Paediatric Hypertension in Africa: A Systematic Review and Meta-Analysis

Simone H. Crouch,a,y Larske M. Soepnel,a,b,* Andrea Kolkenbeck-Ruh,a,† Innocent Maposa,c Sanushka Naidoo,a Justine Davies,a,d Shane A. Norris,a,e and Lisa J. Ware,a,f

aSAMRC/Wits Developmental Pathways for Health Research Unit, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa. 
bJulius Global Health, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Utrecht, The Netherlands.
cDivision of Epidemiology and Biostatistics, School of Public Health, Faculty of Health Sciences, University of Witwatersrand, Johannesburg, South Africa School of Public Health 
dInstitute of Applied Health Research, University of Birmingham, Birmingham, United Kingdom 
eSchool of Health and Human Development, University of Southampton, Southampton, United Kingdom. 
fDSI-NRF Centre of Excellence in Human Development, University of the Witwatersrand, Johannesburg, South Africa.

Summary

Background The burden of cardiovascular disease (CVD) and hypertension is rapidly increasing in low- and middle-income countries. This is evident not only in adults, but also in children. Recent estimates of prevalence in children are lacking, particularly in Africa. As such, we conducted a systematic review and meta-analysis to provide updated estimates of paediatric hypertension in Africa.

Methods We searched PubMed and EBSCO to identify articles published from January 2017 to November 2020. Studies were assessed for quality. We combined results for meta-analyses using a random effects model (Freeman-Tukey arcsine transformation). Heterogeneity was quantified using the I^2 statistic.

Findings In the narrative synthesis of 53 studies, publication bias was low for 28, moderate for 24, and high for one study. Hypertension prevalence ranged substantially (0.2%-38.9%). Meta-analysis included 41 studies resulting in data on 52918 participants aged 3 to 19 years from ten countries. The pooled prevalence for hypertension (systolic/diastolic BP ≥ 95th percentile) was 7.45% (95%CI 5.30-9.92, I^2=98.96%), elevated blood pressure (BP, systolic/diastolic BP ≥ 90th percentile and < 95th percentile) 11.38% (95%CI 7.94-15.33, I^2=98.97%) and combined hypertension/elevated BP 21.74% (95%CI 15.5-28.69, I^2=99.48%). Participants categorized as overweight/with obesity had a higher prevalence of hypertension (18.5% [95%CI 10.2-28.5]) than those categorized as underweight/normal (1.0% [95%CI 0.1-2.6], 4.8% [95%CI 2.9-7.1], p<0.001). There were significant differences in hypertension prevalence when comparing BP measurement methods and classification guidelines.

Interpretation Compared to a previous systematic review conducted in 2017, this study suggests a continued increase in prevalence of paediatric hypertension in Africa, and highlights the potential role of increasing overweight/obesity.

Funding This research was funded in part by the Wellcome Trust [Grant number:214082/Z/18/Z]. LJW and SAN are supported by the DSI-NRF Centre of Human Development at the University of the Witwatersrand.

Copyright © 2021 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

Keywords: Paediatric; Hypertension; Blood pressure; Africa; Child and adolescent
Research in context

Evidence before this study

Mounting evidence has suggested that both hypertension and certain risk factors for its development, such as obesity, occur early in childhood. Prior to this review only one systematic review and meta-analysis focusing on paediatric hypertension specifically in Africa could be found, spanning 21 years (1996-2017) and reporting prevalence of paediatric hypertension in Africa to be 5.5%. Given the rapid increase in exposure to risk factors for hypertension in children, an update of the previous review is needed.

Added value of this study

We searched PubMed and EBSCO to identify articles published from January 2017-November 2020. Studies were assessed for quality and risk of bias. We identified and included 53 and 41 studies in the narrative review and meta-analysis, respectively, suggesting an increase in relevant publications from the previous review, which included 25 studies in the meta-analysis spanning 21 years. The pooled prevalence for hypertension was 7.5%, a 36% increase from the previous review and meta-analysis.

Implications of all the available evidence

Despite the call made in the previous review for measures to reduce paediatric hypertension, it is clear hypertension levels have continued to rise. This highlights the urgency for implementation of prevention strategies across Africa. Given the strong association between blood pressure and BMI, strategies should include evidence-based primary prevention programmes, enhanced development and availability of contextually-relevant paediatric guidelines, and increasing the funding and resources for awareness, detection and management of paediatric hypertension.

Introduction

The prevalence of non-communicable diseases (NCDs) remains a growing concern globally, with a burgeoning NCD burden in low- and middle-income countries (LMICs).1 According to the World Health Organization (WHO), cardiovascular disease (CVD) alone accounts for approximately 17.9 million NCD deaths annually,2 75% of which occurred in LMICs.2 This increase in NCDs seen in LMICs, including in Africa, may result from “rapid, unplanned and unmanaged” urbanisation,3 often associated with an increase in CVD risk factors such as dietary changes, increasingly sedentary lifestyles, increasing obesity, tobacco use and exposure to air pollutants.4,5 The risks are not only evident in adults, but also in children. Obesity in children and adolescents in Southern Africa has shown the largest proportional increase globally with a staggering 400% increase per decade.7 Obesity is, in turn, associated with elevated blood pressure (BP) and hypertension,8 a significant contributor to the development of CVD.9 A previous systematic review evaluating paediatric hypertension in Africa between 1996 and 2017 (21 years) included only 51 studies of which 25 were included in the meta-analysis.10 Due to the rapid increase in risk factors, the previous review’s finding that obesity is significantly associated with hypertension, and the growing focus on the importance of paediatric hypertension, an update of this previous review is urgently needed.

Hypertension is the leading risk factor not only for CVD, but for the burden of disease globally.11 The prevalence of hypertension in children and adolescence is of great concern since elevated BP in childhood and adolescence tracks into adulthood in the majority of cases.12,13 One study found that in adults presenting with hypertension, around half had elevated BP in childhood. Additionally, elevated BP in childhood has been shown to predict increased adult cardiovascular disease and mortality, including coronary heart disease and stroke.14,15 Furthermore, the risk factors for paediatric elevated BP, such as obesity, may also track into adulthood, highlighting the importance of interventions at an early age.16 Despite the clear importance of evaluating childhood and adolescent BP, there are no paediatric BP guidelines for the African region at present.

The aim of this systematic review and meta-analysis is to present a detailed, updated review of the prevalence of hypertension in children and adolescents in Africa, evaluating the availability of information and the impact of covariates such as obesity, age, and sex. Furthermore, we aimed to examine the methods and guidelines used to determine hypertension in child and adolescent populations in Africa.

Methods

This systematic review and meta-analyses was conducted in accordance with the PRISMA guidelines.

Search Strategy

This review aims to serve as an update of a previous review evaluating paediatric hypertension in Africa between 1 January 1996 and 2 February 2016, and as such will closely mimic their search strategy.10 The search for articles was conducted in November 2020 according to the PICO (Participants, Intervention, Comparator, Outcomes) model of formulating a clinical question in the healthcare setting. Restrictions to articles were based on age (between 1-19 years), study population (African countries), date of publication (from 1 January 2017 until 30 November 2020), and language (published in English). The following databases were used in the search: PubMed, EBSCO host
bias. Each study was assessed by SHC, LMS and studies developed by Hoy et al to assess risk of bias. Risk of bias assessment

The results were screened for duplicates which were removed, followed by title and abstract screening: screening was completed by one researcher (SHC), with 10% of titles and abstracts additionally screened by a second member of the research team to check agreement. Full texts of eligible articles were then accessed and divided among three authors (SHC, LMS, AKR) for full text screening, and 10% of full-text articles were screened by a second member of the research team to check agreement. If a full text was unavailable, the authors were contacted to gain access to the article. Full-text articles meeting inclusion criteria for the meta-analysis were double screened.

Study Selection

Randomised control trials, cohort studies, case studies, longitudinal and cross-sectional studies reporting prevalence of elevated blood pressure (BP) (prehypertension), hypertension (systolic and/or diastolic), or combined elevated BP and hypertension in children aged 1-19 years, were included. Letters, reviews, commentaries and editorials as well as animal and genetic studies, studies not written in English, studies among populations of African origin residing outside of Africa, studies selecting participants on the basis of presence of hypertension, and studies not differentiating between adult and child/adolescent data were excluded.

For the meta-analysis, studies were additionally excluded if no raw prevalence data could reliably be extracted (for example, if only a percentage was provided), if no aggregate systolic and diastolic hypertension prevalence data were available, in case of high risk of bias (described below), and/or if participants were selected from within a specific disease. Additionally, if two studies from the same database were identified, the study with the lowest risk of bias and largest sample size was included in the meta-analysis.

Any disagreements in full text screening and selection were resolved through discussion among three authors (SHC, LMS, AKR) until consensus was reached.

Risk of bias assessment

We used a risk of bias tool specific to prevalence studies developed by Hoy et al to assess risk of bias. Each study was assessed by SHC, LMS and AKR according to the tool’s criteria, resulting in a summary score per paper that was categorised as follows: 0-5 high risk of bias; 6-7: moderate risk of bias; 8-10: low risk of bias.

