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# Oscillometric blood pressure by age and height for non overweight children and adolescents in Lubumbashi, Democratic Republic of Congo

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## Abstract

**Background:** The diagnosis of hypertension in children is complex because based on normative values by sex, age and height, and these values vary depending on the environment. Available BP references used, because of the absence of local data, do not correspond to our pediatric population. Accordingly, our study aimed to provide the BP threshold for children and adolescents in Lubumbashi (DRC) and to compare them with German (KIGGS study), Polish (OLAF study) and Chinese (CHNS study) references.

**Methods:** We conducted a cross-sectional study among 7523 school-children aged 3 to 17 years. The standardized BP measurements were obtained using a validated oscillometric device (Datascope Accutor Plus). After excluding overweight and obese subjects according to the IOTF definition ($n = 640$), gender-specific SBP and DBP percentiles, which simultaneously accounted for age and height by using an extension of the LMS method, namely GAMLSS, were tabulated.

**Results:** The 50th, 90th and 95th percentiles of SBP and DBP for 3373 boys and 3510 girls were tabulated simultaneously by age and height (5th, 25th, 50th, 75th and 95th height percentile).

Before 13 years the 50th and 90th percentiles of SBP for boys were higher compared with those of KIGGS and OLAF, and after they became lower: the difference for adolescents aged 17 years was respectively 8 mmHg (KIGGS) and 4 mmHg (OLAF). Concerning girls, the SBP 50th percentile was close to that of OLAF and KIGGS studies with differences that did not exceed 3 mmHg; whereas the 90th percentile of girls at different ages was high. Our oscillometric 50th and 90th percentiles of SBP and DBP were very high compared to referential ausculatory percentiles of the CHNS study respectively for boys from 8 to 14 mmHg and 7 to 13 mmHg; and for girls from 10 to 16 mmHg and 11 to 16 mmHg.

**Conclusions:** The proposed BP thresholds percentiles enable early detection and treatment of children and adolescents with high BP and develop a local program of health promotion in schools and family.

**Keywords:** Blood pressure, Children, Adolescents, Lubumbashi, Percentile tables, GMLSS, LMS

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# Background

Several publications have shown the importance of measuring the blood pressure (BP) and hypertension in childhood and adolescence [1–4]. In children and adolescents, high BP values are associated with left ventricular hypertrophy [5], increase in thickness intima-media of arteries [6] and they are predictive of hypertension in adulthood [7].

Pediatricians have at their disposal BP references tables, which determine whether BP is normal or if it is a threshold that requires the application of the assessment, prevention or treatment. BP references are based on sex, age and height, but also on study populations characteristics such as ethnicity or nationality, including the type of device used to measure BP [1, 2, 8, 9].

Obesity has become epidemic in the world in adults as well as in children and adolescents [10, 11]. Adiposity in childhood, as measured by body mass index (BMI) [12] is an important predictor of elevated BP. In a study among 197,191 children aged 7–17 years obtained from a Chinese national survey in 2010, Dong et al. [13] noted that overweight and obese children have a significantly higher risk of high BP than non-overweight children.

BP references or standards are not available for Congolese children in the Democratic Republic of Congo (DRC) but there are many others [1, 2, 14–16] that do not correspond to our pediatric population.

The objectives of our study were to establish the BP threshold percentiles of non-overweight children and adolescents in Lubumbashi (DRC) and compare them with German, Polish and Chinese BP references.

# Methods

## Design, participants and setting of the study

The study took place in Lubumbashi (Province of Haut-Katanga) the second city of the DRC by its economic, political, social and cultural importance. The studied population was composed of school children aged 3 to 17 years, enrolled in pre-primary, primary and secondary schools during the school-years 2013–2014, 2014–2015 and 2015–2016.

A cross-sectional study was conducted on a representative sample of these pupils, who were recruited in randomly selected clusters using two-stage sampling. The first cluster was comprised of selected schools from all private and public schools of Lubumbashi. The second cluster was comprised of randomly selected classes within each of the selected schools. All pupils in the selected classes were invited to join the study. Sampling was stratified by township.

For a strate (township), the equation allowing the calculation of the sample was the following:

$$n = z^2 \frac{p(1-p)}{e^2}$$

In which: - z is the level of confidence (= 95%).

- $p$ is the initial level of the school attendance rate (= 50%).
- $e$ is the error margin (= 0.05%).

The size calculated in this way had been adjusted according to the effect of the sampling plan (= 1.5%), the number of estimations by age group and by sex (= 3%) and this was reported to the expected number of non-answers (= 20%). The number thus obtained was multiplied by the number of the strate (township) of the city of Lubumbashi (for details, please consult website www.unilu.ac.cd/wp-content/uploads/2016/07/Seuils1.pdf).

Informed written consent was obtained from parents or guardians. The approval to conduct the study and authorizations were obtained from the Medical Ethic Committee of the University of Lubumbashi (UNILU/CEM/027/2013–27 september 2013), the Provincial Ministry of Education, Scientific Research, Transport and Energy of Katanga (N° 10.5/0209/CAB/MIN.PROV/ED.R.TE/KAT/2014–11 march 2014) and the authorities of the selected schools.

Data were collected by trained medical staff. The study team received refresher training at the beginning of each data collection phase.

## BP measurement

BP was measured by using a Datascope Accutorr Plus (Datascope Corporation, USA). The appropriate cuff size (bladder width at least 40% of arm circumference and length to cover 80–100% of arm circumference) was determined by measuring the mid-upper arm circumference.

BP measurements were performed at least 30 min after exercise or the last meal, in a subject at rest 5 min before setting, in a seated position with arm and back supported, feet resting on the floor and legs uncrossed. The cuff was applied to the right arm, at the heart level, then wrapped in a sealing which did not allow two fingers to be inserted under it. The lower edge of the cuff was placed 2 cm from the cubital fossa. Three readings were obtained at a 1 min intervals on the same day and the mean of the second and third readings was used for analysis.

## Anthropometric measurements

Body weight was measured in duplicate with the participant wearing light underwear, barefoot, standing on a digital scale. Body weight was recorded nearest 0.1 kg. Body height recorded nearest 0.1 cm was measured in duplicate. Each participant was in standing upright position, barefoot with shoulders and hips perpendicular at the central axis, heels against the step, knees together, arms relaxed along the body and head straight. Special attention was given to children (under 6 years) using a second investigator to block the movement of the knees. The mean of the two measurements of weight and height and were selected for statistical analysis.

