British Journal of Nutrition (2023), 129, 1993–2000 doi:10.1017/S0007114522002719

Body composition and anthropometric indicators as predictors of blood pressure: a cross-sectional study conducted in young Algerian adults

Corinne Colette Dahel-Mekhancha[1,2]*, Marie-Françoise Rolland-Cachera[3], Jérémie Botton[4,5], Rabiaa Karoune[1,2], Ibrahim Sersar[1,2], Lynda Yagoubi-Benatallah[1,2], Ikram Bouldjedj[1,2], Abderraouf Benini[2], Léopold K. Fezeu[3], Lahcène Nezzal[2,6] and Djamel-Eddine Mekhancha[1,2]

[1]*Institut de la Nutrition, de l'Alimentation et des Technologies Agro-Alimentaires (INATAA), Université Frères Mentouri Constantine 1 (UFMC1), route de Aïn El Bey, 25000 Constantine, Algérie*

[2]*Laboratoire de recherche ALimentation, NUTrition et Santé (ALNUTS), Université Salah Boubnider Constantine 3, Nouvelle ville Ali Mendjeli, 25000 Constantine, Algérie*

[3]*Sorbonne Paris Nord University, INSERM U1153, Inrae U1125, Cnam, Nutritional Epidemiology Research Team (EREN), Epidemiology and Statistics Research Center, University of Paris (CRESS), Bobigny, France*

[4]*EPI-PHARE Scientific Interest Group in Epidemiology of Health Products from the French National Agency for the Safety of Medicines and Health Products and the French National Health Insurance, Saint-Denis, France*

[5]*Faculty of Pharmacy, University Paris-Sud, University Paris-Saclay, F-92296 Châtenay-Malabry, France*

[6]*Faculté de médecine, Université Salah Boubnider, Constantine 3, Nouvelle ville Ali Mendjeli, 25000 Constantine, Algérie*

(Submitted 2 February 2022 – Final revision received 13 July 2022 – Accepted 15 August 2022 – First published online 1 September 2022)

Abstract

Various body indicators are used to predict health risks. However, controversies still exist regarding the best indicators to predict CVD. Using a large number of measurements, our aim was to assess their associations with blood pressure (BP) and to identify the most relevant parameters to be used in health surveillance studies. The population included 589 students (67·2 % women) aged 20–25 years from Constantine (Algeria). Sixteen parameters were considered, including crude body measurements, ratios and body fat indicators based on bioelectrical impedance analysis (BIA). We used multi-adjusted linear regression models to assess the associations between body measurements and BP. According to WHO definitions, underweight, overweight-without obesity, obesity and hypertension (HT) were identified in 6·1, 18·0, 2·4 and 5·1 % of the subjects, respectively. Prevalence of HT was higher in men than in women (11·9 % *v.* 1·8 %; $P < 0·001$). In the whole sample, almost all indicators were positively associated with systolic and diastolic BP. The suprailiac skinfold had the strongest associations with systolic ($\beta = 3·498$; $P < 0·001$) and diastolic ($\beta = 2·436$; $P < 0·001$) BP, and as a whole, arm circumferences and weight were also good candidates. The currently used BMI, waist-to-hip, waist-to-height ratio and BIA indictors also predicted BP, but they did not seem to be better determinants of BP than crude anthropometric measurements. This study showed that overweight and HT were already found in the present population of young Algerian adults. Most body indicators were highly associated with BP, but simple anthropometric measurements appeared to be particularly useful to predict BP.

Keywords: **Anthropometric measurements: Blood pressure: Bioelectrical impedance: Algeria**

Obesity and its associated metabolic risks are growing problems in many countries, including Algeria, where more than half of the population is overweight[1,2]. The high prevalence of obesity accounts for the high prevalence of hypertension (HT)[3,4], and prevention is then a fundamental public health issue. HT was primarily considered an adult pathology, but nowadays it is also reported in childhood[5–8]. A systematic overview of obesity reported that young people generally give little priority to their future health, particularly in countries undergoing rapid demographic and economic transition[9]. Prevention is then crucial in many countries, particularly in those facing the double burden of malnutrition and obesity[10]. Prevention strategies targeting obesity and obesity-related metabolic diseases should be innovative, age and country specific, and culturally acceptable.

Abbreviations: BIA, bioelectrical impedance analysis; BP, blood pressure; DBP, diastolic blood pressure; HT, hypertension; SBP, systolic blood pressure; Sf, skinfold; TESfR, trunk-to-extremity Sf ratio; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

* **Corresponding author:** Corinne Colette Dahel-Mekhancha, email corinne.dahel@umc.edu.dz

They are usually launched on the basis of data assessing the importance of the risk. Epidemiological studies on the prevalence of obesity and HT are then essential. They frequently use anthropometric measurements which are easy and reliable methods for predicting metabolic risks. Another interest of this technique is that measurements recorded at different body sites such as trunk or extremity skinfolds (Sf)[11] or circumferences recorded at different parts of the body[12] correspond to different aspects of body composition and are associated with different health risks. Simple measurements can also be used to calculate indices assessing body shape and predicting metabolic diseases[13,14]. Bioelectrical impedance analysis (BIA) provides additional information on body composition and its use has become more frequent, even in epidemiological studies[15].

Numerous studies have examined body composition indicators in relation with health risks. As they do not always use the same variables, comparisons are difficult. The BMI is widely used in many countries including Algeria[16], as well as simple indicators such as waist circumference (WC)[1,2].

Our aim was to describe the body composition of Algerian students and to analyse the associations between body parameters and blood pressure (BP) in order to identify the most relevant methods to be used in epidemiological studies investigating adiposity–health risks associations and to refine the interpretation of the associations.

A characteristic of our study is the large number and the diversity of body measurements used, including BIA, in a young Algerian adult population where risk factors such as overweight and high BP are already present.

