

The Critical Need for Pooled Data on COVID-19 in African Children: An AFREhealth Call for Action through Multi-Country Research Collaboration

Nadia A. Sam-Agudu, MD, CTropMed^{1,2,3}; Helena Rabie, MBChB, PhD⁴; Michel Tshiasuma Pipo, MD⁵; Liliane Nsuli Byamungu, MD, MSc⁶; Refiloe Masekela, MBChB, PhD⁶; Marieke M. van der Zalm, MBChB, PhD⁴; Andrew Redfern, MBChB, FCPPaed, M Phil⁴; Angela Dramowski, MBChB, PhD⁴; Abdon Mukalay, MD, MPH, PhD⁷; