# Prevalence of elevated blood pressure in children and adolescents in Africa: a systematic review and meta-analysis

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## Summary

**Background** Despite substantial attention paid to the threat of elevated blood pressure in children and adolescents in high-income countries and the epidemic of hypertension in African adult populations, data on the burden of elevated blood pressure in African children and adolescents have not yet been synthesised. We did a systematic review and meta-analysis to provide estimates of the prevalence of elevated blood pressure and assess associated factors among children and adolescents in Africa.

**Methods** We searched Embase, PubMed, African Journals Online, and African Index Medicus to identify articles published from Jan 1, 1996, to Feb 2, 2017, and searched the reference list of retrieved articles. Each study was independently reviewed for methodological quality. We used a random-effects model to estimate the prevalence of elevated blood pressure across studies and heterogeneity ($I^2$) was assessed via the $\chi^2$ test on Cochran's Q statistic. This review is registered with PROSPERO, number CRD42015019029.

**Findings** We included 51 studies in qualitative synthesis and 25 in the meta-analysis reporting data of a pooled sample of 54 196 participants aged 2–19 years. Study quality was high with only four medium-quality studies and no low-quality studies. Prevalence of elevated blood pressure varied widely across studies (range 0·2–24·8%). The pooled prevalence of elevated blood pressure (systolic or diastolic blood pressure ≥95th percentile) was 5·5% (95% CI 4·2–6·9), whereas that of slightly elevated blood pressure (systolic or diastolic blood pressure ≥90th percentile and <95th percentile) was 12·7% (2·1–30·4). The prevalence of elevated blood pressure was largely associated with body-mass index (BMI), with a prevalence of elevated blood pressure six times higher in obese (30·8%, 95% CI 20·1–42·6) versus normal-weight children (5·5%, 3·1–8·4; p<0·0001).

**Interpretation** This study suggests a high prevalence of elevated blood pressure among children and adolescents in Africa, with overweight and obesity being an important risk factor. Efforts to address this burden of elevated blood pressure in children and adolescents should mainly focus on primary prevention at the community level, by promoting healthy lifestyles and avoiding other cardiovascular risk factors, especially overweight and obesity. This study also stresses the need for more elaborate studies using uniform and reliable diagnostic methods to reliably map the burden of elevated blood pressure in children and adolescents in Africa.


**Funding** None.



*Lancet Public Health* 2017; 2: e375–86

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## Introduction

Hypertension is the greatest modifiable risk factor for cardiovascular disease, disability, and deaths worldwide. Globally, it affects about 1 billion adults and is associated with more than 9 million deaths annually.[1] Furthermore, hypertension was the largest contributor to global disability-adjusted life-years (DALYs) in 2015, accounting for 9·2% (95% uncertainty interval 8·3–10·2) of DALYs for men and 7·8% (6·9–8·7) of DALYs for women.[2] Once uncommon in African populations, the burden of hypertension has been continuously rising over the past decades in these populations, driven by reduced physical activity, unhealthy diet, and obesity.[3] According to WHO, Africa has the highest age-standardised prevalence of hypertension, with 46% of adults older than 25 years being affected.[1]

Although hypertension is less common in children than in adults, its burden has increased in children and adolescents in some high-income countries over the past decade, mainly due to the surge in obesity prevalence.[4–10] Indeed, reports from epidemiological studies on blood pressure in children and adolescents done during the past decade have shown a substantial increase in blood pressure levels and in the prevalence of hypertension in these age groups, with rates ranging from 1% to 5% in some western countries.[4–10] However, these increasing trends have not been observed in all countries studied.[11]

Hypertension in children and adolescents is becoming a major concern, not only because of its rising prevalence, but also because of evidence suggesting that hypertension tracks from childhood to adulthood. Almost half of adults with hypertension had elevated blood pressure values during childhood.[8–13] Furthermore, several studies have suggested that elevated blood pressure in childhood correlates with carotid intima-media thickness, atherosclerosis,

## Research in context

### Evidence before this study

There is evidence that hypertension and its cardiovascular complications track from childhood to adulthood. Little is known about the burden of hypertension in children and adolescents in Africa. Only one previous meta-analysis at the global level has provided an estimate of the prevalence of hypertension in adolescents in Africa. Unfortunately, this review included only three studies from Africa and the derived prevalence of 25·5% was therefore questionable.

### Added value of this study

To the best of our knowledge, this study is the first comprehensive summary of available high quality surveys estimating the point prevalence of elevated blood pressure in children and adolescents in Africa. Our study shows that elevated blood pressure is not infrequent in these populations, with overweight and obesity being a driver of the condition. The weak influence of the gross domestic product per capita on the prevalence of elevated blood pressure suggests that elevated blood pressure is equally affecting children and adolescents in poorer and less poor countries in Africa. The influence of socioeconomic level on the occurrence of elevated blood pressure during childhood and adolescence might be more apparent at the individual level than at the country level. Another salient finding is the increased prevalence of elevated blood pressure in children and adolescents in rural areas, which deserves further investigation.

### Implications of all the available evidence

We hope results from this research will prompt implementation of appropriate policy towards improving awareness, diagnosis, and proper management of hypertension in African children and adolescents. In the absence of sufficient evidence to recommend universal blood pressure screening, we advocate for targeted identification of elevated blood pressure according to the clinical context, and early treatment of cases with secondary hypertension. At the population level, efforts should focus on primary prevention of elevated blood pressure by promoting weight control, healthy diet, and regular physical activity. Strategies for blood pressure control and cardiovascular disease prevention in childhood and adolescence might be integrated in existing programmes.

left ventricular hypertrophy, and kidney failure in adulthood.[14–21] Consequently, early diagnosis and control of hypertension in childhood are likely to have an important effect on long-term outcomes of hypertension-related cardiovascular complications.

Although epidemiological data on hypertension and cardiovascular disease in adults in Africa are growing, the prevalence of elevated blood pressure and its drivers in children and adolescents in Africa remain largely unknown. Hence, we did a systematic review of the literature and a meta-analysis to provide a reliable estimate of the prevalence of elevated blood pressure and identify associated factors among children and adolescents in Africa.

## Methods

### Search strategy and selection criteria

For this systematic review and meta-analysis, JJN, ME, and LNA, with the help of an expert librarian, did a comprehensive search of PubMed, Embase, African Journals Online, and African Index Medicus to identify all relevant articles on elevated blood pressure in children and adolescents in Africa published in English and French from Jan 1, 1996, to Feb 2, 2017. We focused on the past 20 years to provide recent estimates and to reduce the heterogeneity between studies. We conceived and applied a search strategy based on the combination of relevant terms and names of each of the 54 African countries and African subregions such as "north Africa" or "central Africa". Names of African countries were included in English and in the official languages of respective countries (eg, "Ivory Coast" and "Côte d'Ivoire"). For countries whose names have changed over time, both the old and the new name were used (eg, "Zaire" and "Democratic Republic of the Congo"). Terms used for hypertension included the following: "hypertension", "blood pressure", "systolic hypertension", and "diastolic hypertension". For children and adolescents, we used "child", "children", "childhood", "adolescent", "teens", "teenage", "youth", "infant", and "pediatric". The main search strategy done in PubMed is available in the review protocol.[22] This search strategy was adapted to fit with other databases. To supplement these bibliographic database searches, references of all relevant research articles and reviews were also scrutinised to identify additional potential data sources.

To be included in this systematic review, primary studies had to be observational studies of children and adolescents aged 1–19 years residing in African countries, irrespective of ethnic, socioeconomic, and educational backgrounds, reporting the prevalence of elevated blood pressure or with enough data to compute these estimates. We excluded studies on non-systemic hypertension (intracranial or pulmonary hypertension), those done among populations of African origin residing outside Africa, studies in subgroups of participants selected on the basis of presence of hypertension (eg, clinical trials or case-control studies), and studies including both adult and paediatric populations in which it was not possible to disaggregate data for children or adolescents. We also excluded case series with a small sample size (<50 participants), letters, reviews, commentaries, editorials, and studies without primary data or explicit description of methods. For studies published in more

than one report (duplicates), we considered the most comprehensive report with the largest sample size.

Two investigators (JJN and ME) independently screened the titles and abstracts of articles retrieved from the literature search, and full texts of articles found potentially eligible were obtained and further assessed for final inclusion. All duplicates were removed during the study selection process. Disagreements were resolved through discussions between investigators until a consensus was reached.

### Data extraction

Two investigators (JJN and ME) independently extracted relevant data from individual studies using a preconceived and standardised data extraction form.

Information extracted included first author's name, year of publication, recruitment period, area (rural *vs* urban), country, study design, setting, sample size, mean or median age, age range, proportion of male participants, proportion of participants with obesity, ascertainment of elevated blood pressure and diagnostic criteria, and the number of participants with slightly elevated blood pressure (systolic or diastolic blood pressure ≥90th percentile and <95th percentile) and elevated blood pressure (systolic or diastolic blood pressure ≥95th percentile). We assigned a United Nations Statistics Division (UNSD) African region (Central [refers to Central Africa], Eastern, Northern, Southern, and Western) to each study regarding the country of recruitment. We retrieved the gross domestic product per capita (GDP) in US dollars of each study from the World Bank database and corresponded it to the GDP of the year of recruitment of each study's country. For studies with recruitment in more than one year, we considered the median GDP of the corresponding country in the years of recruitment. Disagreements between authors were reconciled through discussion and consensus. Where relevant data were not available, we directly contacted the corresponding author to request the information.

### Data analysis

We used a meta-analysis to summarise prevalence data. We determined SEs for study-specific estimates from the point estimate and the appropriate denominators. We pooled the study-specific estimates using a random-effects meta-analysis model to obtain an overall summary estimate of the prevalence across studies,[23] after stabilising the variance of individual studies with the use of the Freeman-Tukey double arcsine transformation.[24]

We evaluated the methodological quality of included studies using the tool developed by Hoy and colleagues.[25] We assigned each item a score of 1 (yes) or 0 (no), and summed scores across items to generate an overall quality score that ranged from 0 to 10. According to the overall scores, we classified studies as having a low (>8), moderate (6–8), or high (≤5) risk of bias. Two investigators (JRN and JJB) independently assessed study quality, with disagreements resolved by consensus.

We assessed heterogeneity using the $\chi^2$ test on Cochran's Q statistic[26] and quantified heterogeneity by calculating the $I^2$ (with values of 25%, 50%, and 75% representing low, medium, and high heterogeneity, respectively).[27] To be included in the meta-analysis, studies had to define elevated blood pressure (or hypertension) as systolic or diastolic blood pressure greater than or equal to the 95th percentile (for all ages) or slightly elevated blood pressure (or pre-hypertension) as systolic or diastolic blood pressure in the 95th percentile but greater than or equal to the 90th percentile, with a random selection of participants with no specific disease or profile, low risk of bias in their methodological quality, and prospective data collection. If substantial heterogeneity was detected, we did subgroup analysis when possible to investigate the possible sources of heterogeneity using the following grouping variables: age group, sex, study setting, UNSD African region, number of blood pressure measurements, representativeness of sample, sample size, period of participants' recruitment, and body-mass index (BMI). Subgroup comparisons used the Q test based on ANOVA. We considered a subgroup difference p value less than 0·05 to be indicative of significant difference between subgroups. We used meta-regression to measure the association between prevalence of elevated blood pressure and GDP. We adjusted for BMI, considering the strong association between GDP and obesity. In the case of non-normal distribution of GDP, we planned a $\log_{10}$-transformation of the GDP for meta-regression and presentation in a scatter plot. We assessed the presence of publication bias using funnel plots and the formal Egger test. We considered an Egger test p value less than 0·10 to be indicative of significant publication bias.[28] We assessed inter-rater agreement for study inclusion and data extraction using Cohen's κ coefficient.[29] We analysed data using Stata version 13.0 for Windows. The meta-analysis was preceded by a qualitative synthesis of data.