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BMI was calculated as weight (in kilograms) divided by the square of height (in meters). The terms overweight and obese were defined according to the International Obesity Task Force (IOTF) definition [17].

### Inclusion and exclusion criteria for the sample on which the percentiles are based

Of 8371 participants consented, we excluded 1488: 795 children were younger than 3 years ($n = 55$) or over 17 years ($n = 740$), 53 had outlying or missing data (date of birth, BP, weight, height) and 640 were recorded overweight ($n = 548$) or obese ($n = 92$). No child had been reported to have a chronic disease likely to influence weight or blood pressure and also no child was taking a medicine having an influence on the blood pressure (Additional file 1).

### Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA) and the free statistical software R 3.1.2 (2014–10-31) (http://www.cran.r-project.org).

Thresholds of BP by gender were constructed by age and height simultaneously using an extension of the LMS method [18], namely generalized additive models for location scale and shape (GAMLSS) with the Box-Cox power exponential (BCPE) and Box-Cox-Cole-Green (BCCG) distributions families, fitted with GAMLSS 4.3–1 in the free statistical software R 3.1.2 (2014–10-31). In GAMLSS [18, 19], four parameters ($\mu$, $\sigma$, $\nu$, $\tau$) were used to define the location, scale and shape of the BP distribution with age and height. To obtain the optimal models by minimizing the Schwarz Bayesian Criterion [20], linear and additive effect of age and height on systolic blood pressure (SBP) and diastolic blood pressure (DBP) were modeled simultaneously. The threshold values of the 50th, 90th and 95th percentiles of SBP and DBP were calculated by age and height (exact heights according to the 5th, 25th, 50th, 75th and 95th percentiles) for boys and girls separately.

Different percentiles of SBP and DBP (50th and 90th percentiles) for boys and girls, were compared with references percentiles of the German Health Interview and Examination Survey for Children and Adolescents (KIGGS) [14], the Elaboration of the Ranks of Reference Arterial Blood Pressure for the Population of Children and Adolescents in Poland (OLAF) [15] and the Chinese reference that used data from the China Health and Nutrition Survey (CHNS) [16]. This comparison was made for the different ages in relation to the target population of these studies (3–17 years for KIGGS and 7–17 years for OLAF and CHNS).

### Results

Of the 11,283 pupils selected and invited to take part in the study, 8371 children and adolescents consented and were enrolled for a global participation rate of 74.2%. Data were collected three times (according to the school calendar in the DRC) from March 2014 to December 2015; in 66 schools. The reference population of non-overweight children and adolescents aged 3 to 17 years consisted of 3373 boys and 3510 girls.

Table 1 summarized the baseline characteristics of 6883 non-overweight children and adolescents. The mean of SBP and DBP increased with age in both sexes. The mean of the first BP (both systolic and diastolic) was the highest and the mean of the third BP was the lowest in the series of three measures in both sexes and in all age groups. The mean of the first and second BP was higher: 0.8 to 1.4 mmHg SBP and 0.9 to 2.0 mmHg DBP, in comparison with the average of the second and third BP (Table 1).

Among the best fitted models for the 4 parameters of distribution of SBP and DBP, the Box-Cox and Cole Green (BCCG) was shown as the best fit model of SBP for both genders and DBP for girls; while the Box-Cox Power Exponential (BCPE) was for the boys' DBP.

The thresholds 50th, 90th and 95th percentiles of SBP and DBP were tabulated simultaneously by age and exact height (5th, 25th, 50th, 75th and 95th height percentile) respectively for boys and girls and are shown in Tables 2 (for boys) and 3 (for girls). The BP increased both in relation to age and height in both sexes. The median SBP and DBP were higher (about 2 mmHg) in girls up to the age 14 years, after this age they were almost similar in both sexes. As an illustration, in adolescents aged 17 years with a median height (167 cm for boys and 162 cm for girls), the median percentiles of SBP and DBP were similar, respectively 115 mmHg and 68 mmHg. The 95 percentile used to define hypertension in children and adolescents had varied between the 5th and 95th percentile height (SBP in boys: 4–7 mmHg and in girls: 5–8 mmHg; DBP in boys: 1–3 mmHg and in girls: 1–2 mmHg).

For adolescents boys aged 11–17 years and girls aged 10–17 years, the 90th SBP percentile for the median height was respectively 120–132 mmHg and 120–131 mmHg.

In the case of boys aged 5–12 years, the 50th SBP percentile of our oscillometric threshold was similar to the corresponding percentile of German oscillometric reference (KIGGS study), whereas compared with the Polish oscillometric reference (OLAF study) the difference were less than 2 mmHg in age 7, 8 and 13, 14 years (Fig. 1). The 50th percentile of SBP of the KIGGS study was higher for boys >14 years (8 mmHg for adolescents aged 17 years). With regard to girls, the 50th SBP percentile of our study was close to the corresponding percentile of the KIGGS and OLAF studies: the differences did not exceed 2 mmHg, except among girls aged 9 and 10 years (for OLAF study) in which the difference was greater than 3 mmHg (Fig. 2).

