 - Height(cm) = 72.75 + (1.86 \* KHt[cm]) - (0.13 \* age[years]) + 3.41 \* **sex** (0:  
212 **women**; 1: **men**)

213 (R<sup>2</sup> of this model was 66.9%)

214 Results of the validation study are presented in Table 3. The ICC was 0.78 (95%CI: 0.76 –  
215 0.81). The percentage of accurate predictions was 71.3% with the new formula and was  
216 significantly better than with CBP (65.3%, p = 0.008). Figure 3 shows the Bland and Altman  
217 plots for the two Chumlea's formulas and the new formula in the validation sample. The  
218 distribution of points was homogeneous between the three formulas studied. The majority of  
219 points was between the 95% limit of agreement.

220 *Impact on nutritional status assessment*

221 In the whole sample, the mean BMI calculated with the PHt with Chumlea's formulas (19.5  
222 kg/m<sup>2</sup> [17.3 – 22.4], p<0.001 and 19.4 kg/m<sup>2</sup> [17.2 – 22.3], p< 0.001 with CBP, CC,  
223 respectively) was significantly lower than when MHt was used (20.1 kg/m<sup>2</sup> [17.8 – 23.1]).  
224 Accordingly, the percentage of older adults with undernutrition was significantly lower when  
225 BMI was calculated using MHt (34.3%) rather than PHt (38.7%, p = 0.008 and 40.1%, p =  
226 0.0004 with CBP and CC, respectively). However, **in the whole sample** BMI using PHt with  
227 the new formula did not differ significantly from BMI using MHt (19.9 [17.7 – 23.0] **vs. 20.1**  
228 **[17.8 – 23.1] kg/m<sup>2</sup>, respectively** - p = 0.74). The percentage of undernutrition defined using  
229 height estimated with the new formula did not differ significantly from that defined by MHt  
230 (34.3% vs. 34.3%, respectively - p = 1.00). **Nutritional status using BMI according to the**

231 MHT or PHt in the total sample and in the Republic of Congo and Central African Republic is

232 presented in table 4.

233

## 234 **Discussion**

235 To the best of the authors' knowledge, this study is the first to assess the validity of  
236 Chumlea's predictive formulas for estimating height in older native central Africans. These  
237 formulas require simple criteria for their use, such as age, sex and KHt [2]. KHt is the  
238 fundamental measurement necessary for the application of these formulas. KHt should be  
239 measured as recommended to avoid biasing the prediction of height [2]. These formulas have  
240 been created and validated in different populations over 60 years old. Their main limitation is  
241 the lack of validation of these formulas in sub-Saharan populations. Recent years have seen  
242 an increase in nutritional studies in older adults in sub-Saharan Africa [5,6,8–18,20]. In the  
243 absence of a validated formula, previous work used CBP and CC formulas. CBP was used in  
244 Pilleron et al. and Samba et al., studies in Central Africa, [5,6,19], and CC was used in one  
245 study in South Africa but in several ethnic groups [7]. According to the results of this study,  
246 the validity of these formulas (CBP and CC) is not adequate in these two countries of Central  
247 Africa (ROC and CAR). These formulas may lead to misclassification of individuals based on  
248 BMI. Validated tools with which to assess height as accurately as possible when its  
249 measurement is impossible are required. Therefore, a specific formula was created that  
250 performed better and allowed for better categorisation of participants based on their  
251 nutritional status as assessed by BMI. Chumlea's formulas tended to overestimate height in  
252 this population leading to increased estimation of the prevalence of undernutrition, which is  
253 not the case with the new formulas. However, CPB was better than the formula for Caucasian  
254 applied in sub-Saharan populations. CC is not recommended for use in this population.  
255 Moreover, CPB seems more reliable in other African countries such as Benin [21]. The  
256 principal strengths of this study are the large sample size and the multicenter design including  
257 rural and urban areas in two neighboring countries in central Africa. In addition, use of a more  
258 precise formula validated in this specific population to estimate height would improve the