Data extraction

Relevant data from each individual paper was extracted using a predefined, standardized data extraction form (Supplementary table 1). Where relevant information for inclusion in the meta-analysis was not available, we contacted the relevant study’s corresponding author, allowing two weeks for a response.

Relevant data included author name, year of publication, year of data collection, country, geographical setting (urban, peri-urban or rural), classification used to determine hypertension status, age range of participants, mean age of participants, participant sex, participant body mass index (BMI), total sample size, prevalence (n and % - if one was not available data n or % was calculated from the other if possible) of hypertension (systolic and/or diastolic BP ≥95% percentile), prevalence (n and %) of elevated BP (systolic and/or diastolic BP ≥90% and <95% percentile), and prevalence (n and %) of combined hypertension and elevated BP (2017 AAP guidelines). We additionally determined the African region (Eastern, Western, Central, Southern, Northern) according to the United Nations (UN) classification and ascertained country gross domestic product per capita (GDP) according to the World Bank.

Data analysis

We performed meta-analysis on the subset of papers meeting the selection criteria outlined above. Using STATA 13 (StataCorp, 2013, College Station, USA), we pooled individual study estimates using a random effects model for meta-analysis following the Freeman-Tukey arcsine transformation to stabilize the variance.

Heterogeneity was quantified using the I² statistic. For the hypertension outcome, subgroup analysis using ANOVA was performed in case of significant heterogeneity, comparing the following a priori determined variables: African region, geographical setting (urban or rural), timing of data collection before or after 2015, age, sex, BMI category (underweight, normal, overweight/obesity), BP measurement method (automatic/oscillometric vs manual/auscultatory), number of occasions of BP measurement, standards used for categorisation of hypertension (for example, the AAP 2004 “Fourth Report; the AAP 2017 guidelines sample size, and risk of bias score. A p-value of <0.05 was set to indicate a significant difference between subgroups. Funnel plots and the Egger test p-value were used to assess the presence of publication bias, considered to be present at a p-value of <0.1 in analyses with at least five studies included.
Additionally, meta-regression analysis was performed to further explore heterogeneity with respect to prevalence of hypertension. Following univariate regression analysis, we performed multivariable regression analysis across three models, namely: Model 1 (M1): country GDP and mean BMI; Model 2 (M2): country GDP, mean BMI and age; Model 3 (M3): country GDP, mean BMI, Age, automatic or manual BP, number of BP measurements.

**Ethical considerations**

As a meta-analysis without original data this study was exempt from ethical approval. To our knowledge all includes studies obtained ethical approval from their respective institutions.

**Role of Funding**

The funders of this study had no role in the study design, data collection, data analysis, data interpretation, or the writing of the article. SHC, LMS and AKR had full access to all the data in the study. All authors had access to data extraction sheet and outputs as well as final responsibility for the decision to submit for publication.

**Results**

Search results were screened for duplicates by title and abstract screening: 1576 of the 1576 articles were excluded as they did not focus on or report paediatric hypertension or were conducted outside of Africa. Of 60 articles identified from the title and abstract screening, 53 presented data on hypertension prevalence specifically for African children between 1-19 years age range. Reasons for the exclusion of the remaining 7 articles were: Blood pressure (BP) was self-reported and not measured (n=1) (Letamo et al),

The study sample spanned outside the desirable age range in which no age specific data could be extracted (n=2) (Bhimma et al, Mokgwathi et al), the study was not conducted within an African population residing in Africa (n=2) (South et al, South et al) and no extractable information regarding hypertension could be extracted from the results (n=2) (Muuyumba et al, Mphekgwana et al) (Figure 1).

Information regarding prevalence of paediatric elevated BP, hypertension and/or combined elevated BP and hypertension was obtained for 58301 participants from ten African countries (representing 18.5% of African countries): Algeria, Cameroon, Egypt, Gambia, Ghana, Nigeria, Seychelles, South Africa, Tanzania, and Uganda. South Africa and Nigeria were represented by 16 studies each, whereas the other countries had between 1-5 studies each. Of all included studies, 51% (n=27) reported both hypertension and elevated BP prevalence, this was followed by 34% (n=18) only reporting on hypertension prevalence, while the remaining 15% reported on either elevated BP (n=4) or combined hypertension and elevated BP (n=4).

Of the studies included in the systematic review, 27 were categorized as low risk of bias, 25 as moderate risk, and one as high risk of bias (Supplementary table 3). External validity (study population, sampling frame, and participant selection) were the main individual items presenting higher risk of bias scores.

An overview of the included studies, subdivided by African regions, can be found in Table 1. In the majority of studies (n=33), hypertension and elevated BP percentiles were calculated using the standards from the “Fourth report on the diagnosis, evaluation and treatment of high BP in children and adolescents” (Fourth Report, AAP 2004). Five studies did not specify which standards they used to determine their age, sex, and height adjusted percentiles, while one study reported using only SBP and/or DBP ≥130/85 as their hypertension classification.

The overall prevalence of hypertension, elevated BP and combined hypertension/elevated BP ranged from 0-2% to 38-9%; 2-5% to 40-3%; and 32-9% to 50-5% respectively. In males, hypertension ranged from 1-8% to 31-8%, while in females, hypertension prevalence was between 2-4% to 33-3%. Elevated BP ranged from 2-2% to 39-3% and from 3-9% to 25-7% in males and females, respectively. The prevalence of both hypertension and elevated BP differed within the various African regions, with Northern Africa showing the highest prevalence (range: 3-3% - 18-9%) and Eastern Africa showing the lowest prevalence (range: 3-1% - 15%).

Of the 53 studies, 37 reported obesity and/or overweight prevalence in their respective samples, with the prevalence of obesity ranging from 0-3% to 50%. These studies consistently found a higher prevalence of elevated BP and/or hypertension in participants with obesity, overweight, or central obesity. A case-control study where authors compared prevalence of hypertension in children with and with obesity found that only the children in the obesity group had hypertension (25%), and this group had significantly more cases of elevated BP than the non-obesity group (19.4% vs 6.5%) (Chedjou-Nono et al). Additionally, three studies found that more than 20% of children with obesity or adolescents had hypertension (Emmanuel et al, Adeomi et al, Ibrahim et al). Similarly, Muhihem et al reported 17.2% of overweight and having obesity children and or adolescents had elevated BP. Of note, Benmohamed et al found that boys with obesity had a significantly higher prevalence of hypertension compared to girls with obesity (36% vs 27%, p=0.002). Of the included studies that quantified the association with obesity/overweight, all but one (Alicke et al, sample size 1885) found a significant association, with the adjusted odds of having hypertension found to be between three
to 25 times increased in children with overweight and/or obesity vs normal BMI in ages ranging from 7-18 years.52,69,71,72

Meta-analysis results

Of the 53 studies included in the systematic review, in total 41 were included for meta-analysis for at least one outcome (hypertension, elevated BP, or both combined). Reasons for exclusion of the remaining 12 articles were as follows: high risk of bias (Masocha et al50), study from the same database included (Nqweniso et al, 73 Schoenbuchner et al,74 Matjuda et al,46 Hassana et al,36 Nkwana et al40), lack of aggregated data for systolic/diastolic hypertension (Sherif et al,38 Elseifi et al,39 Musa et al,39 Gomwe et al37), and lack of extractable raw numerator or denominator data (Raphadu et al,41 Chedjou-Nono et al42) (Figure 1). This resulted in 38 studies, 24 studies, and 27 studies included for hypertension, elevated BP, and combined hypertension/elevated BP, respectively.