Materials and methods

Sample

Analyses were performed in the 589 subjects attending the Food Industry Engineer Course at the Constantine University (Algeria) between the years 2009–2014. Exclusion criteria was pregnancy. Fourteen investigation files were discarded for incomplete data. Basic scientific knowledge such as biology, chemistry, genetics or statistics was disseminated during the first 3 years of the education programme. Measurements were carried out during the 4th year when nutrition and body composition technique assessment were taught.

Ethics statement

Informed consent was obtained from each participant and data were analysed anonymously. The study referred to the Helsinki Declaration Accord (World Medical Association for Human Subjects) and was approved by the Institut de la Nutrition de l'Alimentation et des Technologies Agro-Alimentaires (INATAA) – Université Frères Mentouri Constantine 1 (UFMC1), Algeria.

Data collection

Body measurements and blood pressure. Anthropometric measurements were selected and performed following the protocol recommended by the WHO[17]. The trained research staff of the INATAA campus performed the measurements. Data were recorded three times and averaged the same day. Height (cm) was measured to the nearest millimetre using a telescopic height rod (Seca® 220). Sf thickness (mm) was measured using the Holtain calipers (Holtain® Ltd) at four sites: biceps (BI), triceps (TRI), suprailiac (SI) and subscapular (SS). Arm, hip and WC (cm) were measured to the nearest 0·1 cm using a non-elastic metric measuring tape. Body weight (kg) and body fat (Fat Bia) (kg) were measured with a body composition analyser (BIA Tanita® BC-418, 8 electrodes, precision ± 0·2 kg for weight and ± 12 Ω for resistance; Tanita® UK Ltd). The predictive equations to assess body fat were provided by the manufacturer[18].

Systolic BP (SBP) and diastolic BP (DBP) (mmHg) were performed by trained research staff, at the INATAA campus, using an OMRON® M3 V4 BP monitor, in a sitting position after at least 5 min rest. Measurements recorded at the left arm were repeated three times and averaged on the same day. HT was defined according to WHO[19] as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg.

Body indicators based on body measurements. *Nutritional status* was evaluated by the BMI calculated as the $\text{weight}_{(kg)}$ over $\text{height}_{(m)}$ squared (BMI_{kg/m^2}). Grades of nutritional status were defined according to WHO definition[17]: BMI < 18·5 defines underweight and BMI < 17 defines moderate and severe thinness. All BMI values ≥ 25 correspond to overweight, including obesity. Obesity is defined as BMI ≥ 30.

Body fat percentage based on BIA: Fat $\text{BIA}_{(\%)}$ calculated as Fat $\text{BIA}_{(kg)}$ divided by body $\text{weight}_{(kg)}$ and multiplied by 100 was given by the Tanita body composition analyser.

The *fat mass index* was calculated as Fat $\text{BIA}_{(kg)}$ over $\text{height}_{(m)}$ squared[15,20].

Body fat distribution was predicted from Sf and circumferences: the trunk-to-extremity Sf ratio (TESfR) corresponds to the sum of trunk $\text{Sf}_{(mm)}$ (SS + SI) divided by the sum of extremity $\text{Sf}_{(mm)}$ (BI + TRI); the waist-to-hip ratio (WHR) as the ratio of $\text{WC}_{(cm)}$ divided by hip $\text{circumference}_{(cm)}$ and the waist-to-height ratio (WHtR) as the $\text{WC}_{(m)}$ divided by $\text{height}_{(m)}$.

Data analysis

With the sample size determined by the feasibility of recruitment (*n* 589), we were able to detect as statistically significant at 5 % a correlation coefficient of 0·12 with a power set to 80 %. Characteristics of the population are presented separately by sex as means and standard deviations for continuous variables (Table 1) and as percentage for categorical variables (Table 2). Unpaired *t* tests were used to compare means while χ^2 or Fisher exact tests were used to compare percentages between men and women. In order to allow comparisons of associations between body measurements and BP, the formers were transformed as Z-scores.

Linear regressions adjusted for age (continuous, year) and sex (total population) or for age (sex separately) were used to test the associations between body parameters and BP. In each model, a term of interaction between sex and body parameter was introduced to test the modifying effect of sex on the anthropometry–BP associations.

https://doi.org/10.1017/S0007114522002719 Published online by Cambridge University Press

Table 1. Characteristics of Algerian men and women aged 20–25 years (Mean values and standard deviations)

Variables	Total Mean	Total SD	Males Mean	Males SD	Females Mean	Females SD	P*
n	589		193		396		
General characteristics							
Age (years)	22·5	1·1	22·7	1·3	22·3	1·0	< 0·001
Weight (kg)	62·9	10·6	70·1	9·5	59·4	9·3	< 0·001
Height (cm)	166·1	8·5	175·2	5·9	161·7	5·5	< 0·001
Fat BIA (kg)	15·3	6·8	10·5	4·7	17·6	6·4	< 0·001
Circumferences (cm)							
Arm	27·4	3·1	28·2	2·8	27·0	3·2	< 0·001
Waist	77·5	8·4	80·7	7·4	75·9	8·5	< 0·001
Hip	99·3	6·6	98·3	5·8	99·8	6·9	0·007
Skinfold thickness (mm)							
Biceps	6·4	3·4	4·2	1·9	7·5	3·5	< 0·001
Triceps	13·9	7·0	8·3	3·6	16·7	6·7	< 0·001
Suprailiac	11·1	6·0	7·8	4·3	12·7	6·0	< 0·001
Subscapular	13·5	5·4	10·8	3·7	14·8	5·6	< 0·001
Adiposity indices							
BMI (kg/m^2)	22·7	3·1	22·8	3·0	22·7	3·2	0·54
FMI (kg/m^2)	5·6	2·6	3·4	1·6	6·7	2·3	< 0·001
TESfR	1·28	0·35	1·52	0·34	1·17	0·29	< 0·001
WHR	0·89	1·84	0·82	0·05	0·76	0·06	< 0·001
WHtR	0·47	0·05	0·46	0·04	0·47	0·05	0·03
Fat BIA (%)	24·1	8·9	14·5	5·0	28·8	6·3	< 0·001
Blood pressure (mm Hg)							
SBP	113·9	13·2	119·1	16·3	111·4	10·5	< 0·001
DBP	69·2	9·5	69·6	10·8	68·9	8·7	0·40

BIA, bioelectrical impedance analysis; FMI, fat mass index; TESfR, trunk-to-extremity skinfold ratio; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure.
* Unpaired *t* tests for sex comparison.