This review was registered in the PROSPERO International Prospective Register of systematic reviews, registration number CRD42015019029 and its protocol has been published.[22]

For the **breakdown of African regions** see https://unstats.un.org/unsd/methodology/m49/

### Role of the funding source

There was no funding source for this study. The corresponding author had full access to all study data and had final responsibility for the decision to submit the paper for publication.

## Results

We identified 5891 records; after elimination of duplicates, 3543 records remained (figure 1). After screening titles and abstracts, we found 3468 records to be irrelevant and excluded them. The inter-rater agreement for study selection was high (κ=0·88). We assessed full texts of the remaining 75 papers for eligibility, of which 28 were excluded. We included a total of 51 studies[30–76] from 47 full-text articles in the review,

See Online for appendix

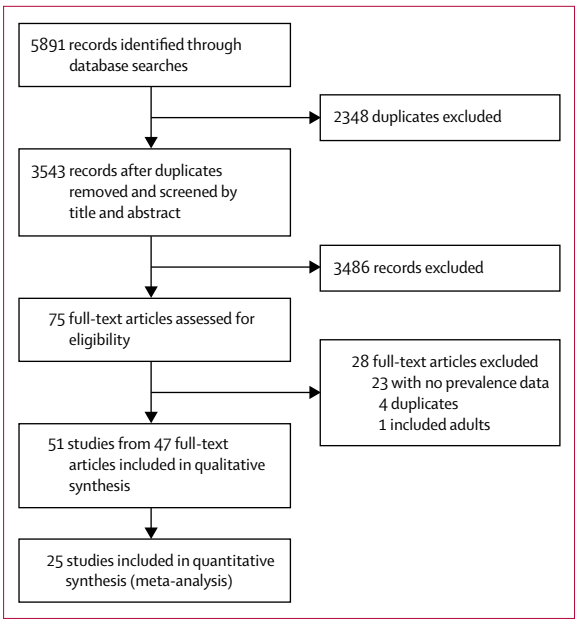


***Figure 1:*** **Study selection**

with only 25 of the studies[30–50] considered in the pooled analysis. Inter-rater agreements were high for both study inclusion (κ=0·93) and data extraction (0·89).

The methodological quality and characteristics of included studies are presented in table 1. Three studies provided cross-sectional data of a cohort study and the other data were pulled out from cross-sectional studies. Data were from 13 countries distributed across the five UNSD regions of Africa. The definitions of elevated blood pressure varied widely across studies. With respect to our criteria, 40 studies were classified as having an acceptable definition for elevated blood pressure[30–53,55–60,62,64,66–68,73,74] whereas ten studies used a non-acceptable definition[54,61,63,65,69,70,72,75,76] and one did not report the definition used.[71] Among these ten studies with non-acceptable definitions of elevated blood pressure, four studies defined elevated blood pressure as blood pressure of 120/80 mm Hg or higher,[63,65,67,72] three as blood pressure greater than the mean plus two SDs,[61,69,70] two as systolic or diastolic blood pressure within the 95th percentile for individuals younger than 18 years and blood pressure of 140/90 mm Hg or higher for individuals aged 18 years or older,[76] and one as blood pressure of 125/84 mm Hg or higher.[75] All 25 studies included in the meta-analysis had low risk of bias in their methodology, randomly selected participants, and were population based.[30–50]

From the 51 studies included in the review, the prevalence of elevated blood pressure varied widely from 0·2% to 24·8%. Prevalence in different UNSD regions in Africa was 9·8–10·1% (Central), 6·5–17·1% (Eastern), 4·8–19·7% (Northern), 4·5–21·2% (Southern), and 0·2–24·8% (Western). Prevalence was between 4·1% and 11·2% in rural areas, 0·2% and 24·8% in urban areas, and 2·6% and 21·2% in studies done in both areas. Among females, prevalence varied from 0·4% to 20·9% and among males from 0·6% to 25·0%. Prevalence widely varied by age group: 2–5 years (0·5–22·4%), 6–12 years (1·5–24·4%), and 13–19 years (1·8–21·2%). Prevalence of elevated blood pressure in the two studies with specific profile (overweight and obese) was high, at 17·4% and 19·7%. Prevalence of elevated systolic blood pressure ranged from 0·1% to 14·2%, and from 0·1% to 14·6% for elevated diastolic blood pressure. Prevalence of slightly elevated blood pressure retrieved from ten studies done in Nigeria, South Africa, Tunisia, and Congo (Brazzaville) varied from 1·4% to 39·1%.

Table 2 summarises results from meta-analyses. The overall prevalence of elevated blood pressure was 5·5% (95% CI 4·2–6·9) in a pooled sample of 54196 children and adolescents from 25 studies (figure 2). The funnel plot did not suggest any publication bias (appendix p 7) and this result is confirmed by the Egger test (table 2). The prevalence of slightly elevated blood pressure was about twice as high as overall prevalence (table 2, appendix p 10). The prevalence of elevated systolic blood pressure and that of elevated diastolic blood pressure were similar (table 2, appendix pp 8–9).