259 screening of nutritional disorders in elderly Africans in both epidemiological surveys and  
260 clinical settings. The main aim is reliable screening of undernutrition in older sub-Saharan  
261 African people, which is found in 8.3 to 34.7% and associated with chronic diseases [26].  
262 Information on the use of this simple tool should be developed in Africa. However, in these  
263 populations, nutritional status may sometimes not be studied with the measurement of weight  
264 and height even estimated, in the absence of appropriate measuring equipment. Other simple  
265 anthropometric criteria can be used to screen undernutrition such as brachial circumference or  
266 mid-upper arm muscle circumference requiring the measurement of the tricipital skin fold [5].  
267 Moreover, these anthropometric measurements are simple to obtain and require little  
268 equipment (measuring tape and Harpenden caliper). This equipment is also more easily  
269 transportable than a mechanical or electronic weight scale and a height scale, allowing easier  
270 screening mainly in rural areas. Several limitations must also be acknowledged.  
271 Anthropometric measurements may be subject to inter-measurer variability. However, all  
272 researchers were specifically trained during three weeks and examiners were selected  
273 according to their performances during the training [22]. This variability was probably  
274 limited. The plastic height scales used during the survey may have been slightly deformed by  
275 high temperatures, leading to small variations in measurement between the beginning and the  
276 end of the survey. Moreover, some conditions such as knee arthrosis, rheumatoid arthritis  
277 could modify the KHt measurement but **to the best of the authors' knowledge**, studies on this  
278 subject have not been found. Patients with these conditions were not excluded. **Validation of**  
279 **the present formula** in another independent sample of older people of CA is required.  
280 Moreover the new formula could be validated in other countries of sub-Saharan Africa, for  
281 example in Benin where height predictive formulas have also been studied [21].  
282



283 **Conclusion**

284 In an older native African population, Chumlea's original formulas provide poor estimation of  
285 height. This could be overcome by creating population-specific formulas that are essential to  
286 the efficient screening of poor nutritional status (undernutrition and overweight/obesity) in  
287 older adults in SSA. It seems important to test this formula in other sub-Saharan African  
288 countries to develop its use in both epidemiologic surveys and clinical settings in sub-Saharan  
289 Africa.

290

291 **Authors' contributions:**

292 PJ, BM, SP, MG, PM, BNB, PMP and JCD designed the research; SP, MG, PM and BNB  
293 provided databases; PJ and BM performed statistical analysis; PJ, BM, SP, MG, PMP, PF and  
294 JCD wrote the paper. All authors approved the final manuscript.

295

296 Figure legends

297 Figure 1: Bland and Altman plots between measured height and predicted height with the two  
298 Chumlea's formulas in the total sample (n=1754), in the Republic of Congo (n=880) and the  
299 Central African Republic (n=874).

300 Chumlea's formula for non-Hispanic Black people: A: in the total sample, B: in ROC, C: in  
301 CAR; Chumlea's formula for Caucasian people: D: in total sample, E: in ROC, F: in CAR.

302 CAR: Central African Republic; ROC: Republic of Congo; SD: standard deviation.

303

304 Figure 2: Percentage of accurate prediction between measured height and height predicted  
305 using the two Chumlea formulas according to sex and age in the total sample (n=1754), in the  
306 Republic of Congo (n=880) and Central African Republic (n=874).

307 Total Sample: A: men; B: women; Republic of Congo: C: men; D: women; Central African  
308 Republic: E: men; F: women

309 Dark column: Chumlea's formula for non-Hispanic Black people; clear column: Chumlea's  
310 formula for Caucasian people

311 CAR: Central African Republic; CBP: Chumlea's formula for non-Hispanic Black people;  
312 CC: Chumlea's formula for Caucasian people; ROC: Republic of Congo.

313

314 Figure 3: Bland and Altman graphics between the measured height and the height predicted  
315 using the three Chumlea formulas and the created formula in the validation subsample  
316 (n=877).