Table 2. Distribution of Algerian men and women aged 20–25 years in different categories of nutritional status according to WHO, 1995[17] and blood pressure to WHO, 1993[19] (Numbers)

Categories	Total	Men	Women	P*
n	589	193	396	
BMI (% of subjects)				
Underweight BMI < 18·5 kg/m^2	6·1 % (*n* 36)	4·2 % (*n* 8)	7·1 % (*n* 28)	0·58
Normal weight 18·5 ≤ BMI < 25 (kg/m^2)	73·5 % (*n* 433)	75·1 % (*n* 145)	72·7 % (*n* 288)	
Overweight (without obesity) 25 ≤ BMI ≥ 30 kg/m^2	18·0 % (*n* 106)	18·7 % (*n* 36)	17·7 % (*n* 70)	
Obesity BMI ≥ 30 kg/m^2	2·4 % (*n* 14)	2·1 % (*n* 4)	2·5 % (*n* 10)	
Blood pressure level (% of subjects)				
SBP ≥ 140 mmHg	4·1 (*n* 24)	10·4 (*n* 20)	1·0 (*n* 4)	< 0·001
DBP ≥ 90 mmHg	1·9 (*n* 11)	4·1 (*n* 8)	0·8 (*n* 3)	0·007
HT SBP ≥ 140 and/or DBP ≥ 90	5·1 (*n* 30)	11·9 (*n* 23)	1·8 (*n* 7)	< 0·001

SBP, systolic blood pressure; DBP, diastolic blood pressure; HT, hypertension.
* χ^2 or Fisher exact test was used for sex comparison.

In order to compare the predictive power of anthropometric parameters across the total population (*n* 589), then men (*n* 193) and women (*n* 396), a minimal β difference for a statistically significant test was computed at the significance levels of 0·05, 0·01 and 0·001, assuming that the SD for each β was 1.

Contrast tests were used to rank the predictive value of BP across body parameters in the same population, that is, total sample, men and women (Tables 3 and 4). A difference among two β values above 0·115 mmHg ($P < 0·05$) or 0·151 mmHg ($P < 0·01$) in the total population, 0·202 mmHg ($P < 0·05$) or 0·266 ($P < 0·01$) in men and 0·140 mmHg ($P < 0·05$) or 0·184 mmHg ($P < 0·01$) in women was statistically significant.

All statistical analyses were performed using SAS software (version 9.4, SAS Institute Inc.). All tests were two-sided and a probability value less than 0·05 was considered significant.

Results

Analyses were performed in 589 subjects (67·2 % women) aged 22·5 years (SD 1·1; range 20–25 years).

Body measurements characteristics

Table 1 presents body characteristics by sex. All mean values were statistically different between sexes except BMI. For

https://doi.org/10.1017/S0007114522002719 Published online by Cambridge University Press

British Journal of Nutrition

Table 3. Association between 1 Z-score increase of various body indicators with SBP changes (mmHg) in 20–25-year-old Algerian men and women (*β*-coefficients and 95 % confidence intervals)

		Total (*n* 589)			Men (*n* 193)			Women (*n* 396)		
Body indicators	*β**	95 % CI	*P*	*β***	95 % CI	*P*	*β***	95 % CI	*P*	*P****(*M/W*)
Weight	2·706	1·717, 3·695	< 0·001	2·219	−0·023, 4·461	0·05	2·931	1·943, 3·919	< 0·001	0·52
Height	1·513	0·507, 2·518	0·003	1·407	−0·850, 3·664	0·22	1·603	0·585, 2·620	0·002	0·84
Circumferences										
Arm	2·937	1·950, 3·924	< 0·001	2·592	0·327, 4·857	0·03	3·057	2·073, 4·041	< 0·001	0·74
Waist	2·653	1·660, 3·646	< 0·001	1·862	−0·400, 4·123	0·11	3·021	2·034, 4·008	< 0·001	0·34
Hip	2·333	1·337, 3·328	< 0·001	1·011	−1·252, 3·273	0·38	2·986	2·000, 3·972	< 0·001	0·06
Skinfolds										
Triceps	1·849	0·847, 2·850	< 0·001	0·530	−1·733, 2·793	0·65	2·488	1·489, 3·488	< 0·001	0·08
Biceps	0·940	−0·070, 1·950	0·07	0·166	−2·098, 2·430	0·89	1·291	0·269, 2·313	0·01	0·31
Suprailiac	3·498	2·522, 4·473	< 0·001	3·665	1·453, 5·876	0·001	3·421	2·446, 4·396	< 0·001	0·74
Subscapular	1·684	0·678, 2·690	0·001	1·153	−1·130, 3·436	0·32	1·896	0·883, 2·908	< 0·001	0·56
BIA										
Fat mass	2·670	1·680, 3·660	< 0·001	1·873	−0·382, 4·128	0·11	3·025	2·040, 4·009	< 0·001	0·31
FMI	2·502	1·510, 3·495	< 0·001	1·621	−0·639, 3·882	0·16	2·892	1·903, 3·881	< 0·001	0·26
%Fat	2·118	1·120, 3·117	< 0·001	1·337	−0·934, 3·607	0·25	2·449	1·448, 3·449	< 0·001	0·34
Ratio										
BMI	2·231	1·234, 3·228	< 0·001	1·581	−0·674, 3·836	0·17	2·518	1·519, 3·517	< 0·001	0·40
TESfR	1·799	0·786, 2·812	0·001	3·391	1·140, 5·642	0·004	1·029	−0·003, 2·061	0·05	0·02
WHR	1·799	0·785, 2·813	0·001	1·946	−0·367, 4·260	0·10	1·692	0·671, 2·713	0·001	0·67
WHtR	2·177	1·177, 3·178	< 0·001	1·250	−1·025, 3·524	0·28	2·599	1·601, 3·597	< 0·001	0·26