The GDP per capita was not normally distributed and therefore $\log_{10}$-transformed (appendix p 11). Prevalence of elevated blood pressure generally increased slightly with the $\log_{10}$-transformed GDP. This was confirmed by the results of meta-regression (coefficient 0·04, 95% CI 0·01–0·07; p=0·015; 25 studies). The $\log_{10}$-transformed GDP explained only 0·13% of the variation in the prevalence of elevated blood pressure. After adjustment for mean BMI, the association remained significant (adjusted coefficient 0·04, 0·01–0·07; p=0·017; 18 studies), explaining only 0·16% of the variation in the prevalence of elevated blood pressure.

Publication bias was found for the following subgroup analyses: elevated diastolic blood pressure, setting, national representative studies, studies using mercury devices for blood pressure measurement, and studies with sample size higher than the median (table 2). Substantial heterogeneity was present within all subgroups (table 2).

Data for the UNSD region of Western Africa came from Nigeria (ten studies) and Côte d'Ivoire (one study). For Northern Africa, data came only from Tunisia (four studies). For the region of Southern Africa, data came only from South Africa (three studies). For Eastern Africa, data came from Seychelles (five studies) and Uganda (one study); and for Central Africa, data came only from Congo (Brazzaville; one study). The prevalence of elevated blood pressure in Western Africa was lower than that in other UNSD regions of Africa (table 2, figure 2). 16 studies presented data from urban areas and four from rural areas; the prevalence of elevated blood pressure was higher in rural areas (table 2; appendix p 12).

Prevalence of elevated blood pressure did not differ between age groups and sex (table 2; appendix pp 13–14).

The prevalence of elevated blood pressure was higher when blood pressure measurements were taken with a digital device compared with aneroid or mercury devices (table 2; appendix p 16). We also found a difference for measurement method: the prevalence with one reading was lower than that obtained with an average of two or three readings (table 2; appendix p 17).

With regard to BMI, the prevalence of elevated blood pressure among obese and overweight children was higher than among normal-weight and underweight populations (table 2, figure 3).

## Discussion

This systematic review and meta-analysis of data from 25 studies involving 54 196 individuals found a pooled prevalence of elevated blood pressure of 5·5% and a pooled prevalence of slightly elevated blood pressure of 12·7% in children and adolescents in Africa. Increased BMI was largely associated with the prevalence of elevated blood pressure, with prevalence six times higher in obese children and adolescents than in those of normal weight.

The prevalence of elevated blood pressure found in this review is below the pooled prevalence estimate (25·5%, 95% CI 10·1–39·1) of elevated blood pressure in African adolescents found by a previous systematic review.[77] This discrepancy might be explained by difference in the number of surveys included in the pooled analyses (25 in the current study *vs* three in the other) as well as different age bands (2–19 years *vs* 10–19 years).[77] de Moraes and colleagues' systematic review[77] was not designed to estimate the prevalence of high blood pressure in adolescents in Africa specifically, but was a worldwide study to compare prevalence estimates of elevated blood pressure in adolescents across different regions. In their review,[77] Africa and Oceania (which had the most limited numbers of included studies) had the highest prevalence estimates when compared with other regions (North America, Latin America, Asia, and the Middle East; p=0·001). Nevertheless, the prevalence of elevated blood pressure found in our review is similar to the 1–5% prevalence reported in children and adolescents from high-income countries and other low-income and middle-income countries.[4–10]

We found no difference between boys and girls in terms of prevalence of elevated blood pressure. This finding supplements results from the most recent meta-analysis[78] on hypertension in adults in Africa. Both studies suggest that male sex might not be a risk factor for elevated blood pressure in Africa, unlike reports from some developed countries.[79]

A key finding of this study is the substantial association of the prevalence of elevated blood pressure with increased BMI. A number of epidemiological studies from Africa and other regions have previously reported this link between elevated blood pressure and increased BMI (obesity and overweight) both in adults and in children and adolescents.[2,8,9,54] Although we could not accurately determine whether the link observed was causal or not, obesity and overweight are known risk factors for elevated blood pressure and high blood pressure-specific cardiovascular disease as well as all-cause cardiovascular disease in all age groups.[8,9] Accordingly, increased BMI is probably an important risk factor for elevated blood pressure in children and adolescents in Africa. Notably, obese individuals have excess fat leading to elevated blood pressure via an increase in sympathetic activity and

| | All studies (n=51) | Studies included in the meta-analysis (n=25) |
|---|---|---|
| **Methodological quality** | | |
| Timing of data collection | Prospective (n=50), retrospective (n=1) | All prospective |
| Risk of bias | Low risk (n=47), moderate risk (n=4) | All low risk |
| Selection of participants | Random selection (n=40), non-random (n=11) | All random |
| Representativeness | National (n=8), subnational (n=43) | National (n=7), subnational (n=18) |
| Population based | All | All |
| **Characteristics** | | |
| Year of publication | 1998–2016 | 2001–2016 |
| Patient recruitment period | 1995–2013 | 1997–2013 |
| Countries | Algeria (n=2), Angola (n=1), Congo (Brazzaville) (n=1), Côte d'Ivoire (n=1), Democratic Republic of the Congo (n=1), Egypt (n=1), Morocco (n=1), Nigeria (n=24), Senegal (n=1), Seychelles (n=6), South Africa (n=6), Tunisia (n=5), and Uganda (n=1) | Congo (Brazzaville) (n=1), Côte d'Ivoire (n=1), Nigeria (n=10), Seychelles (n=5), South Africa (n=3), Tunisia (n=4), and Uganda (n=1) |
| UNSD African regions | Western (n=26), Northern (n=9), Eastern (n=7), Southern (n=7), and Central (n=2) | Western (n=11), Eastern (n=6), Northern (n=4), Southern (n=3), and Central (n=1) |
| Settings | Rural (n=6), urban (31), and both (n=14) | Rural (n=2), urban (n=14), and both (n=9) |
| Blood pressure values considered | One reading (n=2), lowest diastolic blood pressure and its matching systolic blood pressure after three measurements n=1), average of two readings (n=20), and average of three readings (n=22); missing data (n=6) | One reading (n=1), average of two readings (n=8), and average of three readings (n=13); missing data (n=3) |
| Types of device for blood pressure measurement | Aneroid (n=7), digital (n=14), and mercury (n=24); missing data (n=6) | Aneroid (n=5), digital (n=3), and mercury (n=14); missing data (n=3) |
| Elevated blood pressure definition | Good definition* (n=40) and others (n=11) | Good definition* (n=25) |
| Mean age (years) | 3·7–17·7 (from 45 studies) | 3·7–16·9 (from 22 studies) |
| Age range (years) | 1–19 | 2–19 |
| Female participants | 37·7–73·7% (from 44 studies†) | 45·2–61·9% |
| Male participants | 26·3–62·3% (from 44 studies†) | 38·1–54·8% |
| Participants' specific profile or disease | Overweight (n=1), overweight and obese (n=1), and none (n=49) | None (n=25) |
| Gross domestic product per capita, median (IQR) | US$2939·69 (2281·06–4038·07; from 41 studies) | US$2829·05 (2310·86–5814·33) |