317 A: Chumlea's formula for non-Hispanic Black people; B: Chumlea's formula for Caucasian  
318 people; C: Created formula.

319 SD: standard deviation

320

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Figure 1: Bland and Altman plots between measured height and predicted height with the two Chumlea's formulas in the total sample (n=1754), in Republic of Congo (n=880) and Central African Republic (n=874).

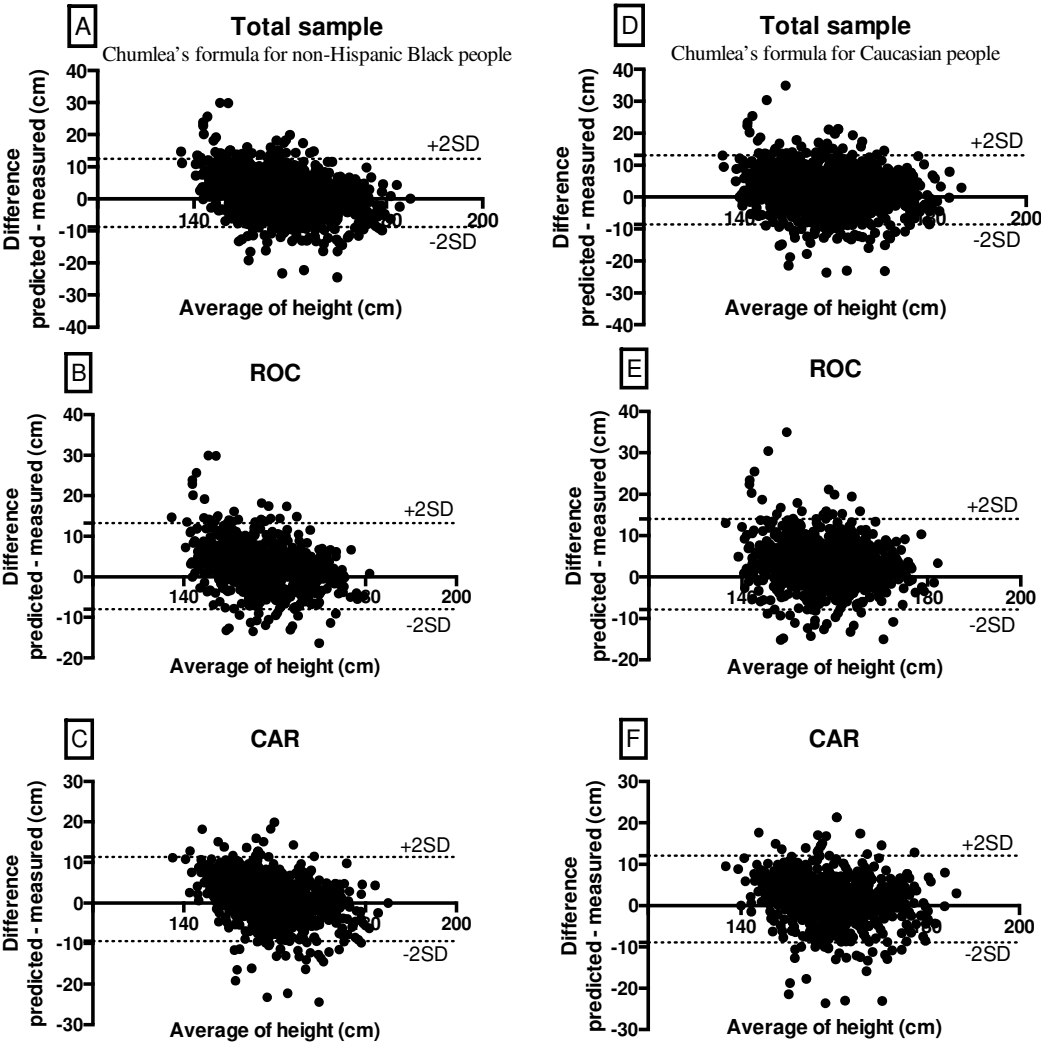




Figure 2: Percentage of accurate prediction between measured height and height predicted using the two Chumlea's formulas according to sex and age in the total sample (n=1754), in the Republic of Congo (n=880) and Central African Republic (n=874).