The forest plots of pooled prevalence for hypertension, elevated BP, and combined hypertension/elevated blood pressure
| Author | Country / Setting | Year data collected | Sample size (n) | Age range yrs@ (mean) | [n] males / females | Hypertension criteria used | % Hypertension | % Elevated BP / Combined high BP* | % Obese / Overweight + obese1 |
|--------|-------------------|---------------------|-----------------|------------------------|------------------------|-----------------------------|----------------|----------------------------------|-------------------------------|
|        |                   |                     |                 |                        |                        |                             |                |                                  |                               |
|        |                   |                     |                 |                        |                        |                             |                |                                  |                               |
| Bennmohammed et al 2018 [70] | Algeria / Urban | 2007 | 1100 | 12-18 (15.1) | 537 / 563 | 4th report 2004 | 12.4 | 13 | 4.6 |
| Bouhenni et al 2017 [90] | Algeria / Both | 2014 | 577 | 10-19 (15.2) | 261 / 316 | 4th report 2004 | 4.3 | 14.7 | 55.6 |
| El-Koofy et al 2020 [34] | Egypt | 2016 | 72 | 3-14 (8.7) | 40 / 32 | 4th report 2004 | 38.9 | Systolic: 3.6 | 18.8 |
| Elseifi et al 2020 [35] | Egypt | 2017-2018 | 224 | 12-14 (13.0) | 115 / 109 | 2017 AAP | 2.7 | 50.5 | 37.5 |
| aHassan et al 2019 [37] | Egypt | 2013-2016 | 200 | 12-18 (16) | 0 / 200 | 4th report 2004 | 0.0 | Systolic: 9.1 | 3.6 |
| aHassana et al 2019 [36] | Egypt | 2017 | 77 | 33 / 42 | | | | 40.3 | 42.9 | 38.8 |
| Sherif et al 2019 [38] | Egypt / Urban | 2016-2017 | 110 | 4-18 | 38 / 72 | Percentiles, undefined | | Systolic: 9.1 | 3.6 |
|        |                   |                     |                 |                        |                        |                             |                |                                  |                               |
|        |                   |                     |                 |                        |                        |                             |                |                                  |                               |
| Katamba et al 2020 [39] | Uganda / Peri-urban | 2018 | 616 | 12-19 (15.6) | 212 / 404 | 4th report 2004 | 3.1 | 7.1 | 6.4 |
| Leyvraz et al 2018 [40] | Seychelles | 1998-2006 | 4519 | 5-6 (5.5) | 2324 / 2195 | 4th report 2004 | 10.2 | 9.1 | 11.4 |
| Lule et al 2019 [91] | Uganda / Rural | 2014-2016 | 1119 | 10-2 | 583 / 536 | 4th report 2004 | 8.4 | 10.5 | 5.2 |
| Muhiri et al 2018 [41] | Tanzania / Urban | 2016 | 446 | 6-17 (11.1) | 209 / 237 | 4th report 2004 | 10.8 | 4.9 | 6.0 |
| Nakiriba et al 2018 [42] | Uganda / Peri-urban | 2018 | 688 | 12-19 (15.4) | 0 / 688 | Percentiles, undefined | 11.6 | 30.5 | 12.0 |
| Nsanya et al 2019 [72] | Tanzania, Uganda / Urban | 2015 | 827 | 12-17 | 410 / 417 | 4th report 2004 | Total: 15.0 | 15.0 | 12-14 yrs: 15.0 |
|                   |                   |                     |                 |                        |                        |                             |                |                                  |                               |
| Nyangasa et al 2019 [43] | Tanzania - @Zanzibar / Rural | 2013 | 165 | 4-9-18 (12) | 85 / 80 | 4th report 2004 | 9.7 | 15.1 | 5.5 |

**Notes:**

1. Overweight + obese: Overweight and obese combined.

**Table 1** (Continued)
### Table 1 (Continued)

| Author | Country / Setting | Year data collected | Sample size (n) | Age range yrs@ (mean) | (n) males / (n) females | Hypertension criteria used | % Hypertension | % Elevated BP / Combined high BP | % Obese / Overweight + obese |
|--------|-------------------|---------------------|-----------------|----------------------|------------------------|---------------------------|----------------|----------------------------------|-----------------------------|
| **Southern Africa** | | | | | | | | | |
| ¹Gerber et al 2018 [44] | RSA / Urban | 2015-2016 | 801 | 8-13 (9.5) | 402 / 399 | Neuhauser et al 2017 | 32.6 | 31.8 | 33.3 | 8.4 | 7.5 | 9.3 | 5.1 |
| ¹Nqwenso et al 2020 [73] | RSA / Urban | 2015-2016 | 842 | 8-16 (14) | 433 / 409 | Neuhauser et al 2017 | 13.5 | 7 | | | | | |
| *Combined high BP; | | | | | | | | | | | | | |
| Odderso et al 2019 [75] | RSA | 876 | 9-14 (11) | 356 / 520 | 4th report 2004 | Systolic: 5.3 Diastolic: 2.6 | Percentiles, undefined | 32.6* | 40.2* | |
| ¹Matjuda et al 2020 [92] | RSA / Both | 2018 | 306 | 6-9 (8) | 135 / 171 | 2017 AAP | 10.5 | 8.1 | 12.2 | 32.3 | 39.3 | 25.7 | |
| ³Matjuda et al 2020 [46] | RSA / Rural | 2013 | 1811 | 5-16 | 934 / 877 | 4th report 2004 | 1.3 | | | | | | |
| Chungag et al 2019 [47] | RSA / Urban | 2016 | 540 | 10-14 (11.9) | 250 / 290 | 4th report 2004 | 20.7 | 15.6 | 26.2 | 12.2 | 11.2 | 15.5 | 14 |
| Mphekgwana et al 2019 [32] | RSA | 2000 | 1811 | 5-16 | 934 / 877 | 4th report 2004 | 1.3 | | | | | | |
| Sekgala et al 2017 [93] | RSA / Rural | 1999-2003 | 9002 | 6-17 | 4678 / 4324 | 4th report 2004 | 4.4 | | | | | | |
| ³Sébati et al 2020 [48] | RSA | 1665 | 5-15 (9.9) | 846 / 819 | 4th report 2004 | Systolic: 4.8 Diastolic: 2.5 | Joint National Committee 7th report, 2003 | 4.3 | | | | | | |
| ⁴Nkwanza et al 2019 [94] | RSA / Urban | 2015 | 81 | 6-8 (7.3) | 81 / 0 | Percentiles, unclear | 14.4 | 6.2 | 12.3 | |
| Mokwatsi et al 2017 [94] | RSA / Urban | 2015 | 81 | 6-8 (7.3) | 81 / 0 | Percentiles, unclear | 14.4 | 6.2 | 12.3 | |
| Masocha et al 2020 [50] | RSA | 2011-2013 | 186 | 14-16 (14.9) | 81 / 105 | NCEP/ATP III criteria, 2007 | 5 | 5 | 5 | 5 | 5 | 6 | |
| Raphadu et al 2020 [51] | RSA / Both | 2012-2014 | 218 | 13-19 (17) | 97 / 121 | 4th report 2004 | 17.1 | 27.3 | 5.5 | 13.2 |
| Houle et al 2019 [95] | RSA / Rural | 2012-2014 | 1536 | 7-11 (9.3) | 4th report 2004 | 4.2 | 14.9 | 19.2 | |
| Negash et al 2019 [52] | RSA / Rural | 2007-2008 | 1559 | 7-18 (13) | 619 / 940 | 4th report 2004 | 2.6 | 2.9 | 2.4 | | | | | |
| Author                        | Country / Setting | Year data collected | Sample size (n) | Age range yrs@(mean) | (n) males / (n) females | Hypertension criteria used | % Hypertension | % Elevated BP / Combined high BP* | % Obese / Overweight + obese† |
|-------------------------------|-------------------|---------------------|-----------------|----------------------|------------------------|---------------------------|-----------------|-------------------------------|-----------------------------|
| Schoenbuchner et al 2018 [74]| Gambia / Rural    | 2012-2015           | 2773            | 10-14: 9 (12.5-15: 9) (17.1) | 1405 / 1368            | 4th report 2004           | 10-14 yrs: 9 15-19 yrs: 8 15-19 yrs: 4 | All M F               | All M F                      | All M F                     |
| Jobe et al 2017 [96]          | Gambia / Rural    | 2012-2014           | 3637            | 5-17: 9              | 1907 / 1730            | 4th report 2004           | 8 2             | 1907 / 1730                   | 20 4                        |
| Aupogo et al 2020 [53]        | Ghana / Both      | 2014                | 1727            | 15-19: 16 (9)        | 870 / 857              | 4th report 2004           | 0 2             | Total: 32 6                    | 7.4, 34.4                   |
| Amponsem-Boateng et al 2019 [54] | Ghana / Urban  | 2018-2019          | 699             | <15:<15-17           | 1405 / 1368            | 4th report 2004           | 10-14 yrs: 9 15-19 yrs: 8 15-19 yrs: 4 | All M F               | All M F                      | All M F                     |
| Alike et al 2017 [55]         | Ghana / Urban     | 2015                | 188             | 14-15-15.5           | 94 / 94                | 4th report 2004           | 9               | Total: 32 6                    | 7.0†                        |
| Ibrahim et al 2019 [56]       | Nigeria / Both    | 2014-2015           | 1745            | 6-12 (8.8)           | 873 / 872              | 4th report 2004           | 3               | 3                             | 0.6                         |
| Okpokowuruk et al 2017 [97]   | Nigeria / P-Urban | 2015                | 200             | 3-17 (12.4)          | 72 / 128               | 4th report 2004           | 3.5             | 3                             | 2.5                         |
| Abu et al 2020 [57]           | Nigeria           | 2015                | 420             | 10-19: 14 (14)       | 179 / 241              | 4th report 2004           | 6.9             | 179 / 241                     | 3.3                         |
| Aiyobion et al 2019 [58]      | Nigeria           | 2014-2017           | 6980            | 15-19: 16.5          | 3509 / 3921            | 4th report 2004           | 25.3            | Total: 32 6                    | 9.6                         |
| Emmanuel et al 2017 [59]      | Nigeria           | 2016                | 416             | 10-19 (14.8)         | 208 / 208              | 4th report 2004           | 10.1            | 208 / 208                     | 25.3                        |
| Ezuedu et al 2018 [60]        | Nigeria / Urban   | 2013-2014           | 984             | 10-19: 14.6          | 470 / 514              | 4th report 2004           | 6.3             | Total: 32 6                    | 2.5                         |
| Amadi et al 2019 [61]         | Nigeria           | 2017                | 491             | @6:<17@              | 219 / 272              | 4th report 2004           | 9.4              | 219 / 272                     | 15.0                        |
| Omosore et al 2018 [62]       | Nigeria / Both    | 2012                | 1000            | 10-16: 13 (7)        | 510 / 490              | 4th report 2004           | 4.1             | Total: 32 6                    | 2.9                         |
| Adeomi et al 2019 [63]        | Nigeria / Urban   | 2014                | 313             | 10-19 (14.4)         | 130 / 183              | 4th report 2004           | 4.6             | 130 / 183                     | 10.2†                       |
| Uko et al 2020 [64]           | Nigeria / Urban   | 2015-2016           | 2401            | 10-19: 15 (1)       | 1196 / 1205            | 4th report 2004           | 4.6             | 1196 / 1205                   | 1.3                         |
| Musa et al 2020 [33]          | Nigeria / Rural   | 2019                | 197             | 11-18: 14.6          | 97 / 100               | 4th report 2004           | 32.9             | Total: 32 6                    | 10.2‡                       |