UNSD=United Nations Statistics Division. *Systolic or diastolic blood pressure ≥95th percentile. †One study included only males.

***Table 1:*** **Characteristics of included studies**

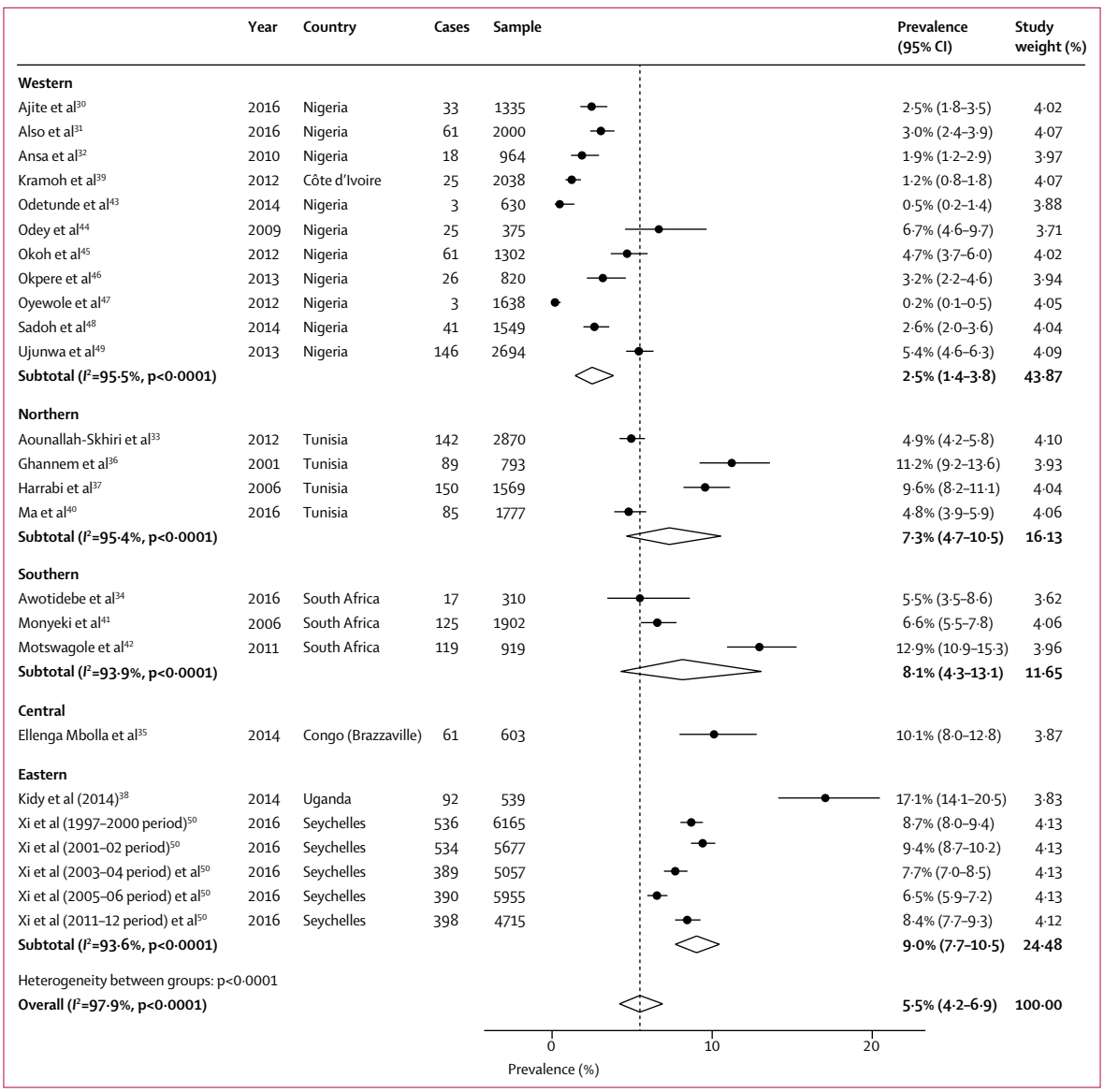


***Figure 2:*** **Prevalence of elevated blood pressure in children and adolescents by UNSD African regions**
UNSD=United Nations Statistics Division.

subsequent sodium reabsorption and increased peripheral vascular resistance.