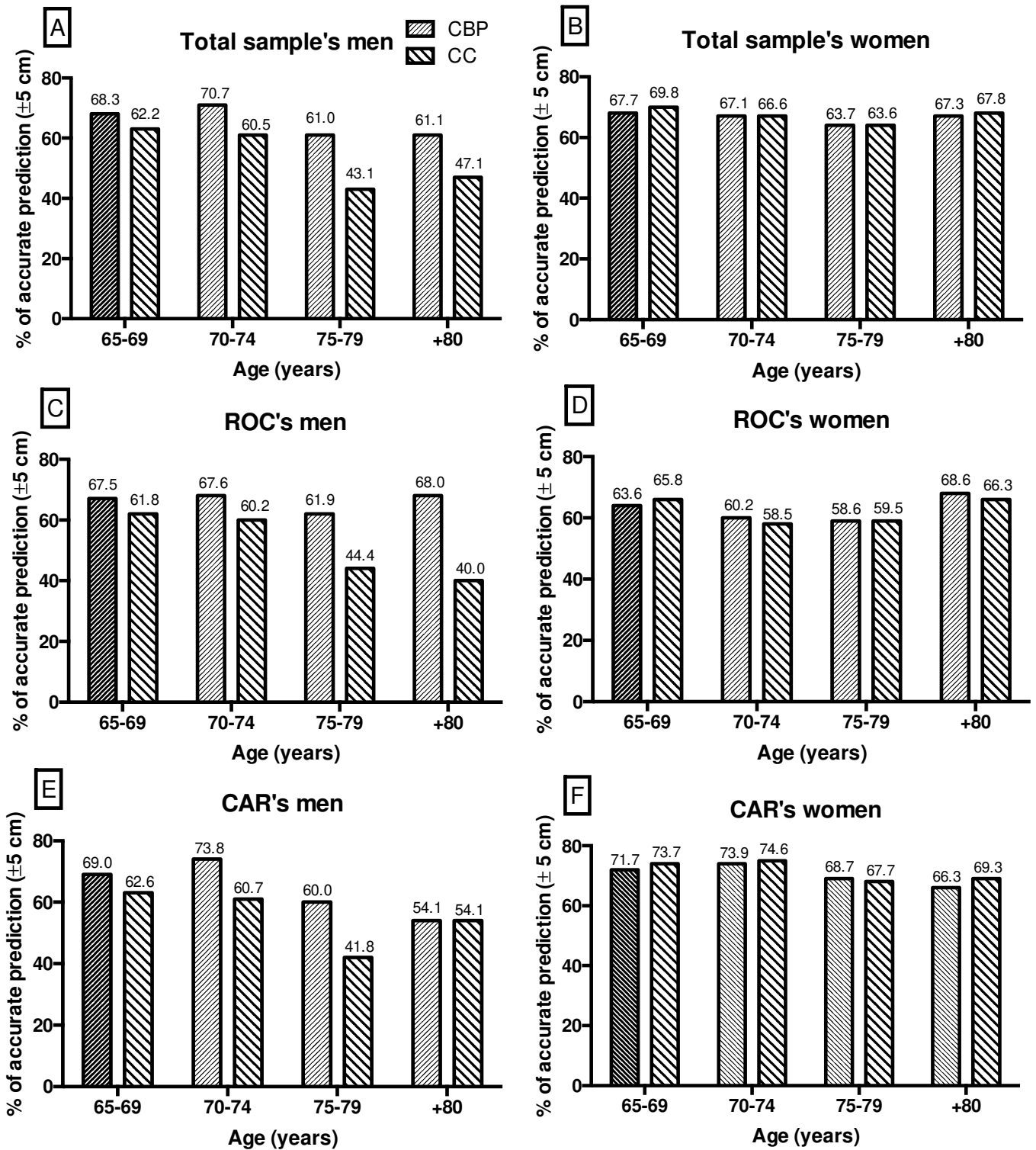


Figure 3: Bland and Altman graphics between the measured height and the height predicted using the two Chumlea's formulas and the created formula in the validation subsample (n=877).