SBP, systolic blood pressure; DBP, diastolic blood pressure; BIA, bioelectrical impedance analysis; FMI, fat mass index; TESfR, trunk-to-extremity skinfold ratio; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.
A difference among two *β* values above 0·115 mmHg ($P < 0·05$) or 0·151 mmHg ($P < 0·01$) in the total population, 0·202 mmHg ($P < 0·05$) or 0·266 ($P < 0·01$) in men and 0·140 mmHg ($P < 0·05$) or 0·184 mmHg ($P < 0·01$) in women is statistically significant.
* Adjusted for age and sex.
** Adjusted for age.
*** Compares the association between body indicator and systolic blood pressure between sexes.

Table 4. Association between 1 Z-score increase of various body indicators with DBP changes (mmHg) in 20–25-year-old Algerian men and women (*β*-coefficients and 95 % confidence intervals)

		Total (*n* 589)			Men (*n* 193)			Women (*n* 396)		
Body indicators	*β**	95 % CI	*P*	*β***	95 % CI	*P*	*β***	95 % CI	*P*	*P****(*M/W*)
Weight	1·407	0·657, 2·158	< 0·001	0·376	−1·141, 1·893	0·63	1·905	1·070, 2·741	< 0·001	0·06
Height	0·613	−0·144, 1·371	0·11	−0·535	−2·052, 0·983	0·49	1·180	0·332, 2·029	0·007	0·04
Circumferences										
Arm	1·798	1·052, 2·545	< 0·001	1·227	−0·302, 2·545	0·12	2·065	1·233, 2·896	< 0·001	0·32
Waist	1·871	1·124, 2·617	< 0·001	1·554	0·043, 3·064	0·04	2·020	1·186, 2·854	< 0·001	0·59
Hip	1·020	0·265, 1·775	0·008	−0·351	−1·870, 1·168	0·65	1·687	0·847, 2·527	< 0·001	0·01
Skinfolds										
Triceps	1·794	1·049, 2·539	< 0·001	0·496	−1·020, 2·012	0·52	2·425	1·603, 3·247	< 0·001	0·02
Biceps	0·749	−0·007, 1·506	0·05	0·629	−0·886, 2·144	0·42	0·802	−0·051, 1·655	0·07	0·83
Suprailiac	2·436	1·701, 3·171	< 0·001	1·979	0·482, 3·476	0·01	2·659	1·841, 3·476	< 0·001	0·42
Subscapular	1·194	0·439, 1·949	0·002	1·491	−0·029, 3·011	0·06	1·045	0·195, 1·896	0·02	0·57
BIA										
Fat mass	1·911	1·167, 2·654	< 0·001	1·209	−0·303, 2·722	0·12	2·244	1·417, 3·071	< 0·001	0·21
FMI	1·877	1·133, 2·621	< 0·001	1·311	−0·201, 2·823	0·09	2·144	1·315, 2·974	< 0·001	0·31
%Fat	1·867	1·123, 2·611	< 0·001	1·398	−0·116, 2·913	0·07	2·087	1·256, 2·918	< 0·001	0·40
Ratio										
BMI	1·277	0·525, 2·029	0·001	0·675	−0·841, 2·191	0·38	1·564	0·721, 2·406	< 0·001	0·28
TESfR	0·862	0·098, 1·626	0·03	2·014	0·497, 3·530	0·01	0·310	−0·553, 1·172	0·48	0·03
WHR	1·867	1·114, 2·620	< 0·001	2·881	1·374, 4·388	< 0·001	1·391	0·542, 2·241	0·001	0·99
WHtR	1·688	0·939, 2·437	< 0·001	1·664	1·153, 3·175	0·03	1·695	0·855, 2·536	< 0·001	0·07

SBP, systolic blood pressure; DBP, diastolic blood pressure; BIA, bioelectrical impedance analysis; FMI, fat mass index; TESfR, trunk-to-extremity skinfold ratio; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.
A difference among two *β* values above 0·115 mmHg ($P < 0·05$) or 0·151 mmHg ($P < 0·01$) in the total population, 0·202 mmHg ($P < 0·05$) or 0·266 ($P < 0·01$) in men and 0·140 mmHg ($P < 0·05$) or 0·184 mmHg ($P < 0·01$) in women is statistically significant.
* Adjusted for age and sex.
** Adjusted for age.
*** Compares the association between body indicator and systolic blood pressure between sexes.

https://doi.org/10.1017/S0007114522002719 Published online by Cambridge University Press

example, fat mass assessed by BIA was 10·5 kg in men and 17·6 kg in women ($P < 0·001$), while BMI corresponded to 22·8 kg/m^2 in men and 22·7 kg/m^2 in women ($P = 0·54$). Men were taller, heavier, had greater arm and WC than women (all $P < 0·001$) while hip circumference was higher in women ($P = 0·007$). Sf and body fat assessed by BIA were higher in women ($P < 0·001$). The percentage of fat mass using BIA was almost twice as high in women as compared with men (28·8 % *v.* 14·5 %; $P < 0·001$). WHR was higher in men as compared with women (0·82 *v.* 0·76; $P < 0·001$) but WHtR was only slightly lower in men as compared with women (0·46 *v.* 0·47; $P = 0·03$). Mean SBP was 7·7 mmHg higher in men as compared with women ($P < 0·001$) but no statistical sex difference appeared for DBP ($P = 0·40$).