**Table 1** Baseline characteristics of children and adolescents of normal weight aged 3 to 17 years in Lubumbashi, DRC

| | Age, year | | | |
|---|---|---|---|---|
| | 3–6 | 7–10 | 11–13 | 14–17 |
| n, included (% 3373 boys, 3510 girls) | | | | |
| Boys | 480 (14.2) | 1161 (34.4) | 995 (29.5) | 737 (21.9) |
| Girls | 393 (11.2) | 1133 (32.3) | 1014 (28.9) | 970 (27.6) |
| Weight, mean (SD), kg | | | | |
| Boys | 18.7 (3.1) | 29.7 (4.8) | 35.9 (6.5) | 50.9 (8.8) |
| Girls | 18.6 (3.5) | 27.1 (5.5) | 39.0 (7.5) | 50.4 (6.5) |
| Height, median (SD), cm | | | | |
| Boys | 111.1 (8.8) | 130.5 (9.0) | 142.3 (9.4) | 162.3 (10.2) |
| Girls | 111.3 (10.2) | 131.2 (9.9) | 148.0 (9.6) | 159.0 (7.4) |
| IMC, mean (SD) kg / m$^2$ | | | | |
| Boys | 15.1 (1.2) | 15.6 (1.4) | 16.9 (1.7) | 19.2 (2.1) |
| Girls | 14.9 (1.1) | 15.6 (1.5) | 17.7 (2.1) | 19.9 (2.1) |
| First SBP, mean (SD), mmHg | | | | |
| Boys | 101.7 (11.0) | 104.6 (10.6) | 109.2 (10.3) | 118.0 (12.4) |
| Girls | 102.0 (11.1) | 106.7 (10.7) | 112.6 (11.9) | 116.9 (11.3) |
| Second SBP, mean (SD), mmHg | | | | |
| Boys | 100.7 (11.0) | 103.4 (10.7) | 107.7 (10.5) | 116.7 (12.3) |
| Girls | 100.3 (10.6) | 105.5 (10.7) | 111.2 (11.1) | 115.5 (10.8) |
| Third SBP, mean (SD), mmHg | | | | |
| Boys | 99.7 (10.9) | 102.4 (10.0) | 106.8 (9.9) | 115.3 (11.9) |
| Girls | 99.4 (10.3) | 104.1 (10.2) | 110.1 (10.8) | 114.1 (10.6) |
| Mean of first and second SBP, mean (SD), mmHg | | | | |
| Boys | 101.2 (10.4) | 104.0 (9.9) | 108.5 (9.7) | 117.4 (11.7) |
| Girls | 101.2 (10.2) | 106.1 (10.1) | 111.9 (10.8) | 116.2 (10.5) |
| Mean of second and third SBP, mean (SD), mmHg | | | | |
| Boys | 100.2 (10.4) | 102.9 (9.8) | 107.2 (9.7) | 116.0 (11.6) |
| Girls | 99.8 (9.8) | 104.8 (10.0) | 110.6 (10.4) | 114.8 (10.2) |
| First DBP, mean (SD), mmHg | | | | |
| Boys | 62.8 (9.6) | 65.1 (9.1) | 67.1 (7.9) | 69.4 (9.0) |
| Girls | 63.5 (9.5) | 66.2 (9.2) | 68.2 (8.8) | 70.5 (8.5) |
| Second SBP, mean (SD), mmHg | | | | |
| Boys | 61.8 (8.5) | 63.4 (9.0) | 65.4 (8.4) | 67.5 (8.8) |
| Girls | 61.9 (9.6) | 65.0 (8.7) | 66.4 (8.7) | 68.1 (8.5) |
| Third DBP, mean (SD), mmHg | | | | |
| Boys | 61.0 (8.9) | 62.2 (8.9) | 64.2 (8.1) | 67.0 (9.2) |
| Girls | 60.9 (8.8) | 63.7 (8.9) | 65.2 (9.0) | 67.0 (8.5) |
| Mean of first and second DBP, mean (SD), mmHg | | | | |
| Boys | 62.3 (8.0) | 64.3 (8.0) | 66.3 (7.2) | 68.4 (7.9) |
| Girls | 62.7 (8.5) | 65.8 (7.8) | 67.3 (7.7) | 69.3 (7.6) |
| Mean of second and third DBP, mean (SD), mmHg | | | | |
| Boys | 61.4 (7.7) | 62.8 (7.9) | 64.8 (7.4) | 67.3 (8.1) |
| Girls | 61.4 (8.1) | 64.3 (7.8) | 65.8 (7.9) | 67.6 (7.6) |

*SD* standard deviation, *BMI* body mass index, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

For boys <13 years the 90th SBP percentile was higher from 1 to 4 mmHg in comparison to KIGGS and OLAF percentiles. After, it became progressively lower: for adolescents aged 17 the difference was 8 mmHg with the KIGGS study and 4 mmHg with the OLAF study (Fig. 1). In the case of girls, our 90th SBP percentile was consistently higher compared to KIGGS and OLAF percentiles (Fig. 2).

The 50th and 90th DBP percentiles of the KIGGS boys (Fig. 3) were higher at all ages (among adolescents aged 17 years the difference was 4 mmHg). In case of the girls age range 7–17 years, the 50th and 90th DBP percentiles of OLAF study were higher when compared with our corresponding percentile.

In comparing the 50th and 90th SBP percentiles for median height for our oscillometric values to the Chinese ausculatory referential (CHNS) values, the 50th and 90th percentiles were consistently very higher among the children and adolescents of the same age: the difference was 8 to 14 mmHg and 7 to 13 mmHg for boys (Fig. 1); and 10 to 16 mmHg and 11–16 mmHg for girls (Fig. 2). The 50th and 90th DBP percentiles for boys (Fig. 3) and girls (Fig. 4) of our study were higher before age 11 years in comparison to the CHNS study; and in the age range 11–17 years, the difference were relatively minor (not exceeding 2 mmHg).

## Discussion

This study presents the first BP threshold percentiles for children and adolescents of normal weight aged 3–17 years in Lubumbashi (DRC), computed by age and height simultaneously, by using an improved statistical method named GAMLSS provided in the package of R software [14, 16, 19]. The BP percentiles were established on the basis of oscillometric measurements of the BP with a device clinically validated in children: the Datascope Accutorr Plus [21]. This device has also been used in several large studies related to BP in children and adolescents worldwide [14, 15, 22]. In addition, the oscillometric BP measurement is increasingly used in pediatric clinical practice.

We have not included overweight or obese subjects in our study. Using a sample of normal weight to develop percentile allows our proposed BP thresholds to be more sensitive to the identification of children and adolescents with high BP because we avoided certain risk factors associated with the BP as being overweight or obese [10, 13]. Sorof et al. [23] found a strong correlation between the BP and overweight and obesity.

Our mean SBP (for girls) and DBP (for boys and girls) were higher compared to those observed by Kulaga et al. [15]. Compared to the mean of the first and second BP (both systolic and diastolic) values were higher than those of children and adolescents in the KIGGS study [14].