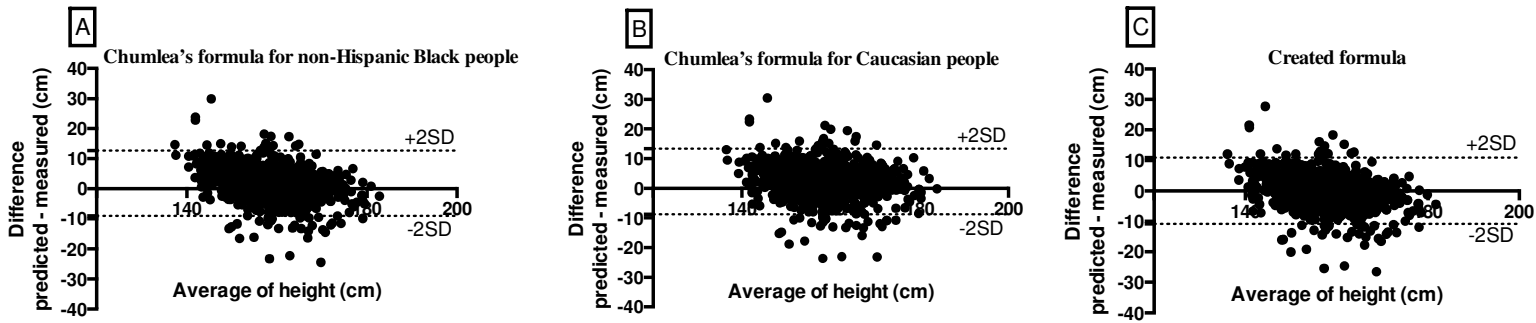


Table 1: Characteristics of the total sample (n=1754), derivation subsample (n=877) and validation subsample (n=877)

	Total sample (n = 1,754) median (IQR) or n (%)	Derivation subsample (n = 877) median (IQR) or n (%)	Validation subsample (n = 877) median (IQR) or n (%)	p Derivation subsample vs. validation subsample
<b>Women</b>	1079 (61.5)	555 (63.3)	524 (59.7)	0.13
Age (years)	72.0 (67.0 - 77.0)	71.0 (78.0 - 77.0)	72.0 (67.0 - 77.0)	0.63
ROC	880 (50.2)	441 (50.3)	439 (50.1)	0.92
Rural area	899 (51.3)	463 (52.8)	436 (49.7)	0.20
Weight (kg)	49.0 (43.0 - 59.0)	49.0 (43.0 - 59.0)	49.0 (43.0 - 58.8)	0.89
Height (cm)	157.0 (150.5 - 164.0)	157.0 (150.2 - 163.8)	157.0 (151.0 - 164.0)	0.91
KHt (cm)	50.0 (48.0 - 52.0)	50.0 (47.5 - 52.0)	50.0 (48.0 - 52.0)	0.78
BMI (kg/m <sup>2</sup> )	20.1 (17.8 - 23.1)	20.2 (17.7 - 23.2)	20.90 (17.8 - 23.0)	0.81

BMI: body mass index; IQR: interquartile range; Kht: knee height; ROC: Republic of Congo.

p (chi square test or Mann-Whitney test): derivation vs. validation subsamples.



- CBP	160.0	7.4	1.0	0.6	-9.4	11.4	94.6	69.4	11.4	19.2
- CC	160.5	8.3	1.5	0.9	-9.0	12.1	94.7	66.6	9.5	23.9

CBP: Chumlea's formula for non-hispanic Black people; CC: Chumlea's formula for Caucasian people; P-M: PHt minus MHt; SD: standard deviation.