Body composition as categorical variables

Table 2 presents the prevalence of subjects according to WHO classification for the different grades of nutritional status[17] and HT[19] for the whole population and separately by sex. Based on BMI (kg/m^2), underweight (BMI < 18·5), normal weight (18·5 < BMI < 25), overweight-without obesity (25 ≥ BMI < 30) and obesity (BMI ≥ 30) were identified in 6·1, 73·5, 18·0 and 2·4 % subjects, respectively. Severe thinness (BMI < 17) affected 1·9 % of subjects (1·0 % in men and 2·3 % in women). According to WHO definition[17,19], overweight including obesity (all BMI ≥ 25) was present in 20·4 % of the population and high SBP, high DBP and HT affected 4·1, 1·9 and 5·1 % of the subjects, respectively.

The prevalence of weight status categories was not significantly different between sexes, but the prevalence of subjects with high SBP or high DBP was higher in men than in women ($P < 0·001$ and $P = 0·007$, respectively). Likewise, the prevalence of HT was higher in men than in women (11·9 % *v.* 1·8 %; $P < 0·001$).

Association between body measurements and blood pressure

In Tables 3 and 4, sixteen indicators were considered for their associations with BP: nine crude measurements (weight, height, arm, waist and hip circumferences, four Sf), four ratios (BMI, TESfR, WHR, WHtR) and three indicators assessed from BIA (Fat BIA$_{kg}$, fat mass index and Fat BIA$_{\%}$).

In the whole sample, almost all indicators were significantly positively associated with SBP (Table 3) and DBP (Table 4), except the BI Sf with both SBP ($P = 0·07$) and DBP ($P = 0·05$) and height with DBP ($P = 0·11$).

After introducing a term of interaction between sex and anthropometric parameter to test the modifying effect of sex on body measurements–BP associations, differences between sexes were generally not significant with some exceptions: with SBP, 1 Z-score increase in TESfR had a significantly higher association in men ($\beta = 3·391$ mmHg) than in women ($\beta = 1·029$) ($P_{interaction} = 0·02$); with DBP, the association was higher in women than in men for height ($\beta = 1·180$ *v.* −0·535; $P = 0·04$), hip ($\beta = 1·687$ *v.* −0·351; $P = 0·01$) and TRI Sf ($\beta = 2·425$ *v.* 0·496; $P = 0·02$) and higher in men for TESfR ($\beta = 2·014$ *v.* 0·310; $P = 0·03$).

SI Sf had the highest association with BP and was the only indicator significantly associated with both SBP and DBP in both sexes. According to contrast tests, the best predictors of SBP were SI Sf and arm circumference (all $P < 0·01$) in the whole sample; the SI Sf and TESfR (all $P < 0·01$), arm circumference ($P < 0·05$) and weight ($P = 0·05$) in men; and the SI Sf ($P < 0·01$) in women. The best predictors of DBP were SI Sf ($P < 0·01$) in the whole sample; WHR ($P < 0·01$) in men; and SI and TRI Sf (all $P < 0·01$) in women. The aim of contrast tests is to identify which indicators are significantly the best predictors of BP in each population (whole sample, men and women separately). Nevertheless, most of those in the following ranks were also strongly associated with BP (e.g. arm circumference ($\beta = 3·057$) compared with SI Sf ($\beta = 3·421$) for SBP in women), but with significantly less predictive values. Of note, within each population, none of the BIA indicators was significantly stronger predictors of BP than the anthropometric measurements cited above.

Based on the results of contrast tests and considering the performances of each indicator in Tables 3 and 4, it appears that SI Sf, arm circumference and weight were particularly useful predictors of BP.

Discussion

Our study described the body composition of 20–25-year-old Algerian subjects and analysed the associations between body parameters and BP.

We found that underweight and overweight and HT were already present in Algerian students. Categories of weight status did not differ significantly between sexes, but HT was clearly more prevalent in men as compared with women. The SI Sf had the best predictive value of BP in men and women, but simple measurements such as arm circumference and weight were also good candidates. Indicators such as BMI, WHR, WHtR and BIA were also good predictors of BP, but they did not appear to perform better than crude anthropometric measurements. By using a large number of measurements, our study allowed a comprehensive ranking of the predictive value of each indicator, facilitating comparisons between studies.

Weight status

The prevalence of underweight (BMI < 18·5 kg/m^2) was 6·1 %, including 1·9 % of severe thinness (BMI < 17·0). Overweight (including obesity) (BMI ≥ 25) was present in 20·4 % of participants. Similar results were reported in another Algerian study where 7·1 % of 23·3 (SD 2·0)-year-old students were underweight (6·9 % of men and 7·3 % of women) and the prevalence of overweight (including obesity) was 18 %[21]. In other parts of the world, for example in 20 (SD 9)-year-old Lebanese students, 4·1 % were underweight (1 % men and 6·4 % women) and the prevalence of overweight including obesity was 31·1 % (40 % men and 16·8 % women)[22]. In 18–34-year-old French respondents of the Esteban study[23], underweight prevalence was 4·4 % and overweight 33·3 %. In 18–29-year-old Afghan subjects, underweight was present in 8·9 % of the population, and overweight in 42·7 % of them including 11·3 % of subjects with

https://doi.org/10.1017/S0007114522002719 Published online by Cambridge University Press

obesity[24]. In Colombian students aged 19–24 years, 6 % were underweight and 25 % were overweight[25]. As a rule, the prevalence of underweight and overweight reported in these different countries is of the same order as those of the present study.

Body measurement and composition differences appeared between sexes, except for BMI. Data of 20-year-old subjects of the French ELANCE study[26] were compared with a sample of 19–21-year-old students from Constantine (Algeria). While BMI did not differ between the two populations, lean mass measured by BIA was higher in French men and fat mass was higher in Algerian women[27]. These observations confirm that BMI does not precisely reflect differences in body composition.