GDP is generally associated with obesity,[80–82] and obesity is strongly associated with elevated blood pressure.[2,8,9,54] We found a weak influence of GDP on prevalence of elevated blood pressure in this study, suggesting that elevated blood pressure is equally affecting children and adolescents in poorer and less poor countries in Africa. This result has implications in terms of the coping capacities of countries; less developed countries can be disproportionately affected by the burden of disease, but tackling the burden of elevated blood pressure in children and adolescents in such countries in Africa might not require supplemental efforts and resources.

Prevalence of elevated blood pressure was higher in rural areas than in urban areas. This pattern of elevated blood pressure has also been reported in children and adolescents from Poland.[83] Environmental variations of blood pressure levels are difficult to explain. Nevertheless, two potential underlying mechanisms have been described: low socioeconomic status and obesity.[77,83–86] Elevated blood pressure has been associated with low socioeconomic status in previous studies[84–87] from low-income and middle-income countries including African countries, in both adult and paediatric populations. Along the same lines, a study[88] in South Africa has shown that improvement in socioeconomic status between infancy and adolescence has a protective effect on systolic

blood pressure in young adulthood. Rural area inhabitants often live in impoverished conditions with low household status, exposing them to increased stress perception, a factor that is known to enhance activation of the autonomic nervous system and subsequently increase blood pressure. Lower socioeconomic conditions in rural areas might therefore account for the increased prevalence of elevated blood pressure in children and adolescents living in these settings, as compared to those in urban areas. In addition, studies[89,90] in several

| | Number of studies | Number of participants | Number of cases | Prevalence (95% CI) | $I^2$ | p values | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Heterogeneity | Subgroup difference | Egger test |
| **Global analysis** | | | | | | | | |
| Overall elevated blood pressure | 25 | 54196 | 3569 | 5·5% (4·2–6·9) | 97·9% | <0·0001 | .. | 0·265 |
| Elevated systolic blood pressure | 10 | 18473 | 938 | 3·6% (1·7–6·4) | 98·6% | <0·0001 | .. | 0·113 |
| Elevated diastolic blood pressure | 10 | 18473 | 1395 | 3·0% (0·3–8·5) | 97·7% | <0·0001 | .. | 0·034 |
| Slightly elevated blood pressure | 5 | 8437 | 1746 | 12·7% (2·1–30·4) | 99·6% | <0·0001 | .. | 0·402 |
| **Subgroup analysis** | | | | | | | | |
| United Nations Africa region | | | | | | | | |
| Overall | 25 | 51986 | 4069 | 5·5% (4·2–6·9) | 97·9% | <0·0001 | <0·0001 | 0·265 |
| Central | 1 | 603 | 61 | 10·1% (8·0–12·8) | .. | .. | .. | Not estimable* |
| Eastern | 6 | 21108 | 2339 | 9·0% (7·7–10·5) | 93·6% | <0·0001 | .. | 0·071 |
| Northern | 4 | 7009 | 466 | 7·3% (4·7–10·5) | 95·4% | <0·0001 | .. | 0·181 |
| Southern | 3 | 3131 | 261 | 8·1% (4·3–13·1) | 93·9% | <0·0001 | .. | 0·915 |
| Western | 11 | 15345 | 442 | 2·5% (1·4–3·8) | 95·5% | <0·0001 | .. | 0·910 |
| Setting | | | | | | | | |
| Both urban and rural | 20 | 23301 | 1196 | 5·4% (3·7–7·4) | 97·4% | <0·0001 | 0·013 | 0·057 |
| Urban | 16 | 19089 | 872 | 4·6% (2·8–6·7) | 97·5% | <0·0001 | .. | 0·173 |
| Rural | 4 | 4212 | 324 | 9·2% (6·2–12·8) | 91·7% | <0·0001 | .. | 0·105 |
| Age group | | | | | | | | |
| Overall | 16 | 17844 | 2013 | 8·7% (5·8–12·0) | 98·0% | <0·0001 | 0·631 | 0·797 |
| 2–5 years | 2 | 1656 | 233 | 10·7% (9·3–12·2) | 99·9% | <0·0001 | .. | Not estimable* |
| 6–12 years | 4 | 2634 | 319 | 7·0% (0·4–20·0) | 98·8% | <0·0001 | .. | 0·752 |
| 13–19 years | 10 | 13554 | 1461 | 9·5% (6·8–12·4) | 96·2% | <0·0001 | .. | 0·466 |
| Sex | | | | | | | | |
| Overall | 30 | 43345 | 3418 | 6·6% (5·3–7·9) | 96·7% | <0·0001 | 0·856 | 0·896 |
| Male | 15 | 21065 | 1689 | 6·4% (4·6–8·5) | 96·9% | <0·0001 | .. | 0·246 |
| Female | 15 | 22280 | 1729 | 7·0% (5·2–9·0) | 96·8% | <0·0001 | .. | 0·581 |
| Sample representativeness | | | | | | | | |
| Overall | 25 | 51986 | 4069 | 5·5% (4·2–6·9) | 97·9% | <0·0001 | 0·065 | 0·532 |
| National | 7 | 32216 | 2474 | 7·2% (6·0–8·4) | 94·4% | <0·0001 | .. | 0·074 |
| Subnational | 18 | 21980 | 1095 | 4·9% (3·2–7·0) | 97·7% | <0·0001 | .. | 0·157 |
| Device type for blood pressure measurement | | | | | | | | |
| Overall | 22 | 50334 | 3478 | 5·9% (4·5–7·3) | 97·7% | <0·0001 | <0·0001 | 0·999 |
| Mercury | 14 | 39401 | 2697 | 4·8% (3·6–6·2) | 97·0% | <0·0001 | .. | <0·0001 |
| Aneroid | 5 | 7932 | 450 | 5·8% (2·0–11·5) | 98·7% | <0·0001 | .. | 0·325 |
| Digital | 3 | 2901 | 331 | 12·3% (8·6–16·6) | 90·1% | <0·0001 | .. | 0·259 |
| Number of measurements | | | | | | | | |
| Overall | 22 | 48028 | 3860 | 5·4% (4·2–6·8) | 97·9% | <0·0001 | <0·0001 | 0·144 |
| One | 1 | 1638 | 3 | 0·2% (0·1–0·5) | .. | .. | .. | Not estimable* |
| Average of two | 8 | 11167 | 575 | 4·9% (3·1–7·2) | 95·9% | <0·0001 | .. | 0·092 |
| Average of three | 13 | 38059 | 2822 | 6·4% (5·1–7·9) | 96·7% | <0·0001 | .. | 0·392 |