**Table 1 (Continued)**
| Author                          | Country / Setting | Year data collected | Sample size (n) | Age range yrs@mean | (n) males / (n) females | Hypertension criteria used | % Hypertension | % Elevated BP / Combined high BP* | % Obese / Overweight + obese† |
|--------------------------------|-------------------|---------------------|-----------------|--------------------|------------------------|--------------------------|----------------|---------------------------------|------------------------------|
| Isezuo et al 2018 [65]         | Nigeria           | 2014-2015           | 800             | 10-18 (14.5)       | 424 / 376              | 4th report 2004          | Total: 3.1    | 10-13 yrs: 0.4 14-16 yrs: 2.9 16-18 yrs: 6.3 | Total: 7.5 10-13 yrs: 7.3 14-16 yrs: 7.7 16-18 yrs: 0.3 |
| Yilgwan et al 2017 [66]        | Nigeria / Urban   | 2014-2015           | 241             | 6-12 (9.2)         | 104 / 131              | Joint National Committee 7th report, 2003 | Total: 9.1 | 10-13 yrs: 10.6 14-16 yrs: 8 16-18 yrs: 13.7 |                          |
| Akinbodewa et al 2020 [98]     | Nigeria / Rural   | 2014-2015           | 114             | 3-9 (5.6)@10-17    | 55/59                  | 4th report 2004          | Total: 7.3    | 9-13 yrs: 1 14-17 yrs: 11.9 | Total: 12.3 9-13 yrs: 9.1 14-17 yrs: 15.3 |
| Sadoh et al 2017 [67]          | Nigeria / Urban   | 2011-2012           | 1466            | 5-15 (9)           | 814 / 652              | 4th report 2004          | Total: 2.7 | 10-13 yrs: 1.8 14-17 yrs: 3.6 | Total: 3.1 10-13 yrs: 2.2 14-17 yrs: 3.9                  |
| Wariri et al 2018 [71]         | Nigeria / Rural   | 2015                | 367             | 10-18 (14.9)       | 191 / 176              | 4th report 2004          | Total: 5.7 | 10-13 yrs: 4.2 14-17 yrs: 7.4 | Total: 10.6 10-17 yrs: 9.1 14-17 yrs: 11.4 |
| Chedjou-Nono et al 2017 [68]   | Cameroon          | 2013-2014           | 76              | 2-17 (9.9)         | 4th report 2004        | Obese: 25.0  Control: 0 | Obese: 19.4  Control: 5.3 | 40                             |
| Chelo et al 2019 [69]          | Cameroon / Both   | 2017-2018           | 822             | 5-17 (9.0)         | 353 / 469              | 2017 AAP                 | Total: 1.6 |                             | Obese: 19.4  Control: 5.3 | 0.6                             |

Table 1: Prevalence of hypertension and elevated blood pressure in African children and adolescents

*Combined high BP; †Overweight + Obese; Studies with same superscript made use of same dataset but made use of either different classifications or study outcomes.
| Subgroup                  | N studies | Number of participants | Prevalence (95% CI) | $\chi^2$ (%) | p-values | Egger test |
|--------------------------|-----------|------------------------|---------------------|--------------|----------|------------|
|                          |           |                        |                     |              |          |            |
|                          |           |                        | Heterogeneity       | Heterogeneity|          |            |
| Africa region            |           |                        |                     |              |          |            |
| Western                  | 18        | 23,876                 | 6.0 (2.8-10.2)      | 99.3         | $<0.001$ | $<0.001^*$ | 0.029*     |
| Northern                 | 3         | 1749                   | 15.2 (5.4-28.8)     | -            | -        | -          |            |
| Central                  | 1         | 822                    | 1.6 (0.9-2.7)       | -            | -        | -          |            |
| Southern                 | 9         | 17,207                 | 7.9 (4.0-12.9)      | 98.9         | $<0.001$ | 0.263      |            |
| Eastern                  | 7         | 8380                   | 9.5 (7.1-12.3)      | 92.1         | $<0.001$ | 0.863      |            |
| Total                    | 38        | 52,034                 | 7.5 (5.3-9.9)       | 99.0         | $<0.001$ | 0.452      |            |
| Geographical setting     |           |                        |                     |              |          |            |
| Urban                    | 9         | 8805                   | 9.2 (4.6-15.1)      | 98.6         | $<0.001$ | 0.129      | 0.465      |
| Rural                    | 11        | 21,069                 | 5.3 (3.8-7.0)       | 95.4         | $<0.001$ | 0.700      |            |
| Total                    | 20        | 29,874                 | 7.0 (5.0-9.3)       | 97.8         | $<0.001$ | 0.226      |            |
| Timing of data collection|           |                        |                     |              |          |            |
| Only after 2015          | 14        | 8631                   | 10.0 (5.7-15.4)     | 98.1         | $<0.001$ | 0.108      | 0.410      |
| Before 2015              | 17        | 39,633                 | 5.6 (2.9-9.1)       | 99.4         | $<0.001$ | 0.140      |            |
| Total                    | 31        | 48,264                 | 7.4 (5.0-10.2)      | 99.1         | $<0.001$ | 0.484      |            |
| Age group                |           |                        |                     |              |          |            |
| Over 13                  | 8         | 11,673                 | 6.8 (0.8-17.5)      | 99.6         | $<0.001$ | 0.953      | 0.050*     |
| Under 13                 | 13        | 12,673                 | 6.9 (3.8-10.8)      | 97.8         | $<0.001$ | 0.847      |            |
| Total                    | 21        | 24,346                 | 6.8 (3.5-11.1)      | 99.2         | $<0.001$ | 0.048*     |            |
| Sex                      |           |                        |                     |              |          |            |
| Male                     | 16        | 10,791                 | 8.2 (3.5-14.7)      | 99.0         | $<0.001$ | 0.478      | 0.133      |
| Female                   | 16        | 11,488                 | 10.8 (7.4-14.7)     | 97.1         | $<0.001$ | 0.482      |            |
| Total                    | 32        | 22,279                 | 9.6 (6.4-13.0)      | 98.5         | $<0.001$ | 0.095*     |            |
| BMI Category             |           |                        |                     |              |          |            |
| Underweight              | 4         | 1809                   | 1.0 (0.1-2.6)       | 63.5         | $<0.001$ | -          |            |
| Normal                   | 9         | 6885                   | 4.8 (2.9-7.1)       | 93.4         | $<0.001$ | 0.449      |            |
| Overweight/Obese         | 9         | 823                    | 18.5 (10.2-28.5)    | 90.5         | $<0.001$ | 0.302      |            |
| Total                    | 22        | 9517                   | 7.5 (5.0-10.3)      | 95.0         | $<0.001$ | 0.009*     |            |
| BP methodology           |           |                        |                     |              |          |            |
| Automatic (oscillometric) | 21        | 32,806                 | 8.2 (6.0-10.6)      | 98.1         | $<0.001$ | 0.007*     | 0.171      |
| Manual (auscultation)    | 11        | 8230                   | 4.6 (3.3-6.0)       | 87.9         | $<0.001$ | 0.044*     |            |
| Total                    | 32        | 41,036                 | 6.9 (5.3-8.6)       | 97.5         | $<0.001$ | 0.275      |            |
| Number of measurement occasions to define HTN | | | | | | |
| Single                   | 26        | 35,832                 | 8.0 (5.9-10.5)      | 98.3         | $<0.001$ | 0.018*     | 0.122      |
| Multiple                 | 10        | 8802                   | 4.8 (3.3-6.5)       | 91.0         | $<0.001$ | 0.494      |            |
| Total                    | 36        | 44,634                 | 7.0 (5.4-8.8)       | 97.8         | $<0.001$ | 0.150      |            |
| Standards used for classification of HTN | | | | | | |
| Fourth Report, AAP 2004  | 30        | 46,731                 | 7.2 (4.9-9.9)       | 99.1         | $<0.001$ | 0.003*     | 0.367      |
| Clinical Practice, AAP 2017 | 2        | 1128                   | 3.2 (3.3-4.4)       | -            | -        | -          |            |
| Other/unclear            | 6         | 4175                   | 9.8 (2.0-20.1)      | 98.8         | $<0.001$ | 0.849      |            |
| Total                    | 38        | 52,034                 | 7.5 (5.3-9.9)       | 99.0         | $<0.001$ | 0.477      |            |
| Sample size              |           |                        |                     |              |          |            |
| >699 (median)            | 20        | 45,407                 | 6.3 (3.6-9.7)       | 99.4         | $<0.001$ | 0.206      | 0.208      |
| <699                     | 18        | 6627                   | 8.8 (6.4-11.5)      | 92.4         | $<0.001$ | 0.337      |            |
| Total                    | 38        | 52,034                 | 7.5 (5.3-9.9)       | 99.0         | $<0.001$ | 0.477      |            |
| Risk of bias score       |           |                        |                     |              |          |            |
| Moderate                 | 15        | 15,476                 | 11.5 (6.3-18.0)     | 99.1         | $<0.001$ | 0.021*     | 0.129      |
| Low                      | 23        | 36,558                 | 5.3 (3.9-6.9)       | 97.3         | $<0.001$ | 0.973      |            |
| Total                    | 38        | 52,034                 | 7.5 (5.4-9.9)       | 99.0         | $<0.001$ | 0.477      |            |