Blood pressure

Since the turn of the century, Algeria shows an epidemiological transition towards chronic non-communicable diseases. As a result, Algeria is witnessing a growing increase in the incidence of CVD, diabetes, obesity and cancer[28]. Among these, HT is the most prevalent public health concern, followed by diabetes[29].

Mean blood pressure values. Our study showed that BP values (mmHg) differ between sexes for SBP but not for DBP. Mean SBP was higher in men than in women (119·1 *v.* 111·4; $P < 0·001$), but no difference was observed for DBP (69·6 *v.* 68·9; $P = 0·40$). In the 19–34-year-age range of the French Esteban study[23], SBP was 123·4 in men and 111·5 in women and DBP was 72·7 in men and 70·6 in women. In 22–28-year-old Chilean subjects[30], SBP was 123·5 in men and 107·8 in women and DBP was 75·7 in men and 70 in women. A pooled analysis of 1018 populations, including 88·6 million participants in the NCD-RisC collaboration analysis[31], showed worldwide trends of BP by sex, age range and social status. In the 20–29-year-old range of this population, during the 2005–2016 period, SBP for the region of Central Asia, Middle East and North Africa was 119·6 in men and 112·4 in women. The BP values recorded in the present study are of the same order as those recorded in these different countries.

Hypertension. In the present young population, the prevalence of HT was 5·1 % (30 in 589 subjects). This value is within the range of prevalence recorded in other countries. Several studies have been conducted in Africa. Among the Algerian sub-population of the 'Africa/Middle East Cardiovascular Epidemiological study' the prevalence of HT was 8·5 % in 18–29-year-old subjects[32]. In South Africa, the prevalence of HT was 1·9 % in 18–29-year-old subjects[33]. In European countries, for example, in Crete, the prevalence was 6·7 % in 22 (SD 2)-year-old subjects[34]. In 18–34-year-old French subjects of the Esteban study, the prevalence of HT was 6·3 % (11·7 % in men and 1·8 % in women)[23]. Consistent with our results, all these studies confirm that the prevalence of HT was higher in men than in women in spite of higher body fat in women, underlying the importance of body fat localisation.

In summary, it appears that the prevalence of weight status and HT, and mean BP values reported in our study were within the ranges of values recorded in other young adult populations. More pronounced differences may exist when comparing older populations.

Associations between body measurements and blood pressure

Our data showed that most body indicators were strongly and positively associated with BP in the whole population, but when stratifying the analyses on sex, the associations were less often significant in men than in women. As the interaction tests were most often non-significant, the weaker associations in men as compared with women were likely due to smaller sample size rather than to weaker body measurement–BP associations. This lack of marked differences between sexes is consistent with the results of previous studies[14,35].

In our study, the commonly used BMI was significantly associated with both SBP and DBP, but regressions showed that its predictive value was only moderate. The high prediction of BP found with SI Sf is consistent with other studies[11,35] and fits with the abdominal-metabolic risk association established years ago[36].

A meta-regression analysis of prospective studies showed that both WC and WHR were good predictors of CVD[14]. Another meta-analysis found WHtR to be a good screening tool for detecting cardiometabolic diseases[13]. It appears then that various indicators are recommended in the different studies, making ranking difficult.

Differences are also observed in studies comparing body measurements–BP associations in various countries. An analysis performed in developing and developed countries showed that BMI, WHR and WC were all associated with BP, even in widely contrasted contexts such as in the Seychelles and Switzerland[37]. However, the similarity of results recorded in these different countries contrasts with the results of a study comparing France and Cameroon[38] which showed that the association between WC and metabolic abnormalities was higher in Cameroon as compared with France. Besides, this latter study found a stronger association in urban than in rural Cameroonian participants suggesting that environmental factors may affect the body measurements–BP associations.

Various reasons may explain the variety of results reported in the literature. The results can depend on the choice and number of measurements considered. In addition, many indicators are associated with BP, but the difference in the levels of the associations is often marginal, making graduation uncertain. Nevertheless, it appears that trunk Sf, WC and indices such as BMI, WHR and WHtR are generally selected as good candidates and are often used in epidemiological studies. Our results confirm the validity of these indicators, but note that other simple measurements such as Sf recorded at various body sites, arm circumference or weight are less frequently considered.

The differences between crude anthropometric measurements and other methods predicting BP can be related to their associations with body composition and to technological aspects. The good performance of SI Sf reflects the established association between abdominal fat and metabolic diseases[39], but that of body weight and arm circumference is less clear although they are also associated with body fat[40,41]. Measures of body size rather than body shape (ratio) may be more directly related to risk factors such as genetic or early growth processes[42].

BIA which is a more specific method for assessing body composition was also a good predictor of BP (total fat rather than fat mass index or % of fat) but did not seem to provide better associations than simple measurements. Similar findings were reported in studies using either dual-energy X-ray absorptiometry[43,44] or densitometry[45]. These methods use prediction equations which may not be always accurately adapted to the subjects. Crude measures may correspond more precisely to each individual.

Given the various results obtained according to the methods used, it appears useful to consider a variety of measurements in order to investigate which body characteristics are particularly associated with risk factors. Comparison of the different results can help understand the processes contributing to the development of metabolic diseases.

Limitations and strengths of the study

Our study has some limitations. The analysis is based on cross-sectional data and the sample is not representative of the Algerian young adult population. However, the main aim of the study was to compare the strength of the associations of various body measurements with BP, but indeed, results could be different in other populations. Another limitation is the lack of confounding factors used in our study. They are important to improve the validity of the results, but given the homogeneity of our sample of Algerian students, except physical activity, adjustment for factors such as genetics, smoking and alcohol use may not be crucial in this population. In addition, the smaller sample size of men as compared with women may cause less precise association estimates and a lower statistical power, but this sex difference reflects the population of the Algerian University where 62·5 % of students were young women in 2017[46].