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**Table 2** Age-height-specific thresholds: 50th, 90th and 95th percentiles of SBP and DBP values for boys aged 3–17 years

| Age, year | Height, cm | Height percentile | SBP, mmHg | | | | DBP, mmHg | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S* | 50th percentile (median) | 90th percentile | 95th percentile | S* | 50th percentile (median) | 90th percentile | 95th percentile |
| 3 | 87 | 5th | 0.0983 | 91 | 103 | 107 | 0.0712 | 59 | 68 | 71 |
| | 94 | 25th | 0.0974 | 92 | 105 | 109 | 0.0678 | 59 | 69 | 72 |
| | 97 | 50th | 0.0970 | 93 | 105 | 110 | 0.0667 | 59 | 69 | 72 |
| | 101 | 75th | 0.0964 | 94 | 106 | 111 | 0.0647 | 60 | 69 | 72 |
| | 107 | 95th | 0.0956 | 95 | 108 | 112 | 0.0623 | 60 | 70 | 72 |
| 4 | 95 | 5th | 0.0972 | 93 | 106 | 110 | 0.0674 | 60 | 69 | 72 |
| | 99 | 25th | 0.0967 | 94 | 107 | 111 | 0.0655 | 60 | 70 | 72 |
| | 103 | 50th | 0.0961 | 95 | 108 | 112 | 0.0638 | 60 | 70 | 73 |
| | 108 | 75th | 0.0955 | 96 | 108 | 113 | 0.0619 | 60 | 70 | 73 |
| | 112 | 95th | 0.0949 | 97 | 110 | 114 | 0.0599 | 61 | 70 | 73 |
| 5 | 101 | 5th | 0.0964 | 95 | 108 | 112 | 0.0648 | 60 | 70 | 73 |
| | 106 | 25th | 0.0957 | 96 | 109 | 113 | 0.0626 | 61 | 70 | 73 |
| | 109 | 50th | 0.0953 | 97 | 109 | 114 | 0.0612 | 61 | 71 | 73 |
| | 114 | 75th | 0.0946 | 98 | 111 | 115 | 0.0592 | 61 | 71 | 74 |
| | 122 | 95th | 0.0936 | 99 | 112 | 116 | 0.0561 | 61 | 71 | 74 |
| 6 | 105 | 5th | 0.0959 | 96 | 109 | 113 | 0.0630 | 61 | 71 | 73 |
| | 112 | 25th | 0.0949 | 98 | 111 | 115 | 0.0601 | 61 | 71 | 74 |
| | 116 | 50th | 0.0944 | 98 | 112 | 116 | 0.0584 | 61 | 71 | 74 |
| | 120 | 75th | 0.0938 | 99 | 113 | 117 | 0.0567 | 62 | 72 | 74 |
| | 127 | 95th | 0.0929 | 101 | 114 | 118 | 0.0542 | 62 | 72 | 75 |
| 7 | 112 | 5th | 0.0949 | 98 | 111 | 116 | 0.0598 | 62 | 71 | 74 |
| | 118 | 25th | 0.0941 | 99 | 113 | 117 | 0.0576 | 62 | 72 | 75 |
| | 123 | 50th | 0.0935 | 100 | 114 | 118 | 0.0557 | 62 | 72 | 75 |
| | 126 | 75th | 0.0930 | 101 | 114 | 119 | 0.0544 | 62 | 72 | 75 |
| | 137 | 95th | 0.0916 | 103 | 117 | 121 | 0.0506 | 63 | 73 | 76 |
| 8 | 112 | 5th | 0.0949 | 99 | 112 | 116 | 0.0599 | 62 | 72 | 75 |
| | 123 | 25th | 0.0934 | 101 | 114 | 119 | 0.0556 | 62 | 72 | 75 |
| | 128 | 50th | 0.0928 | 102 | 115 | 120 | 0.0538 | 63 | 73 | 76 |
| | 132 | 75th | 0.0922 | 103 | 116 | 121 | 0.0523 | 63 | 73 | 76 |
| | 140 | 95th | 0.0912 | 105 | 118 | 122 | 0.0495 | 63 | 74 | 77 |
| 9 | 122 | 5th | 0.0936 | 101 | 115 | 119 | 0.0562 | 63 | 73 | 76 |
| | 127 | 25th | 0.0930 | 102 | 116 | 120 | 0.0543 | 63 | 73 | 76 |
| | 132 | 50th | 0.0923 | 103 | 117 | 121 | 0.0525 | 63 | 73 | 76 |
| | 137 | 75th | 0.0917 | 104 | 118 | 122 | 0.0507 | 63 | 74 | 77 |
| | 145 | 95th | 0.0906 | 106 | 120 | 124 | 0.0479 | 64 | 74 | 77 |
| 10 | 123 | 5th | 0.0934 | 102 | 115 | 120 | 0.0556 | 63 | 73 | 76 |
| | 131 | 25th | 0.0924 | 104 | 117 | 121 | 0.0527 | 64 | 74 | 77 |
| | 136 | 50th | 0.0917 | 105 | 118 | 123 | 0.0509 | 64 | 74 | 77 |
| | 141 | 75th | 0.0910 | 106 | 119 | 124 | 0.0491 | 64 | 74 | 77 |
| | 149 | 95th | 0.0901 | 108 | 121 | 125 | 0.0466 | 64 | 75 | 78 |
| 11 | 129 | 5th | 0.0927 | 104 | 117 | 122 | 0.0536 | 64 | 74 | 77 |
| | 136 | 25th | 0.0917 | 105 | 119 | 123 | 0.0508 | 64 | 74 | 77 |

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**Table 2** Age-height-specific thresholds: 50th, 90th and 95th percentiles of SBP and DBP values for boys aged 3–17 years (Continued)