Table 3: Prediction of height (PHt) using the two Chumlea's formulas and the created formula compared to measured height (MHt) in the validation subsample (n=877).

	Height		Bias		95% limit of agreement			ICC (95%CI)	Prediction		
	Mean (cm)	SD	P-M (cm)	%	From	to	% between limit		Accurate (%)	Under 5cm (%)	Over 5cm (%)
All (n=877)											
- MHt	157.5	9.3	-	-	-	-	-	-	-	-	-
- CBP	159.3	7.4	1.8	1.2	-9.1	12.7	94.4	0.76 (0.70 – 0.81)	65.3	8.8	25.9
- CC	159.8	8.3	2.3	1.4	-8.7	13.4	94.6	0.77 (0.67 – 0.83)	61.8	7.8	30.4
- Created formula	157.5	7.5	0.0	0.0	-10.8	10.9	94.1	0.78 (0.76 – 0.81)	71.3*	14.0*	14.7*

\*Comparison of percentage of prediction with CBP vs. created formula,  $p < 0.05$

CBP: Chumlea's formula for non-Hispanic Black people; CC: Chumlea's formula for Caucasian; CI: confidence interval; ICC: intraclass correlation coefficient; P-M: PHt minus MHt; SD: standard deviation.

Table 4: Nutritional status using body mass index (BMI) according to the measured or predicted height in the total sample (n=1748), Republic of Congo (n=878) and in Central African Republic (n=870).

	<b>Total sample</b>			
	measured	CBP	CC	Created formula
BMI (kg/m <sup>2</sup> ) median (IQR)	20.1 (17.8 - 23.1)	19.5 (17.3 - 22.4)*	19.4 (17.2 - 22.3)*	19.9 (17.7 - 23.0)
Undernutrition n (%)	600 (34.3)	676 (38.7)*	701 (40.1)*	599 (34.3)
Normal status n (%)	868 (49.7)	811 (46.4)	797 (45.6)	857 (49.0)
Overweight n (%)	199 (11.4)	183 (12.4)	174 (10.0)	204 (11.7)
Obesity n (%)	81 (4.6)	78 (4.5)	76 (4.3)	88 (5.0)
	<b>Republic of Congo</b>			
	measured	CBP	CC	Created formula
BMI (kg/m <sup>2</sup> ) median (IQR)	20.4 (18.0 - 23.6)	19.8 (17.3 - 22.9)*	19.8 (17.3 - 22.9)*	20.2 (17.8 - 23.5)
Undernutrition n (%)	265 (30.2)	320 (36.5)*	328 (37.4)*	281 (32.0)



Normal status n (%)	444 (50.6)	410 (46.7)	408 (46.5)	432 (49.2)
Overweight n (%)	116 (13.2)	102 (11.6)	97 (11.0)	110 (12.5)
Obesity n (%)	53 (6.0)	46 (5.2)	45 (5.1)	55 (6.3)
<b>Central African Republic</b>				
BMI (kg/m <sup>2</sup> ) median (IQR)	19.7 (17.5 - 22.2)	19.2 (17.3 - 22.1)	19.1 (17.1 - 22.0)*	19.7 (17.6 - 22.5)
Undernutrition n (%)	335 (38.5)	356 (40.9)	373 (42.9)	318 (36.6)
Normal status n (%)	424 (48.7)	401 (46.1)	389 (44.7)	425 (48.8)
Overweight n (%)	83 (9.6)	81 (9.3)	77 (8.8)	94 (10.8)
Obesity n (%)	28 (3.2)	32 (3.7)	31 (3.6)	33 (3.8)

\* Comparison between measured height and predictive formulas,  $p < 0.05$

CBP: Chumlea's formulas for non-Hispanic Black people; CC: Chumlea's formulas for Caucasian people; IQR: interquartile range.