The main strength of our study is the large number of indicators considered, including various crude anthropometric measurements, ratios and BIA, thus permitting fruitful comparisons with previous body indicators–BP associations reported in the literature. It also provides detailed information on the weight status and body composition of young Algerian adults, including grades of thinness and overweight and on BP parameters that can be compared with other countries.

The study was conducted in 20–25-year-old subjects, an age range not often represented as many studies in this area are conducted in children or in more general adult populations. This age range is particularly interesting as co-morbidities and use of treatments are not frequent compared with older adults.

In conclusion, our study presents detailed information on the health status of Algerian students, showing that overweight and high BP are already present in young adults. Therefore, assessing the presence of cardiovascular risk factors is of particular importance. However, controversies still exist regarding the best indicators to be used. Based on a large number of measurements, we found that most indicators were strongly associated with BP, but the currently used BMI, waist-to-hip, waist-to-height ratio and BIA indictors did not seem to perform better than crude anthropometric measurements.

Our study identified the most relevant parameters to predict BP in young adults and showed that simple anthropometric measurements are valuable screening tools for assessing cardiovascular risks.

Acknowledgements

The authors thank all those who contributed to this study, in particular the ALNUTS laboratory for its support, the students who participated in the study and Dr France Bellisle for editing the manuscript.

No financial support was provided during this study.

C. C. D.-M.: study concept and coordination, data management and analysis and drafted the manuscript; M.-F. R.-C.: data analysis and drafted the manuscript; J. B.: data analysis and critical reading of manuscript; R. K., I. S., L. Y.-B., I. B. and A. B.: study concept and organisation, standardisation, training and collection of data; L. F.: statistical supervision; L. N. and D.-E. M.: study concept, administrative coordination and critical feedback.

The authors have no conflicts of interest to declare.

References

1. Atek M, Traissac P, El Ati J, *et al.* (2013) Obesity and association with area of residence, gender and socio-economic factors in Algerian and Tunisian adults. *PLoS One* **8**, e75640.
2. World Health Organization (2018) Ministry of Health, Population and Hospital Reform (Algeria). Algeria STEPS Noncommunicable Disease Risk Factors Survey 2016–2017. https://www.who.int/publications/m/item/2016–2017-steps-fact-sheet-algeria (accessed July 2022).
3. Kannel WB, Brand N, Skinner JJ, *et al.* (1967) The relation of adiposity to blood pressure and development of hypertension. The Framingham study. *Ann Intern Med* **67**, 48–59.
4. Landsberg L, Aronne LJ, Beilin LJ, *et al.* (2013) Obesity-related hypertension: pathogenesis, cardiovascular risk, and treatment: a position paper of The Obesity Society and the American Society of Hypertension. *J Clin Hypertens* **15**, 14–33.
5. Botton J, Heude B, Kettaneh A, *et al.* (2007) Cardiovascular risk factor levels and their relationships with overweight and fat distribution in children: the Fleurbaix Laventie Ville Santé II study. *Metabolism* **56**, 614–622.
6. Plachta-Danielzik S, Landsberg B, Johannsen M, *et al.* (2008) Association of different obesity indices with blood pressure and blood lipids in children and adolescents. *Br J Nutr* **100**, 208–218.
7. Benmohammed K, Valensi P, Benlatreche M, *et al.* (2015) Anthropometric markers for detection of the metabolic syndrome in adolescents. *Diabetes Metab* **41**, 138–144.
8. Wühl E (2019) Hypertension in childhood obesity. *Acta Paediatr* **108**, 37–43.
9. Poobalan A & Aucott L (2016) Obesity among young adults in developing countries: a systematic overview. *Curr Obes Rep* **5**, 2–13.
10. Varela-Silva MI, Dickinson F, Wilson H, *et al.* (2012) The nutritional dual-burden in developing countries–how is it assessed and what are the health implications? *Coll Antropol* **36**, 39–45.
11. Sardinha LB, Teixeira PJ, Guedes DP, *et al.* (2000) Subcutaneous central fat is associated with cardiovascular risk factors in men independently of total fatness and fitness. *Metab Clin Exp* **49**, 1379–1385.