| Age, year | Height, cm | Height percentile | SBP, mmHg | | | | DBP, mmHg | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S* | 50th percentile (median) | 90th percentile | 95th percentile | S* | 50th percentile (median) | 90th percentile | 95th percentile |
| | 142 | 50th | 0.0910 | 107 | 120 | 124 | 0.0489 | 64 | 75 | 78 |
| | 147 | 75th | 0.0903 | 108 | 121 | 126 | 0.0471 | 65 | 75 | 78 |
| | 156 | 95th | 0.0892 | 110 | 123 | 128 | 0.0443 | 65 | 76 | 79 |
| 12 | 132 | 5th | 0.0922 | 105 | 119 | 123 | 0.0522 | 64 | 74 | 77 |
| | 140 | 25th | 0.0912 | 107 | 120 | 125 | 0.0495 | 65 | 75 | 78 |
| | 145 | 50th | 0.0906 | 108 | 121 | 126 | 0.0479 | 65 | 75 | 78 |
| | 151 | 75th | 0.0898 | 109 | 123 | 127 | 0.0460 | 65 | 76 | 79 |
| | 161 | 95th | 0.0886 | 111 | 125 | 129 | 0.0430 | 66 | 76 | 79 |
| 13 | 133 | 5th | 0.0921 | 106 | 119 | 124 | 0.0519 | 65 | 75 | 78 |
| | 143 | 25th | 0.0909 | 108 | 121 | 126 | 0.0487 | 65 | 75 | 78 |
| | 150 | 50th | 0.0900 | 109 | 123 | 127 | 0.0464 | 65 | 76 | 79 |
| | 157 | 75th | 0.0890 | 111 | 125 | 129 | 0.0440 | 66 | 76 | 79 |
| | 164 | 95th | 0.0882 | 112 | 126 | 131 | 0.0420 | 66 | 77 | 80 |
| 14 | 139 | 5th | 0.0914 | 108 | 121 | 126 | 0.0499 | 65 | 75 | 78 |
| | 149 | 25th | 0.0901 | 110 | 123 | 128 | 0.0466 | 66 | 76 | 79 |
| | 157 | 50th | 0.0891 | 111 | 125 | 130 | 0.0442 | 66 | 77 | 80 |
| | 164 | 75th | 0.0883 | 113 | 127 | 131 | 0.0422 | 66 | 77 | 80 |
| | 172 | 95th | 0.0872 | 115 | 128 | 133 | 0.0398 | 67 | 78 | 81 |
| 15 | 145 | 5th | 0.0906 | 109 | 123 | 128 | 0.0479 | 66 | 76 | 79 |
| | 157 | 25th | 0.0891 | 112 | 126 | 130 | 0.0442 | 67 | 77 | 80 |
| | 162 | 50th | 0.0884 | 113 | 127 | 131 | 0.0425 | 67 | 77 | 81 |
| | 168 | 75th | 0.0876 | 114 | 128 | 133 | 0.0408 | 67 | 78 | 81 |
| | 177 | 95th | 0.0866 | 116 | 130 | 135 | 0.0385 | 67 | 78 | 82 |
| 16 | 153 | 5th | 0.0896 | 112 | 126 | 130 | 0.0453 | 67 | 77 | 80 |
| | 161 | 25th | 0.0886 | 113 | 127 | 132 | 0.0430 | 67 | 78 | 81 |
| | 168 | 50th | 0.0877 | 115 | 129 | 133 | 0.0410 | 67 | 78 | 81 |
| | 172 | 75th | 0.0871 | 116 | 130 | 134 | 0.0397 | 68 | 78 | 82 |
| | 179 | 95th | 0.0864 | 117 | 131 | 136 | 0.0380 | 68 | 79 | 82 |
| 17 | 153 | 5th | 0.0895 | 112 | 126 | 131 | 0.0452 | 67 | 77 | 81 |
| | 165 | 25th | 0.0881 | 115 | 129 | 133 | 0.0419 | 68 | 78 | 81 |
| | 167 | 50th | 0.0878 | 115 | 129 | 134 | 0.0411 | 68 | 78 | 82 |
| | 173 | 75th | 0.0871 | 116 | 130 | 135 | 0.0395 | 68 | 79 | 82 |
| | 180 | 95th | 0.0862 | 118 | 132 | 136 | 0.0377 | 68 | 79 | 82 |

SBP systolic blood pressure, DBP diastolic blood pressure
S *, coefficient of variation of blood pressure

The height is a key covariate associated with BP levels [1]. Indeed, not taking into account the height in establishing the BP references could lead to an inaccurate assessment of the BP in pediatric practice particularly for children who are very small (5th percentile) or very tall (95th percentile). Our BP thresholds do not require the use of height reference tables because it is presented in centimeters. In addition, this presentation of exact height by value (in centimeters) in different categories of height percentile is proposed to the allow evaluation of the children and adolescents BP more convenient and accurate.

We proposed the 90th and 95th BP percentiles to allow the detection of prehypertension and hypertension

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**Table 3** Age-height-specific thresholds: 50th, 90th and 95th percentiles of SBP and DBP values for girls aged 3–17 years

| Age, year | Height, cm | Height percentile | SBP, mmHg | | | | DBP, mmHg | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S * | 50th percentile (median) | 90th percentile | 95th percentile | S * | 50th percentile (median) | 90th percentile | 95th percentile |
| 3 | 88 | 5th | 0.0994 | 93 | 106 | 109 | 0.1313 | 60 | 70 | 73 |
| | 92 | 25th | 0.0996 | 94 | 107 | 110 | 0.1313 | 60 | 70 | 74 |
| | 99 | 50th | 0.0998 | 95 | 108 | 112 | 0.1313 | 60 | 71 | 74 |
| | 103 | 75th | 0.1000 | 96 | 109 | 113 | 0.1313 | 60 | 71 | 74 |
| | 109 | 95th | 0.1002 | 97 | 110 | 114 | 0.1313 | 61 | 71 | 75 |
| 4 | 95 | 5th | 0.0984 | 95 | 108 | 111 | 0.1298 | 60 | 71 | 74 |
| | 98 | 25th | 0.0985 | 96 | 108 | 112 | 0.1298 | 61 | 71 | 74 |
| | 102 | 50th | 0.0987 | 97 | 109 | 113 | 0.1298 | 61 | 71 | 74 |
| | 108 | 75th | 0.0989 | 98 | 111 | 114 | 0.1298 | 61 | 72 | 75 |
| | 121 | 95th | 0.0993 | 100 | 113 | 117 | 0.1298 | 62 | 72 | 76 |
| 5 | 98 | 5th | 0.0973 | 96 | 109 | 113 | 0.1283 | 61 | 71 | 74 |
| | 105 | 25th | 0.0975 | 98 | 110 | 114 | 0.1283 | 61 | 72 | 75 |
| | 110 | 50th | 0.0977 | 98 | 111 | 115 | 0.1283 | 61 | 72 | 75 |
| | 115 | 75th | 0.0979 | 99 | 113 | 117 | 0.1283 | 62 | 72 | 75 |
| | 122 | 95th | 0.0981 | 101 | 114 | 118 | 0.1283 | 62 | 73 | 76 |
| 6 | 105 | 5th | 0.0963 | 98 | 111 | 115 | 0.1269 | 62 | 72 | 75 |
| | 113 | 25th | 0.0966 | 100 | 113 | 117 | 0.1269 | 62 | 72 | 76 |
| | 117 | 50th | 0.0967 | 100 | 114 | 118 | 0.1269 | 62 | 73 | 76 |
| | 123 | 75th | 0.0969 | 101 | 115 | 119 | 0.1269 | 62 | 73 | 76 |
| | 131 | 95th | 0.0972 | 103 | 117 | 121 | 0.1269 | 63 | 73 | 77 |
| 7 | 110 | 5th | 0.0953 | 100 | 113 | 116 | 0.1254 | 62 | 73 | 76 |
| | 118 | 25th | 0.0955 | 101 | 114 | 118 | 0.1254 | 62 | 73 | 76 |
| | 123 | 50th | 0.0957 | 102 | 116 | 120 | 0.1254 | 63 | 73 | 76 |
| | 128 | 75th | 0.0959 | 103 | 116 | 121 | 0.1254 | 63 | 73 | 77 |
| | 134 | 95th | 0.0961 | 104 | 118 | 122 | 0.1254 | 63 | 74 | 77 |
| 8 | 117 | 5th | 0.0943 | 102 | 115 | 118 | 0.1240 | 63 | 73 | 76 |
| | 123 | 25th | 0.0945 | 103 | 116 | 120 | 0.1240 | 63 | 74 | 77 |
| | 128 | 50th | 0.0947 | 104 | 117 | 121 | 0.1240 | 63 | 74 | 77 |
| | 133 | 75th | 0.0948 | 104 | 118 | 122 | 0.1240 | 63 | 74 | 77 |
| | 142 | 95th | 0.0952 | 106 | 120 | 124 | 0.1240 | 64 | 75 | 78 |
| 9 | 121 | 5th | 0.0932 | 103 | 116 | 120 | 0.1226 | 63 | 74 | 77 |
| | 129 | 25th | 0.0935 | 104 | 118 | 122 | 0.1226 | 64 | 74 | 77 |
| | 133 | 50th | 0.0937 | 105 | 119 | 123 | 0.1226 | 64 | 74 | 77 |
| | 138 | 75th | 0.0938 | 106 | 120 | 124 | 0.1226 | 64 | 75 | 78 |
| | 149 | 95th | 0.0942 | 108 | 122 | 127 | 0.1226 | 65 | 75 | 78 |
| 10 | 126 | 5th | 0.0922 | 104 | 118 | 122 | 0.1212 | 64 | 74 | 77 |
| | 133 | 25th | 0.0925 | 106 | 119 | 123 | 0.1212 | 64 | 75 | 78 |
| | 137 | 50th | 0.0926 | 107 | 120 | 124 | 0.1212 | 64 | 75 | 78 |
| | 143 | 75th | 0.0928 | 108 | 121 | 126 | 0.1212 | 65 | 75 | 78 |
| | 152 | 95th | 0.0931 | 109 | 123 | 128 | 0.1212 | 65 | 76 | 79 |
| 11 | 127 | 5th | 0.0911 | 105 | 118 | 122 | 0.1198 | 64 | 75 | 78 |
| | 138 | 25th | 0.0915 | 107 | 121 | 125 | 0.1198 | 65 | 75 | 78 |