(Table 2 continues on next page)

| | Number of studies | Number of participants | Number of cases | Prevalence (95% CI) | $I^2$ | p values | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Heterogeneity | Subgroup difference | Egger test |
| (Continued from previous page) | | | | | | | | |
| BMI† | | | | | | | | |
| Overall | 14 | 6829 | 469 | 14·4% (10·1–19·3) | 95·4% | <0·0001 | <0·0001 | <0·0001 |
| Underweight | 1 | 219 | 16 | 7·3% (4·5–11·5) | .. | .. | .. | Not estimable* |
| Normal | 4 | 5091 | 224 | 5·5% (3·1–8·4) | 92·6% | <0·0001 | .. | 0·326 |
| Overweight | 5 | 1271 | 162 | 16·6% (9·1–25·9) | 92·8% | <0·0001 | .. | 0·119 |
| Obese | 4 | 248 | 67 | 30·8% (20·1–42·6) | 64·9% | 0·0359 | .. | 0·010 |
| Recruitment period | | | | | | | | |
| Overall | 18 | 47199 | 3320 | 6·5% (5·2–8·0) | 97·3% | <0·0001 | 0·054 | 0·302 |
| 1997–2006 | 8 | 30114 | 2385 | 8·1% (6·8–9·4) | 94·0% | <0·0001 | .. | 0·619 |
| 2007–16 | 10 | 17085 | 935 | 5·3% (3·3–7·8) | 97·6% | <0·0001 | .. | 0·844 |
| Median sample size | | | | | | | | |
| Overall | 25 | 51986 | 4069 | 5·5% (4·2–6·9) | 97·9% | <0·0001 | 0·557 | 1·0 |
| ≤1569 | 13 | 11708 | 735 | 5·9% (3·6–8·7) | 97·1% | <0·0001 | .. | 0·425 |
| >1569 | 12 | 42488 | 2834 | 5·1% (3·5–6·9) | 98·4% | <0·0001 | .. | <0·0001 |

..=not applicable. BMI=body-mass index. *Because of insufficient observations. †Underweight: BMI less than 2 SDs below the WHO growth standard mean for age and sex; normal: BMI between 2 SDs below and 1 SD above the mean; overweight: BMI more than 1 SD above the mean; and obesity: BMI more than 2 SDs above the mean.

***Table 2:*** **Prevalence of elevated blood pressure among children and adolescents in Africa using random-effects model and double arcsine transformation**

developed countries have shown that overweight and obesity are more prevalent in children and adolescents living in rural areas, representing a plausible explanation for the higher prevalence of elevated blood pressure in rural areas than in urban areas in these age groups. However, data on urban–rural differences in terms of prevalence of obesity in African countries are insufficient to support this assumption.

Taken collectively, elevated blood pressure is a health problem that might be largely driven by high BMI in children and adolescents in Africa. Some questions therefore arise from our study. First, can primary prevention of hypertension be beneficial for children and adolescents in Africa? Second, if necessary, what are the most suitable preventive strategies? Third, is treatment of essential hypertension necessary and for how long is it recommended?

Primary prevention of hypertension in children and adolescents aims to reduce the risk of cardiovascular disease and prevent hypertension in adulthood. Although high blood pressure is associated with detrimental cardiovascular effects in children and teens, no direct evidence exists to estimate the absolute risk of cardiovascular disease associated to a particular level of blood pressure in childhood. The robustness of hypertension tracking should be further evaluated given the difficulty of obtaining perfect blood pressure measurements, especially in children and adolescents.[8–13] As a result, existing guidelines do not endorse primary prevention of hypertension in childhood through systematic screening.[85] Nevertheless, early identification of children and adolescents with elevated blood pressure could help to reduce the hypertension epidemic in adults and cardiovascular disease across the continent. Primary prevention of elevated blood pressure in children and adolescents should first and foremost rely on population interventions addressing modifiable blood pressure determinants—mainly weight control, modification of unhealthy diet and promotion of regular physical activity. Blood pressure control and cardiovascular prevention programmes addressing modifiable risk factors are already in place in most African countries, but are mostly designated for adults. Their implementation should be extended to younger age groups. Existing programmes, such as child and maternal health programmes, and school programmes could be useful. Second, depending on resources available, primary prevention of elevated blood pressure at the individual level should rely on weight control (as weight excess is by far the main determinant of elevated blood pressure in children). Blood pressure screening would mostly be useful to detect secondary hypertension (eg, due to renal or endocrine disorders) in the very few cases of children with elevated blood pressure who are not obese, considering existing local resources. Drug therapy might be initiated only if blood pressure is persistently elevated despite lifestyle modification. However, unsolved questions regarding drug therapy for elevated blood pressure in children and adolescents concern its absolute cardiovascular disease risk