Table 2: Subgroup analyses performed for meta-analysis of hypertension prevalence
BMI: Body mass index; BP: Blood pressure; HTN: Hypertension; * indicates statistical significance (p<0.05)
BP are shown in Figures 2, 3, and 4, respectively. None of these three meta-analyses showed significant asymmetry indicative of publication bias, as indicated by the funnel plot (supplementary figure 1) and the Egger test (Figure 2-4). The pooled prevalence for hypertension was 7.45% (CI 5.30-9.02), and for elevated BP was 11.38% (CI 7.94-15.31). The pooled prevalence for combined hypertension/elevated BP was 21.74% (CI 15.5-28.69). High between-study heterogeneity was found, with an I² statistic of 98.96%, 98.97%, and 99.48% respectively for the analysis of hypertension, elevated BP, and combined hypertension/elevated BP.

In subgroup analysis, the Northern (3 studies) and Eastern African (7 studies) regions had the highest prevalence of hypertension at 15.2% (95% CI 5.4-28.8) and 9.5% (7.1-12.3), respectively. No significant difference in hypertension prevalence was found for studies conducted in urban vs rural settings, although 18 of the included studies did not report on geographical setting. Similarly, while studies with more recent timing of data collection (after 2015) showed a higher prevalence (10.0% [95%CI 5.7-15.4]) vs 5.6% (95% CI 2.9-9.1), this subgroup difference was not statistically significant.

![Figure 2. Meta-analysis results in the form of a forest plot for prevalence of hypertension with cases (n), sample size, 95% confidence intervals, estimated prevalences and percent weight per included study.](https://example.com/figure2.png)

ES= estimated prevalence.

| Study ID | Cases (n) | Sample Size | ES (95% CI) | % Weight |
|----------|-----------|-------------|-------------|----------|
| Cheilo et al | 13 | 822 | 1.58 (0.93, 2.69) | 2.67 |
| Katamba et al | 19 | 616 | 3.08 (1.98, 4.77) | 2.66 |
| Leyvraz et al | 461 | 4519 | 10.20 (9.35, 11.12) | 2.71 |
| Lule et al | 94 | 1119 | 8.40 (6.91, 10.17) | 2.68 |
| Mutabi et al | 48 | 446 | 10.76 (8.21, 13.98) | 2.63 |
| Nakiria et al | 80 | 668 | 11.63 (9.44, 14.24) | 2.66 |
| Nyangasa et al | 16 | 165 | 9.70 (6.06, 15.17) | 2.51 |
| Nsanyana et al | 124 | 827 | 14.99 (12.72, 17.59) | 2.67 |
| Bonnhammed et al | 136 | 1100 | 12.36 (10.55, 14.44) | 2.68 |
| Bouhenni et al | 25 | 577 | 4.33 (2.95, 6.32) | 2.65 |
| El-Koofy et al | 28 | 72 | 38.89 (28.47, 50.44) | 2.28 |
| Changag et al | 112 | 540 | 20.74 (17.53, 24.36) | 2.65 |
| Gerber et al | 261 | 801 | 32.58 (29.43, 35.91) | 2.67 |
| Houe et al | 64 | 1530 | 4.18 (3.29, 5.31) | 2.69 |
| Matiruda et al | 32 | 306 | 10.46 (7.51, 14.39) | 2.60 |
| Mokwatsi et al | 5 | 81 | 6.17 (2.67, 13.65) | 2.32 |
| Mphelgwana et al | 23 | 1811 | 1.27 (0.85, 1.90) | 2.69 |
| Ngash et al | 38 | 1471 | 2.58 (1.89, 3.53) | 2.69 |
| Sebati et al | 71 | 1665 | 4.26 (3.39, 5.34) | 2.69 |
| Sokala et al | 423 | 9002 | 4.70 (4.28, 5.16) | 2.71 |
| Abiodun et al | 1769 | 6980 | 25.34 (24.34, 26.38) | 2.71 |
| Akimbodewa et al | 8 | 114 | 7.02 (3.60, 13.24) | 2.43 |
| Alickie et al | 16 | 188 | 8.51 (5.31, 13.38) | 2.53 |
| Amadi et al | 46 | 451 | 9.37 (7.10, 12.27) | 2.64 |
| Anpomsem-Boateng et al | 23 | 699 | 3.29 (2.20, 4.89) | 2.66 |
| Azupogo et al | 4 | 1727 | 0.23 (0.09, 0.59) | 2.69 |
| Emmanuel et al | 42 | 416 | 10.10 (7.56, 13.37) | 2.63 |
| Ezuewu et al | 62 | 984 | 6.30 (4.95, 8.00) | 2.68 |
| Ibrahim et al | 53 | 1745 | 3.04 (2.33, 3.95) | 2.69 |
| Isezou et al | 25 | 800 | 3.12 (2.13, 4.57) | 2.67 |
| Jobe et al | 300 | 3637 | 8.25 (7.40, 9.19) | 2.70 |
| Okpokowuru et al | 7 | 200 | 3.50 (1.71, 7.05) | 2.54 |
| Orsore et al | 41 | 1000 | 4.10 (3.04, 5.51) | 2.68 |
| Onuche Abu et al | 29 | 420 | 6.90 (4.85, 9.74) | 2.63 |
| Sadoh et al | 40 | 1466 | 2.73 (2.01, 3.69) | 2.69 |
| Ukoh et al | 110 | 2401 | 4.58 (3.82, 5.49) | 2.70 |
| Wariri et al | 21 | 367 | 5.72 (3.77, 8.59) | 2.62 |
| Yigwam et al | 22 | 241 | 9.13 (6.11, 13.43) | 2.57 |
| Overall (*2 = 98.96%, p = 0.00) | | | 7.45 (5.30, 9.92) | 100.00 |

Egger test p-value = 0.477
Participants categorized as overweight or with obesity were found to have a significantly higher prevalence of hypertension (18.5% [95% CI 10.2-28.5]) than those categorized as underweight or normal BMI (1.0% [95%CI 0.1-2.6], 4.8% [95% CI 2.9-7.1], p<0.001). No significant difference was found for age or sex subgroups.

In terms of diagnostic methodology, a significantly higher prevalence of hypertension was found for studies using automated (oscillometric) BP measurement (8.2% [95%CI 6.0-10.6]) than those using manual auscultation (4.6% [95% CI 3.3-6.0], p=0.007). Moreover, studies measuring BP on at least two occasions to define hypertension had significantly lower hypertension prevalence than studies categorizing hypertension based on measurements on a single occasion (4.8% [95%CI 3.3-6.5] vs 8.6% [95% CI 5.9-10.5], p=0.018). Only two studies did not report multiple measures on different occasions or at least 2 measures on one occasion,14 44 one of which statistically adjusted for this according to a reference standard.14 When omitting the remaining study, the pooled hypertension prevalence was 7.0 (4.9-9.4) (Supplementary figure 13). Hypertension prevalence was higher in studies using the undefined or other diagnostic standards for the classification of hypertension (9-8% [95%CI 2.0-20.1]) than those using the AAP 2004 or 2017 guidelines (7-2% [95%CI 4.9-9.9], 3-2% [95%CI 2.3-4.4], p=0.003). Reflecting these other methodological considerations, studies assigned a moderate risk of bias score had a higher prevalence of hypertension than those with a lower risk of bias score (11.5% [95%CI 6.3-18.0] vs 5.3% [95%CI 3.6-9.9], p=0.021).