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**Table 3** Age-height-specific thresholds: 50th, 90th and 95th percentiles of SBP and DBP values for girls aged 3–17 years *(Continued)*

| Age, year | Height, cm | Height percentile | SBP, mmHg | | | | DBP, mmHg | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S * | 50th percentile (median) | 90th percentile | 95th percentile | S * | 50th percentile (median) | 90th percentile | 95th percentile |
| | 145 | 50th | 0.0917 | 108 | 122 | 127 | 0.1198 | 65 | 76 | 79 |
| | 150 | 75th | 0.0919 | 110 | 123 | 128 | 0.1198 | 65 | 76 | 79 |
| | 157 | 95th | 0.0921 | 111 | 125 | 130 | 0.1198 | 66 | 76 | 79 |
| 12 | 132 | 5th | 0.0901 | 107 | 120 | 124 | 0.1184 | 65 | 75 | 78 |
| | 142 | 25th | 0.0905 | 109 | 122 | 126 | 0.1184 | 65 | 76 | 79 |
| | 149 | 50th | 0.0907 | 110 | 124 | 128 | 0.1184 | 66 | 76 | 79 |
| | 154 | 75th | 0.0908 | 111 | 125 | 129 | 0.1184 | 66 | 76 | 79 |
| | 161 | 95th | 0.0911 | 112 | 126 | 131 | 0.1184 | 66 | 77 | 80 |
| 13 | 139 | 5th | 0.0892 | 109 | 122 | 126 | 0.1171 | 65 | 76 | 79 |
| | 148 | 25th | 0.0895 | 110 | 124 | 128 | 0.1171 | 66 | 76 | 79 |
| | 154 | 50th | 0.0897 | 111 | 125 | 130 | 0.1171 | 66 | 77 | 80 |
| | 159 | 75th | 0.0899 | 112 | 126 | 131 | 0.1171 | 66 | 77 | 80 |
| | 166 | 95th | 0.0901 | 114 | 128 | 133 | 0.1171 | 67 | 77 | 80 |
| 14 | 143 | 5th | 0.0882 | 110 | 123 | 128 | 0.1157 | 66 | 76 | 79 |
| | 153 | 25th | 0.0885 | 112 | 125 | 130 | 0.1157 | 66 | 77 | 80 |
| | 157 | 50th | 0.0887 | 113 | 126 | 131 | 0.1157 | 67 | 77 | 80 |
| | 162 | 75th | 0.0888 | 113 | 128 | 132 | 0.1157 | 67 | 77 | 80 |
| | 168 | 95th | 0.0890 | 115 | 129 | 134 | 0.1157 | 67 | 78 | 81 |
| 15 | 147 | 5th | 0.0872 | 111 | 125 | 129 | 0.1144 | 67 | 77 | 80 |
| | 154 | 25th | 0.0874 | 113 | 126 | 131 | 0.1144 | 67 | 77 | 80 |
| | 159 | 50th | 0.0876 | 113 | 127 | 132 | 0.1144 | 67 | 77 | 80 |
| | 164 | 75th | 0.0878 | 114 | 128 | 133 | 0.1144 | 67 | 78 | 81 |
| | 171 | 95th | 0.0880 | 116 | 130 | 135 | 0.1144 | 68 | 78 | 81 |
| 16 | 148 | 5th | 0.0862 | 112 | 125 | 130 | 0.1131 | 67 | 77 | 80 |
| | 156 | 25th | 0.0864 | 114 | 127 | 131 | 0.1131 | 67 | 77 | 80 |
| | 161 | 50th | 0.0865 | 114 | 128 | 133 | 0.1131 | 68 | 78 | 81 |
| | 164 | 75th | 0.0867 | 115 | 129 | 133 | 0.1131 | 68 | 78 | 81 |
| | 174 | 95th | 0.0870 | 117 | 131 | 136 | 0.1131 | 68 | 78 | 81 |
| 17 | 150 | 5th | 0.0851 | 113 | 126 | 131 | 0.1118 | 67 | 77 | 80 |
| | 156 | 25th | 0.0853 | 114 | 128 | 132 | 0.1118 | 68 | 78 | 81 |
| | 162 | 50th | 0.0855 | 115 | 129 | 133 | 0.1118 | 68 | 78 | 81 |
| | 166 | 75th | 0.0856 | 116 | 130 | 134 | 0.1118 | 68 | 78 | 81 |
| | 173 | 95th | 0.0858 | 117 | 131 | 136 | 0.1118 | 68 | 79 | 82 |