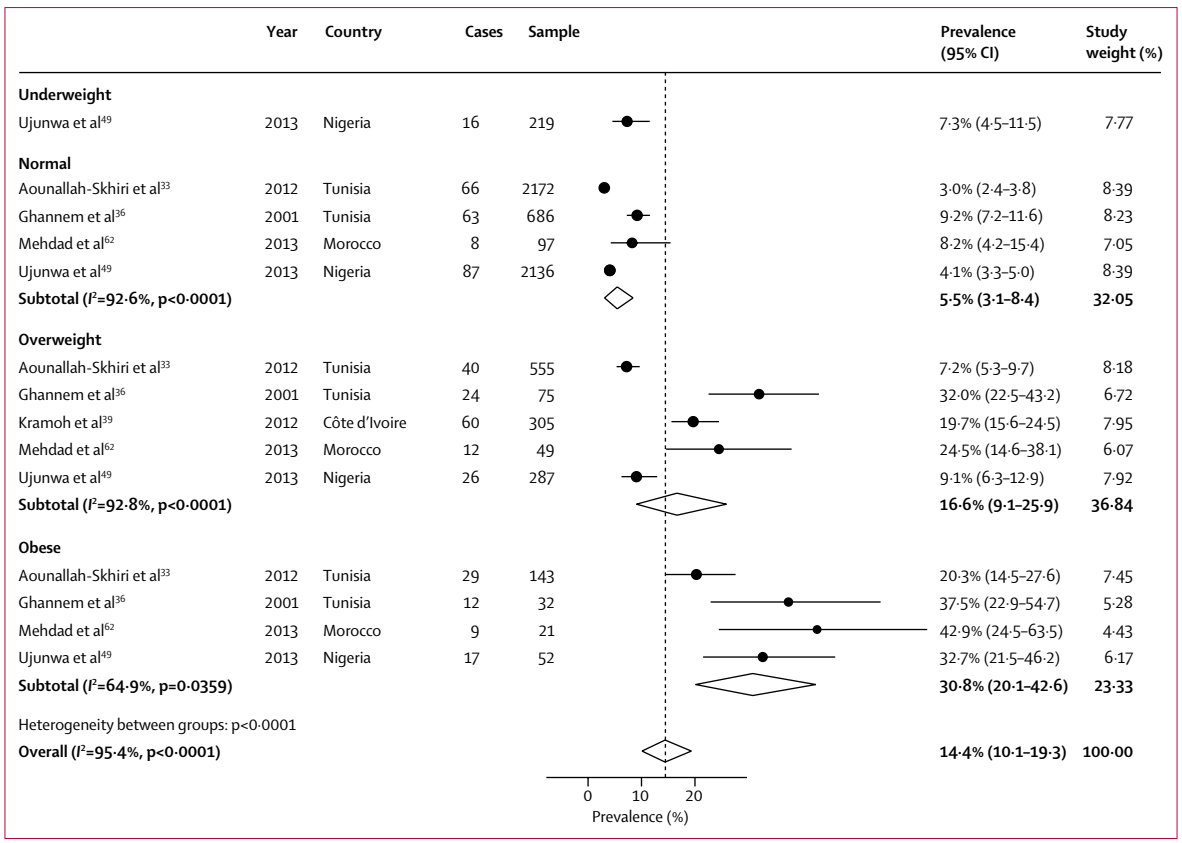


***Figure 3:*** **Prevalence of elevated blood pressure in children and adolescents in Africa stratified by BMI category**
Underweight: BMI less than 2 SDs below the WHO growth standard mean for age and sex; normal: BMI between 2 SDs below and 1 SD above the mean; overweight: BMI more than 1 SD above the mean; and obesity: BMI more than 2 SDs above the mean. BMI=body-mass index.

reduction following blood pressure reduction and its effect on prevention of hypertension in adulthood (and thus duration of treatment), as well as risk–benefit ratio.

Results from this study should be interpreted with caution in the context of its limitations. First, definitions of elevated blood pressure differed across studies. Hypertension definition is a major problem in both adult and paediatric studies given the high correlation between blood pressure and growth stature, weight, and sexual maturity in children and adolescents. Hence, the situation might not be well reflected in studies with unacceptable definitions of elevated blood pressure as well as studies involving only participants with high BMI. Even the definition of high blood pressure in children and adolescents considered acceptable in this review might not be suitable for African children and adolescents given that it was derived from the US population.[11,91] The results from ongoing endeavours to establish international blood pressure references among children and adolescents will help in comparisons of the prevalence of elevated blood pressure in children and adolescents between countries and regions.[92] Second, we found substantial heterogeneity in estimation of the prevalence of elevated blood pressure across studies. This heterogeneity might in part be explained by between-study differences in methodology (including setting, device used for blood pressure measurement, and number of measurements) and in population characteristics (eg, proportion of participants with obesity), but it might also reflect true differences of elevated blood pressure burden. Third, we did not have enough data to allow optimal age-stratified analyses. Our results are limited by the wide age band of our study population and the proposed age-stratified analysis. Fourth, UNSD African regions were not uniformly represented, partly owing to difficult retrieval of African medical literature, especially for older articles and those published in local journals.

In conclusion, this study suggests a high prevalence of elevated blood pressure among children and adolescents in Africa, with overweight and obesity being important risk factors. Efforts to address the burden of elevated blood pressure in children and adolescents should mainly focus on primary prevention at the community level by promoting healthy lifestyle and avoiding other cardiovascular risk factors, especially overweight and obesity. More elaborate studies using uniform and reliable diagnostic methods are needed to better estimate

the prevalence of elevated blood pressure and its determinants in children and adolescents within and across countries in Africa.

#### Contributors

JJN, ME, and JJB conceived the study and, together with JRN, LNA, and AMJ, designed the protocol. JJN, ME, and LNA did the literature search. ME, JJN, and JJB selected the studies and extracted the relevant information. JJB, ME, and JJN synthesised the data. JJN, ME, and JJB wrote the first draft of the paper. JJN, JJB, ME, JRN, LNA, and AMJ critically revised successive drafts of the paper and approved its final version.

#### Declaration of interests

We declare no competing interests.

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