Heterogeneity remained high within each subgroup analysis (>90%). An indication of publication bias by Funnel plot and Egger test statistic was found for the Western Africa region, age, sex, BMI category, and manual BP auscultation.

In univariate meta-regression analysis, no significant associations were found between hypertension prevalence and individual variables, including GDP per capita, which was log-transformed for normality, mean BMI, and mean age (supplementary table 2). In multivariable meta-regression, a significant association with hypertension prevalence was found for country log-

Figure 3. Meta-analysis results in the form of a forest plot for prevalence of elevated blood pressure with cases (n), sample size, 95% confidence intervals, estimated prevalences and percent weight per included study. ES= estimated prevalence.
GDP (adjusted coefficient: 0.082, 95%CI: 0.014-0.151, p=0.024) and mean age (adjusted coefficient: -0.026, 95%CI: -0.044 to -0.008, p=0.010), when also adjusting for mean study BMI (model 2, table 3), with this model accounting for 69.5% of between-study variance (adjusted R²). However, these associations were no longer significant when additionally adjusting for methodological characteristics (automated vs manual BP measurement and number of measurement occasions) (model 3, table 3).

Discussion

We found an overall prevalence of hypertension, elevated blood pressure (BP) and combined elevated BP and hypertension in African children and adolescents of 7.5%, 11.4% and 21.7%, respectively. Our analysis showed that hypertension was four times more prevalent in participants classified as overweight or with obesity than in those classified as normal weight.

As our methods were similar to the previous review, we found significantly higher levels of hypertension in children and adolescents classified as with obesity. While our subgroup meta-analysis indicated that the prevalence of hypertension in participants that were with obesity was four times as high as participants with normal BMI, the previous review identified a six-fold increase when comparing these groups. A lack of a significant association between BMI and hypertension prevalence in the meta-regression could be due to the small number of papers included (n=15 to 11), and differences in BMI trends across included studies in terms of age group, sex, and geographical location that we could not entirely correct for. Both studies reported data on paediatric elevated BP have increased significantly (from 51 papers in 21 years, representing 13 countries, to 53 papers in four years, representing ten countries). As in the previous review, we found significantly higher levels of hypertension in children and adolescents classified as with obesity or overweight.

Figure 4. Meta-analysis results in the form of a forest plot for prevalence of combined hypertension and elevated blood pressure with cases (n), sample size, 95% confidence intervals, estimated prevalences and percent weight per included study.

ES = estimated prevalence.
reviews are in line with numerous studies showing a connection between overweight and obesity and hypertension and CVD both in Africa and globally.76 This apparent change in the risk may reflect a change in prevalence of elevated BP, of obesity or of both. Obesity levels amongst children and adolescents in Africa are rapidly growing,7 with North Africa among the regions with the largest absolute increase in the number of children and adolescents with obesity.7

This obesity increase in North Africa was mirrored by increased hypertension prevalence. There were significant differences seen between the different African regions (Northern (15±2%), Eastern (9±7%), Central (1±6%), Southern (7±9%) and Western (6±0%). Though this may result from limited data in this area, with only three studies from Northern Africa included in the meta-analyses, and one in particular (El-Koofy et al 34) reporting significantly higher levels of hypertension and obesity compared to other studies in the North African region.

We also found no differences in hypertension prevalence between boys and girls. This is different to findings from other world regions, for example, in North America boys were more likely to have high BP compared to girls.15 This could be driven by underlying cultural, behavioural, and biological factors that are not necessarily the same worldwide. The wide variety of countries, regions, and ages included in this review may have prevented us from identifying population-specific sex differences in hypertension prevalence.

In our multivariable meta-regression analysis, higher country GDP was found to be significantly associated with higher hypertension prevalence, when also adjusting for BMI. Variations in cardiovascular risk factors across different socioeconomic status groups tend to differ in high-income countries vs LMIC, which we are unable to further evaluate in more detail within this pooled meta-analysis.77 However, the association between GDP and hypertension was lost when additional variables concerning measurement method were added to the model. With this said, countries with a higher GDP may be better equipped both to follow measurement protocols resulting in a lower prevalence and to roll out effective prevention, diagnosis, and treatment programs to ultimately reduce the burden of hypertension. Our results may indicate suppression of the association between log-GDP and hypertension prevalence when not adjusting for age and BMI, due to confounding or selection of studies with available data.

We found no difference in hypertension prevalence between rural and urban areas — as opposed to the previous review, which found prevalence to be higher in rural areas. This may be because an increase in prevalence of risk factors for high blood pressure have become more pervasive in all areas, or it may be that the mix of countries in each study were at different stages of the nutritional and demographic transition. Indeed, studies in adults in the region suggest that urban/rural differences may be country specific. For example, a study in Zambia found rural adults had twice the hypertension prevalence (47%) of urban Zambians (23%),78 while in Sierra Leone, prevalence in rural or urban areas was similar,79 and in Kenyan women, those in urban areas had higher hypertension prevalence than their rural counterparts.80

In this systematic review we also investigated the impact of measurement methods on the reported prevalence. The impact of variations in cuff size, measurement number, technique and type of device used are well described and this was evident in our review.81 Significant differences were seen with type of BP measurement device used (automated oscillometric vs manual auscultation), the number of measurements taken...
(single vs multiple) and the classification standard used (2004 AAP Fourth Report vs 2017 AAP Clinical Practice vs Other/unclear). This was found to partially account for the high heterogeneity seen between studies, although significant heterogeneity remained in subgroup analyses. These findings highlight several problems in the evaluation of paediatric hypertension in Africa, including the lack of standardized clinical guidelines for the region. Therefore, defining acceptable methods appropriate to African settings is essential for determining the prevalence of hypertension amongst children in this region, which clearly varies widely with the method used.

Of the studies reporting method of BP collection, 21 made use of automated machines while 11 collected BP manually. We found a higher prevalence of hypertension in children and adolescents measured with automated oscillometric devices (oscillometric 8.2%; auscultatory 4.6%), which is in contrast to existing studies in adults. However, a systematic review comparing automated oscillometric and manual auscultatory methods in children did conclude automated oscillometric devices may be suitable for initial screening. This is in line with the most recent (2017) paediatric hypertension guidelines. The use of manual BP devices requires a skilled observer and more time, which may also present a challenge in low resource settings. Manual auscultatory devices also eliminate the possibility of effective home monitoring. When collecting BP using automated oscillometric devices, it is important to ensure the device is validated for use in children, a factor rarely reported. An additional barrier to both oscillometric and auscultatory methods in children and adolescents is the importance of using paediatric cuffs. Paediatric cuffs are expensive and may not be available in low-resource settings. Similar to the used of validated devices, cuff size is often not reported.

When evaluating BP, the number of measures and measurement occasions is also of importance. This review found that the prevalence of hypertension in studies measuring BP on a single occasion was almost double that of the studies that measured BP on multiple (at least 2) occasions (single 8.0%; multiple 4.8%). While epidemiological studies frequently assess blood pressure utilising 2-3 readings on a single occasion, the 2004 AAP Fourth Report only recommends clinical diagnosis of hypertension if BP is consistently high on three occasions, and the updated 2017 AAP Clinical Practice Guideline recommends clinical diagnostic evaluation and treatment initiation upon high BP measured on multiple occasions. However, settings in which healthcare has limited resources and is less accessible may struggle to implement such recommendations in clinical settings, and our results indicate that this may have implications for the identification of hypertension and, therefore, the appropriate use of resources.

In addition to these methodological differences in the collection of blood pressure, we found significant differences in hypertension prevalence based on the standards used to classify hypertension. Of the 41 studies included in this review, 32 used the 2004 AAP Fourth Report (hypertension prevalence 7.2%), two used the more recent 2017 AAP Clinical Practice (hypertension prevalence 3.2%), and 7 studies either made use of other guidelines or did not clearly report which guidelines were used (hypertension prevalence 9.8%). The lower prevalence of hypertension in the studies using the 2017 AAP guidelines is unexpected, since they have lower cut-offs. This is likely due to differences in other population characteristics, such as the lower overweight/obesity prevalence, in those two studies. Currently there are no African specific guidelines for the classification of hypertension in children and adolescent. As a result, clinicians and researchers make use of different international guidelines, leading to inconsistent classification of hypertension. While the two most prevalent classification standards used in this review are internationally accepted, their suitability for an African child and adolescent populations remains unknown. A study comparing the 2017 AAP guidelines to that of the 2004 4th report, in 47200 paediatric subjects from an international cohort (China, India, Iran, Korea, Poland, and Tunisia), found that making use of the 2017 AAP guidelines resulted in a 6.3% reduction in elevated BP. However, the prevalence of both stage one (7.9% increase) and stage two (1.3% increase) hypertension increased. Additionally, a case control sub-study of 1606 subjects from the above mentioned cohort showed that, compared to normotensive children, those reclassified upwards were more likely to have a higher fasting blood glucose and advance lipid profile. This highlights the potential clinical significance of appropriately classifying paediatric hypertension.