*SBP* systolic blood pressure, *DBP* diastolic blood pressure
S *, coefficient of variation of blood pressure

in children and adolescents. These cut-off values for pre-hypertension and hypertension respectively, were used according to the criteria's definition of the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents [1] and to the recommendations of the European Society of Hypertension on the Management of High Blood Pressure in Children and Adolescents [2]. Because of the large amount of data available, the Task Force for Blood Pressure in Children [1] is still the study of reference. We have not presented the 99th BP percentile. Indeed, a child or adolescent with BP value that defines hypertension (≥ 95th percentile compared to reference tables) will not be diagnosed by this measure alone as being hypertensive but other additional BP measures are recommended on different occasions [1, 2]. Owing to

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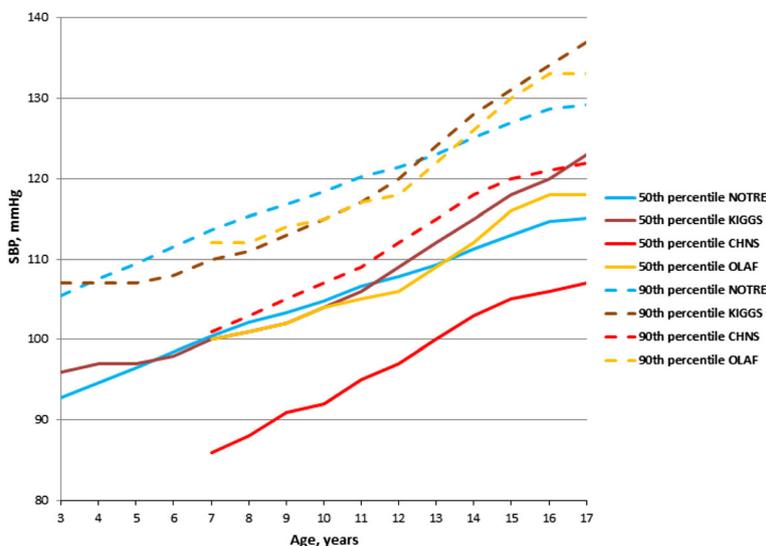


**Fig. 1** The 50th and 90th percentiles of SBP for the median height for our study (NOTRE) compared with the German (KIGGS), Polish (OLAF) and Chinese (CHNS) boys

cultural and ethnic diversity of the peoples of the DRC, our results cannot extrapolate to the entire nation.

The 90th SBP percentile for the median height of adolescents for boys aged 11–17 years and girls aged 10–17 years, respectively of 120–132 mmHg and 120–131 mmHg, was equal to or higher than the threshold 120 mmHg for the identification of prehypertension as recommended by the fourth report of the National High Blood Pressure Education Program (NHBPEP) Working Group on High Blood Pressure in Children and Adolescents [1], the European Society of Hypertension [2] and the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and treatment of High Blood Pressure (JNC VII)

[24]. This observation may indicate the need for careful consideration of changes to the definition of prehypertension in the case of adolescent. The fact that the BP of Congolese children of Lubumbashi is so high at the beginning of adolescence, could be justified by several observations showing that hypertension in black subjects occurs at the early age [25, 26]. In addition, the 90th BP percentile for adolescents aged 17 years (in both sexes) was 130 mmHg, which is equal to the recommended optimal SBP for adult to define metabolic syndrome [27]. Our results are almost similar to those reported by Kulaga et al. [15] and Neuhauser et al. [14]. For the first authors, the 90th SBP percentile for adolescents age range 13–17 years
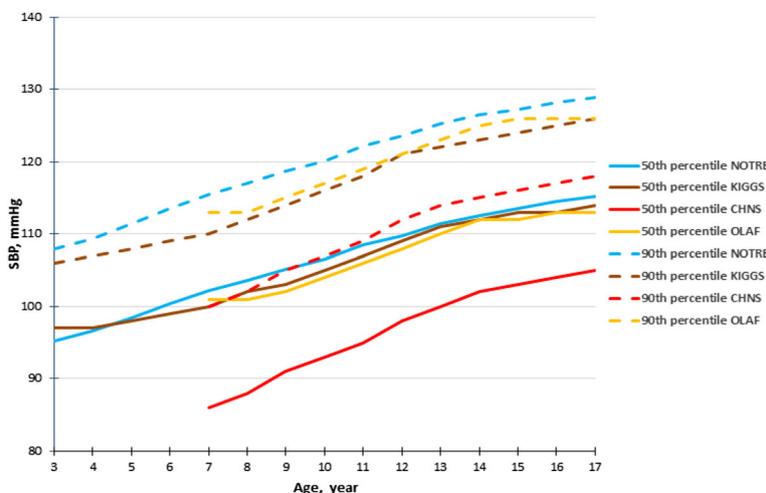


**Fig. 2** The 50th and 90th percentiles of SBP for the median height for our study (NOTRE) compared with the German (KIGGS), Polish (OLAF) and Chinese (CHNS) girls

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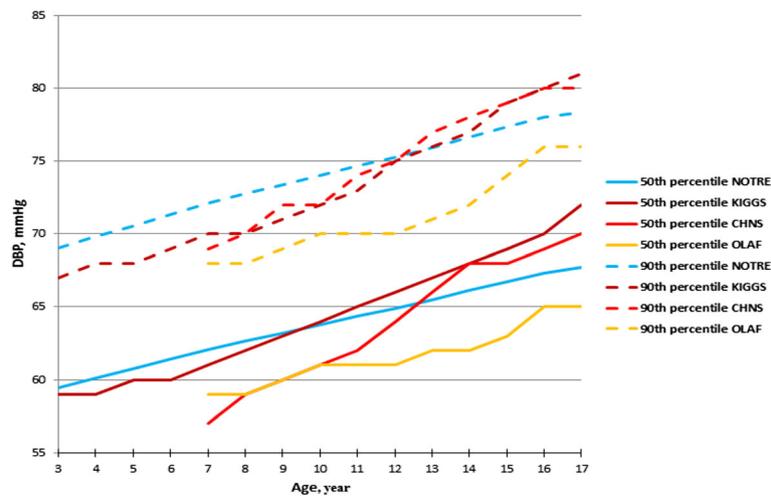


**Fig. 3** The 50th and 90th percentiles of DBP for the median height for our study (NOTRE) compared with the German (KIGGS), Polish (OLAF) and Chinese (CHNS) boys

(boys) and 12–17 years (girls) was respectively 122–133 mmHg and 120–126 mmHg. While for the second author, adolescents aged 12 to 17 (both boys and girls) had their 90th SBP percentile respectively 120–137 mmHg and 122–126 mmHg. In the CHNS study [16], only adolescent boys aged 15 to 17 had the 90th percentile of SBP and DBP at 122 and 80 mmHg close to the threshold of 120/80 mmHg for the identification of prehypertension. In this study the BP values are examined by mercury sphygmomanometer.