British Journal of Nutrition

12. Seidell JC, Pérusse L, Després JP, *et al.* (2001) Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. *Am J Clin Nutr* **74**, 315–321.
13. Ashwell M, Gunn P & Gibson S (2012) Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes Rev* **13**, 275–286.
14. de Koning L, Merchant AT, Pogue J, *et al.* (2007) Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. *Eur Heart J* **28**, 850–856.
15. Wells JC, Williams JE, Fewtrell M, *et al.* (2007) A simplified approach to analysing bio-electrical impedance data in epidemiological surveys. *Int J Obes* **31**, 507–514.
16. Dahel-Mekhancha CC, Karoune R, Yagoubi L, *et al.* (2016) Statut pondéral et pratiques alimentaires des jeunes en Algérie (Weight status and dietary behaviours among young Algerians). *Nutr Santé* **5**, 69–80.
17. World Health Organization (1995) *Physical Status: the Use and Interpretation of Anthropometry. Report of a WHO Expert Committee. World Health Organization Technical Report Series no. 854*. Geneva: WHO.
18. Jebb SA, Cole TJ, Doman D, *et al.* (2000) Evaluation of the novel Tanita body-fat analyser to measure body composition by comparison with a four-compartment model. *Br J Nutr* **83**, 115–122.
19. World Health Organization (1993) Guidelines for the management of mild hypertension: memorandum from a WHO/ISH meeting. *Bull World Health Organ* **71**, 503–517.
20. Peltz G, Aguirre MT, Sanderson M, *et al.* (2010) The role of fat mass index in determining obesity. *Am J Hum Biol* **22**, 639–647.
21. Sersar I, Mekhancha DE, Vuillemin A, *et al.* (2019) Association de l'activité physique et du sommeil avec la composition corporelle des étudiants universitaires algériens (Association of physical activity and sleep with body composition in Algerian students). *Sci Sports* **34**, 73–81.
22. Yahia N, Achkar A, Abdallah A, *et al.* (2008) Eating habits and obesity among Lebanese university students. *Nutr J* **7**, 32.
23. Verdot EC, Torres M, Salanave B, *et al.* (2017) Corpulence des enfants et des adultes en France métropolitaine en 2015 (Corpulence of adults and children in France in 2015: Results of the ESTEBAN study and changes since 2006). Résultats de l'étude Esteban et évolution depuis 2006. *Bull Épidémiologique Hébdomadaire* **13**, 234–241.
24. Pengpid S & Peltzer K (2021) Underweight and overweight/obesity among adults in Afghanistan: prevalence and correlates from a national survey in 2018. *J Health Popul Nutr* **40**, 25.
25. Ramírez-Vélez R, Correa-Bautista JE, Sanders-Tordecilla A, *et al.* (2017) Percentage of body fat and fat mass index as a screening tool for metabolic syndrome prediction in Colombian University students. *Nutrients* **9**, 1009.
26. Rolland-Cachera MF, Maillot M, Deheeger M, *et al.* (2013) Association of nutrition in early life with body fat and serum leptin at adult age. *Int J Obes* **37**, 1116–1122.
27. Bahchachi N, Mekhancha CC, Nezzal L, *et al.* (2007) Nutritional status in Algerian and French young adults assessed using BMI and bio-impedance. *Obes Rev* **8**, 1–42.
28. Mammeri A & Tebaibia A (2020) Cardiometabolic risk in Algeria: past and present. *Intern Emerg Med* **15**, 531–535.
29. Benini A, Nezzal L, Mekhancha DE, *et al.* (2017) Étude de cohorte des travailleurs postés diabétiques d'une entreprise algérienne (1995–2014) (Cohort study of diabetic shift workers in an Algerian company (1995-2014)). *Médecine Maladies Métaboliques* **5**, 300–306.
30. Lara M, Bustos P, Amigo H, *et al.* (2012) Is waist circumference a better predictor of blood pressure, insulin resistance and blood lipids than body mass index in young Chilean adults? *BMC Public Health* **12**, 638.
31. NCD Risk Factor Collaboration (NCD-RisC) (2018) Contributions of mean and shape of blood pressure distribution to worldwide trends and variations in raised blood pressure: a pooled analysis of 1018 population-based measurement studies with 88·6 million participants. *Int J Epidemiol* **47**, 872–883.
32. Brouri M, Ouadahi N, Nibouche D, *et al.* (2018) Facteurs de risque cardio-vasculaires en Algérie. Une analyse du sous-groupe de l'étude « Africa/Middle East Cardiovascular Epidemiological » (Cardiovascular risk factors in Algeria. Analysis of the subgroup from the 'Africa/Middle East Cardiovascular Epidemiological' Study). *Annales Cardiologie D'angeiologie* **67**, 61–66.
33. Sebati B, Monyeki K, Kemper H, *et al.* (2019) Anthropometric indices for predicting cardiovascular risk factors: Ellisras longitudinal study. *Am J Hum Biol* **31**, e23293.
34. Bertsias G, Mammas I, Linardakis M, *et al.* (2003) Overweight and obesity in relation to cardiovascular disease risk factors among medical students in Crete, Greece. *BMC Public Health* **3**, 3.
35. Gerber LM, Schwartz JE, Schnall PL, *et al.* (1995) Body fat and fat distribution in relation to sex differences in blood pressure. *Am J Hum Biol* **7**, 173–182.
36. Vague J (1956) The degree of masculine differentiation of obesities: a factor determining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. *Am J Clin Nutr* **4**, 20–34.
37. Doll S, Paccaud F, Bovet P, *et al.* (2002) Body mass index, abdominal adiposity and blood pressure: consistency of their association across developing and developed countries. *Int J Obes Relat Metab Disord* **26**, 48–57.
38. Fezeu L, Balkau B, Sobngwi E, *et al.* (2010) Waist circumference and obesity-related abnormalities in French and Cameroonian adults: the role of urbanization and ethnicity. *Int J Obes* **34**, 446–453.
39. Després JP & Lemieux I (2006) Abdominal obesity and metabolic syndrome. *Nature* **444**, 881–887.
40. Roche AF, Sievogel RM, Chumlea WC, *et al.* (1981) Grading body fatness from limited anthropometric data. *Am J Clin Nutr* **34**, 2831–2838.
41. Shifraw T, Selling K, Worku A, *et al.* (2021) Mid-upper arm circumference for identifying adult overweight in large-scale population-based surveys: empirical evaluation using data of the EAT Addis study, Ethiopia. *BMJ Open* **11**, e049602.
42. Barker DJ, Osmond C, Forsén TJ, *et al.* (2005) Trajectories of growth among children who have coronary events as adults. *N Engl J Med* **353**, 1802–1809.
43. Farajian P, Renti E & Manios Y (2008) Obesity indices in relation to cardiovascular disease risk factors among young adult female students. *Br J Nutr* **99**, 918–924.
44. Katzmarzyk PT, Heymsfield SB & Bouchard C (2013) Clinical utility of visceral adipose tissue for the identification of cardiometabolic risk in white and African American adults. *Am J Clin Nutr* **97**, 480–486.
45. Spiegelman D, Israel RG, Bouchard C, *et al.* (1992) Absolute fat mass, percent body fat, and body-fat distribution: which is the real determinant of blood pressure and serum glucose? *Am J Clin Nutr* **55**, 1033–1044.
46. International conference on the processes of Bologne (2018) Mr. Tahar Hadjar Presents in Paris the Many Algerian Achievements in Higher Education https://amb-algerie.fr/4623/m-tahar-hadjar-presente-a-paris-les-nombreuses-realisations-algeriennes-dans-lenseignement-superieur/ (accessed July 2022).

British Journal of Nutrition