Taking into consideration the numerous barriers to effective diagnosis and management of hypertension in African children and adolescents, primary prevention is essential. Given the clear association between obesity and hypertension, programs such as those focusing on weight control via the encouragement of balanced child and maternal nutrition, feeding schemes and promotion of regular exercise may help reduce the development of hypertension. Programs promoting regular and effective home screening may additionally prove a valuable strategy. Furthermore, the education of primary healthcare providers on the importance of regular and accurate BP screening even in resource-constrained environments is required. With this said, the previous review by Noubiap et al similarly suggested the need for primary prevention through population interventions such as weight control, diet modification and the promotion of physical activity, potentially through the use of existing child and maternal health and school
programmes. While some programs focused on physical activity, diet and weight have been implemented in Africa, they remain scarce, are often (temporarily) implemented by individual organisations, and are inaccessible for many. However, country-level programs, such as the South African salt legislation, have proven to be effective in eliciting population level changes. It is clear that the prevalence of hypertension is continuing to rise and the need for effective increased primary prevention programmes, including at country-level remains. Without intervention, the continued increase in paediatric hypertension, often tracking into adulthood, will increasingly burden often already strained health care systems.

Our results should be viewed within the context of the strengths and limitations. The overall prevalence estimates should be interpreted considering the significant heterogeneity present amongst studies. While potentially due in part to methodological and participant differences between studies, this could not be fully accounted for by subgroup or regression analyses. Furthermore, studies differed in the classification used to define hypertension. As such it is difficult to determine the actual prevalence of hypertension. Moreover, the Egger test for some of the subgroup comparisons was significant, indicating possible presence of publication bias against smaller studies with different (larger or smaller) prevalence estimates. However, the presence of significant between-study heterogeneity can ‘confound’ the assessment of publication bias, so that funnel plots and quantitative measures such as the Egger test cannot be reliably interpreted as measures of publication bias. While this review did take into consideration all papers fitting the inclusion criteria, data pertaining to paediatric hypertension was not equally distributed across all regions of Africa, affecting the comparability of the different regions. Moreover, the identified papers only represented ten African countries, three fewer than the previous review. Such unrepresented geographical differences may have impacted our findings, for example for the Northern region for which only three papers were available, one of which had prevalence of 38.9%, likely driving the high prevalence estimate for the region. This highlights the importance of encouraging paediatric hypertension research across all African countries. As the previous review did not report on classification guidelines used we are unable to compare prevalence based on differing guidelines, Lastly, not all studies included in the meta-analysis had data available for the variable(s) of interest, resulting in a lower number of studies included in the meta-analysis and subgroup analyses than in the systematic review.

In conclusion, despite difficulties in determining the true prevalence of hypertension, this review shows a rapidly expanding interest in paediatric hypertension and elevated BP across the continent, suggesting that countries are recognising this growing problem. Further, the review suggests prevalence of hypertension among children and adolescents in Africa has continued to increase over the last three years, in line with increases in obesity in Africa. On a continent plagued by low resources and sub-optimal access to healthcare, prevention and strategies for effective early detection are of paramount importance. Additionally, pan-African guidelines and standards are urgently needed to help guide the measurement, screening, and management of hypertension for children in the region.

Contributors
SHC and LJW conceived the study and, together with LMS and AKR designed the protocol. SHC conducted the literature search. SHC, LMS and AKR selected the studies and extracted the relevant data. LMS, AKR and IM analysed the data. SHC, LMS and AKR wrote the original draft and SHC, LMS, AKR, SN, JD, SAN, LJW critically revised and edited successive drafts of the paper. All authors gave final approval of the version to be submitted.

Data Sharing
All data shall be made available upon reasonable request to the corresponding author and all articles included in the analysis are available online.

Funding
This research was funded in part by the Wellcome Trust [Grant number:214082/Z/18/Z]. LJW and SAN are supported by the DSI-NRF Centre of Human Development at the University of the Witwatersrand.

Declaration of Competing Interest
We declare no competing interests.

Supplementary materials
Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2021.101229.