We compared our percentiles with the KIGGS [14], OLAF [15] and CHNS [16] studies because they are all

tools that aim to solve the same problem: screening and detection of elevated BP in children. In addition, the construction of the BP percentiles was based on the normal weight subjects and developed simultaneously by age and height.

Several reasons could explain the differences with each study. In particular, the devices used for the BP measurement (auscultatory, oscillometric). It is known as oscillometric devices provide high values of the BP compared to mercury sphygmomanometer [1]. The Datascope Accutor Plus had passed the standards of the Association for the
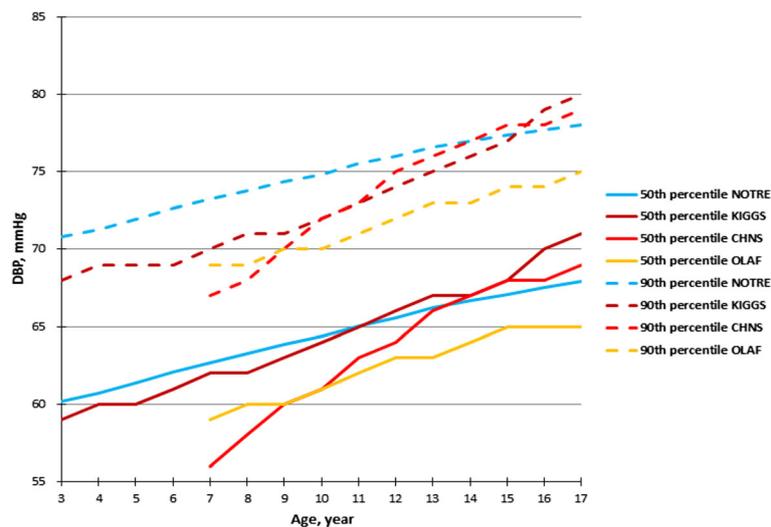


**Fig. 4** The 50th and 90th percentiles of DBP for the median height for our study (NOTRE) compared with the German (KIGGS), Polish (OLAF) and Chinese (CHNS) girls

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Advancement of Medical Instrumentation [28] and the British Hypertension Society [29] for adults and had been validated in children aged 5 to 15 years compared to the mercury sphygmomanometer as required of the International Protocol of the European Society of Hypertension (ESH-IP) [30]. In the validation study in children [21], measures of the Datascope Accutor Plus were close to the sphygmomanometer measurements: the mean (SD) of the differences was for PAS values (oscillometric least auscultation) of - 0.9 (4.33) mmHg and DBP - 1.2 (6.48) mm Hg. The number of the BP measurements used for the establishment of the BP percentiles. As for Kulaga et al. [15], our study used the mean of the last two measures (of the three) BP for statistical analysis because the first one are often high [31, 32]. The statistical method used for the BP percentiles construction. The GAMLSS method was used in our study and those of Neuhauser et al. [14] et Yan et al. [16]; while Kulaga et al. [15] had used the polynomial regression. Another possible reason is the lack of a uniform definition for overweight and obesity for the non-inclusion of this group of children and adolescents in the study of normal weight population. Neuhauser et al. [14] had used the 90th percentile of the BMI of the German reference and Yan et al. [16] were based on the reference BMI of Chinese children and adolescents. Like in the OLAF study [15], we used the definition IOTF [17], because we have not BMI reference for children in our country and it is consistent with the levels of overweight and obesity in childhood and adolescence (2–18 years), with the definition of overweight (≥ 25 kg / m2) and obesity (≥ 30 kg / m2) in adults. We also took into account the recommendations of the European Childhood Obesity Group [33]: which suggest the use of the definition of the IOTF or the WHO definition in epidemiological studies. Ethnic, racial, geographic differences may also explain the variability of the BP in the populations studied [25, 34].

A possible limitation of our study is the selection bias. Owing to the lack of official documents, we used a reported age declaration by parents or guardians. Another limitation was related to a lack external validation made to assess the performance of our proposed BP thresholds.

## Conclusion

We established, for the first time, the thresholds percentiles (50, 90 and 95) of the BP for specific age and height of children and adolescents aged 3 to 17 years in Lubumbashi (DRC) for the use in pediatric clinical practice. Early identification of prehypertension and hypertension in children and adolescents leads to early action to the support and possibly the prevention of late morbidity and mortality. The BP thresholds percentiles proposed by the current study enable to develop a local program of health promotion in schools and family.

We observed that the 90th percentile of SBP in early adolescence is high and this corresponds to the prehypertension thresholds requiring further studies.

## Additional file

**Additional file 1:** Data on Oscillometric Blood Pressure for Non Overweight Children and Adolescents in Lubumbashi. Tabular datasets of this study is presented as an Excel spreadsheet. (XLSX 2513 kb)

### Authors' contributions

EKM, CKM, JMM, PKK, CNK, OM, DNN and WY carried out the conceptualization, design, data collection and analysis for the study. ONL, JKK, FKM and OM contributed to the interpretation of the findings and the drafting of the article. EKM and OM wrote the manuscript. All authors read and approved the final manuscript.

### Ethics approval and consent to participate

The approval to conduct the study and authorizations were obtained from the Medical Ethic Committee of the University of Lubumbashi (UNILU/CEM/027/2013–27 september 2013), the Provincial Ministry of Education, Scientific Research, Transport and Energy of Katanga (N° 10.5/0209/CAB/MIN.PROV/ED.R.TE/KAT/2014–11 march 2014) and the authorities of the selected schools. Data was used with high confidentiality and no names were recorded. The informed written consent to participate was obtained from the parent/guardians of the child or adolescent.

### Consent for publication

The informed written consent to participate and for the publication of individual clinical details was obtained from the parent/guardians of the child or adolescent.

### Competing interests

The authors declare that they have no competing interests.

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