References
1 Abegunde DO, Mathers CD, Adam T, Ortegon M, Strong K. The burden and costs of chronic diseases in low-income and middle-income countries. The Lancet 2007;370(9603):1920–8.
2 World Health Organisation. Cardiovascular diseases (CVDs) 2017 [Available from: https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
3 Juma K, Juma PA, Shumba C, Otieno P, Asiki G. Non-communicable diseases and urbanization in African cities: A narrative review. Public Health in Developing Countries-Challenges and Opportunities 2019; 1:1–10.
4 Pirgon O, Aslan N. The role of urbanization in childhood obesity. Journal of clinical research in pediatric endocrinology 2015;7(1):165.
5 Pieters M, Vorster HH. Nutrition and hemostasis: a focus on urbanization in South Africa. Molecular nutrition & food research 2008;52 (1):164–72.
6 Pranata R, Vania R, Tondas AE, Setianto B, Santoso A. A time-to-event analysis on air pollutants with the risk of cardiovascular disease and mor-
tality: A systematic review and meta-analysis of 54 cohort studies. Journal of Evidence-Based Medicine 2020;2(4):102–15.
7 Abanca-Gomez I, Abdeen ZA, Hamid ZA, Abu-Rmeileh NM, Acouts-Camou B, Avou M, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. The Lancet 2017;390(10101):243–67.
8 Leggio M, Lombardi M, Caldarone E, Severi P, D’emidio S, Armeni M, et al. The relationship between obesity and hypertension: an updated comprehensive overview on vicious twins. Hypertension Research 2017;40(12):947–63.
9 Kannell WB. Blood pressure as a cardiovascular risk factor: preven-
tion and treatment. JAMA 1976;235(2):171–6.
10 Noubiap JJ, Eissouma M, Bigna JJ, Jiring AM, Arninde LN, Nansseu JR. Prevalence of elevated blood pressure in children and adoles-
cents in Africa: a systematic review and meta-analysis. The Lancet Public Health 2017;2(8):375–86.
11 Bromfeld S, Muntner P. High blood pressure: the leading global burden of disease risk factor and the need for worldwide prevention programs. Current hypertension reports 2015;17(1):134–45.
12 Chen X, Wang Y. Tracking of blood pressure from childhood to adoles-
cence: a systematic review and meta-regression analysis. Circulation 2016;174(19):1973–81.
13 Toschke AM, Kohl I, Mansmann U, Von Kries R. Meta-analysis of blood pressure tracking from childhood to adulthood and implica-
tions for the design of intervention trials. Acta Paediatrica 2010;99(1):24–7.
14 Yang L, Magnusson CG, Yang L, Boett P, Xi B. Elevated blood pres-
sure in childhood or adolescence and cardiovascular outcomes in adulthood: a systematic review. Hypertension 2020;75(3):49–55.
15 Higseth M, Nordstrom A, Eriksson M, Nordstrom P. Risk factors assessed in adolescence and the later risk of stroke in men: a 33-year follow-up study. Cerebrovascular Diseases 2015;39(3):63–71.
16 Rundle AG, Factor-Litvak P, Suglia SF, Susser ES, Kezios KL, Lovasi GS, et al. Tracking of obesity from childhood to adulthood and the correlates of self-reported chronic non-communicable diseases in a 12-14 years old cohort of children born preterm. Journal of Epidemiology Community Health 2011;67(7):594–9.
17 Huy D, Brooks P, Woolf A, Blyth F, March L, Bain C, et al. Assess-
ing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. Journal of clinical epidemi-
ed 2012;65(9):934–9.
18 Macaulay S, Dugan DB, Norris SA. Gestational diabetes mellitus in Africa: a systematic review. PLoS ONE 2014(9):e97871.
19 Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Dan-
nels SR, et al. Clinical practice guideline for screening and manage-
ment of high blood pressure in children and adolescents. Pediatrics 2017;140(5):.
20 United Nations Statistics Division. Africa geosize 2021. [Available from: http://millenniumindicators.un.org/unsd/methods/m49/ m49regin.htm.]
21 The World Bank. GDP ranking 2020 [Available from: https://data-
talog.worldbank.org/dataset/gdp-ranking.]
22 Barendregt JG, Don S, Lee TY, Norman RE, Vos T. Meta-analysis of prevalence. Journal of Epidemiological Community Health 2011;67(7):594–9.
23 Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-
comparison of statistical tests for publication bias. Journal of Epidemiology Community Health 2011;65(7):594–9.
24 Jenkins A, White A, Cragg L, Haines T, West KM. Research tools and evidence of interrater agreement. Journal of clinical epidemi-
ed 2008;61(1):211–9.
25 Hayashino Y, Noguchi Y, Fukui T. Systematic evaluation and com-
parison of statistical tests for publication bias. Journal of Epidemiology Community Health 2007;61(1):211–9.
26 Letano G, Keetle M, Navaneetham K, Phatismo M. Prevalence and correlates of self-reported chronic non-communicable diseases in Botswana: a cross-sectional study. International Health 2017;9(1):31–9.
27 Bhamma R, Naicker E, Goudien V, Nandlal I, Connolly C, Haripar-
sah A, et al. Prevalence of Primary Hypertension and Risk Factors in Grade XII Learners in KwaZulu-Natal, South Africa. International Journal of Hypertension 2018.
28 Mokgwathi M, Mwita JC. Prevalence of hypertension and selected cardiovascular risk factors among adolescents in selected rural and urban secondary schools in Botswana. Cardiovascular Journal of Africa 2020;31(1):144–6.
29 South AM, Nixon PA, Chappell MC, Diz DJ, Russell GB, Shalt-
out HA, et al. Obesity is Associated with Higher Blood Pressure and Higher Levels of Angiotensin II but Lower Angiotensin-(1-
7) in Adolescents Born Preterm. The Journal of Pediatrics 2019;205:55–60.
30 South AM, Nixon PA, Chappell MC, Diz DJ, Russell GB, Jensen ET, et al. Renal function and blood pressure are altered in adolescents born preterm. Pediatr 2015;134(5):1117–74.
31 Muyumha EK, Nkula D, Mukeng CK, Musing S, Kakoma PK, Kaki-
sings CN, et al. Oscillometric blood pressure by age and height for non- overweight children and adolescents in Lubumbashi, Democratic Repub-
lic of Congo. BMC Cardiovascular Disorders 2018;8:1–12.
32 Mpekhwana PM, Monyeki KD, Magkopa HM, Magkake PJ. Mul-
tiple Points Change in the Association of Blood Pressure Sub-
types with Anthropometric Indices of Adiposity among Children in a Rural Population. Children 2020;7(1):1–8.
33 Musa DI, Toriola AL, Goen DT, SU Jonathan. Association of fitness and fitness with clustered cardiovascular disease risk factors in Nigerian adolescents. International Journal of Environmental Research and Public Health 2021;18(7):6581.
34 El-Koofy M, Melahed W, Elbarbary MA, Garhy ASE, Shaba M, Foud H. Use of Anthropometry Versus Ultrasound for the Assess-
ment of Body Fat and Comorbidities in Children With Obesity. Journal of Pediatric gastroenterology and nutrition 2020;70(6):728–8.
35 Elsenf OS, Abdelrahman DM, Mortada EM. Effect of a nutritional education intervention on breakfast consumption among prepara-
tory school students in Egypt. International Journal of Public Health 2020;65(6):893.
36 Hassana NE, El Shehni SM, El-Mazyar SA, Ahmed MH, Alia MM, El-Saeed GSM, et al. Association between dietary sodium, cal-
cium, saturated fat and blood pressure in obese Egyptian adoles-
cents. Egyptian Pediatric Association Gazette 2019;66(1):1–6.
37 Hassana NE, El Ashmawi AA, El-Mazyar SA, Zatrout WA, Mira MF, El-Saeed GSM, et al. Metabolic syndrome in a sample of Egyptian adolescent girls and its association with apolipoprotein E. Journal of Pediatrics & Child Health 2019;55(11):1144–50.
38 Shierf EM, El Makoud AAA, Youssef OS, Salih El-Din NY, Khater OKM. Soluble urokinase plasminogen activator receptor in type I diabetic children, relation to vascular complications. Journal of Diabetes and Its Complications 2019;33(9):625–31.
39 Katamba A, Agala DC, Mipsha R, Namanyana A, Namanyana R, Turyakira E. Prevalence of hypertension in relation to anthropomet-
ric indices among secondary adolescents in Mbarara, Southwestern Uganda. Italian Journal of Pediatrics 2020;46(1):1–7.
40 Leyvaiz V, Wahlen R, Bloezer C, Paradis G, Boett P, Chiolerio A, et al. Persistence of elevated blood pressure during childhood and adolescence: a school-based multiple cohort study. Journal of Hypertension 2018;36(6):1106–10.
41 Muchiri AJ, Nyekela MA, Chillo O, Lujani B, Maghembe M, Ngar-
shii D, et al. Elevated blood pressure among primary school children in Dar es salaam, Tanzania: Prevalence and risk factors. BMC Pediat-
rics 2018;18(1):1–8.
42 Nakirira R, Mayoga RW, Piloya T, Nabukwasi-Barungi N, Idrho R. Prevalence and factors associated with dyslipidemia among girls in selected boarding secondary schools in Wakiso District, Uganda. Adolescent Health, Medicine and Therapeutics 2019;5(9):167–76.
43 Nyangasa MA, Buc K, Kelin S, Sheikh MA, Bradenmann KL, Hebes-
trett A. Association between cardiometabolic risk factors and body mass index, waist circumferences and body fat in a Zanzibari cross-
sectional study. BMC open 2019;9(7):263957.
44 Gerber M, Müller I, Walter C, du Randt A, Adams L, Gall S, et al. Physical activity and dual disease burden among South African pri-
mary schoolchildren from disadvantaged neighbourhoods. Preventive Medicine 2018;112:104–10.
45 Sekokota MA, Goswami N, Sewangi-Rusike CR, Iputo JE, Nkeh-
Chung Bun. Prevalence of metabolic syndrome in adolescents liv-
ing in Mitha, South Africa. Therapeutics and Clinical Risk Manage-
ment 2017;13:1107–12.
46 Matjuda EN, Ngwpa LA, Letswalo PB, Mungamba MM, Sewani-
Ruise CR, BN Nkhe-Chung. Association of Hypertension and Obesity with Risk Factors of Cardiovascular Diseases in Children Aged 6–9 Years Old in the Eastern Cape Province of South Africa. Children 2020;7(4):1–10.
47 Chprung A, Tata CM, Sewangi-Rusike CR, Nel W, Nkeh-Chung Bun. Elissis Longitudinal Study 2017: association of hypertension with increasing levels of adiposity in six 14-year-old boys and girls in the Eastern Cape (ELS 31). Cardiovascular Journal of Africa 2019;30(3):258–61.
of Pediatrics guideline on hypertension prevalence compared with the Fourth Report in an international cohort. *Hypertension* 2019;74(6):1343–8.

88 Charlton K, Corso B, Ware L, Schutte AE, Wepener L, Minicuci N, et al. Effect of South Africa’s interim mandatory salt reduction programme on urinary sodium excretion and blood pressure. *Preventive Medicine Reports* 2021;101469.

89 Peters JL, Sutton AJ, Jones DR, Abrams KR, Rushton L, Moreno SG. Assessing publication bias in meta-analyses in the presence of between-study heterogeneity. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 2010;173(3):575–91.

90 Bouhenni H, Daoudi H, Djemai H, Noirez P, Rosabah A, Vitiello D, et al. Relationships between metabolic profile, hypertension and uric acid with cardiometabolic risk in adolescents with abdominal obesity: impact of geodemographic factors on the prevalence of abdominal obesity. *International journal of adolescent medicine and health* 2017;34(2).

91 Lule SA, Namara B, Akurat H, Muhangi L, Luhayi L, Nampijja M, et al. Are birthweight and postnatal weight gain in childhood associated with blood pressure in early adolescence? Results from a Ugandan birth cohort. *International Journal of Epidemiology* 2019;48(1):148–56.

92 Matjuda EN, Sewani-Rusike CR, Anye SNC, Engwa GA, Nkhe-Chungag BN. Relationship between High Blood Pressure and Microalbuminuria in Children Aged 6-9 Years in a South African Population. *Children* 2020;7(9):1–10.

93 Sekgala M, Monyeki K, Mogale M, Ramosohla N. Performance of blood pressure to height ratio as a screening tool for elevated blood pressure in rural children: Ellisras Longitudinal Study. *Journal of Human Hypertension* 2017;31(9):591–5.

94 Mokwatsi GG, Schutte AE, Kruger R. Ethnic differences regarding arterial stiffness of 6–8-year-old black and white boys. *Journal of Hypertension* 2017;35(4):960–7.

95 Houle B, Rochat TJ, Newell M-L, Stein A, Bland RM. Breastfeeding, HIV exposure, childhood obesity, and prehypertension: A South African cohort study. *PLoS Medicine* 2019;16(8):1–23.

96 Jobe M, Agbala SC, Prentice AM, Henning BJ. High blood pressure and associated risk factors as indicator of preclinical hypertension in rural West Africa: A focus on children and adolescents in The Gambia. *Medicine* 2017;96(13):1–8.

97 Okpokowuruk FS, Akpan MU, Ikpenne EE. Prevalence of hypertension and prehypertension among children and adolescents in a semi-urban area of Uyo Metropolis, Nigeria. *Pan African Medical Journal* 2017;281–10.

98 Akinbodewa AA, Adeyemo AO, Lamidi OA, Adeyemi O. Clustering of Cardiometabolic Risk Factors among Children and Adolescents in a Rural Community in Ondo, Southwest Nigeria. *Journal of Tropical Pediatrics* 2020;66(4):366–76.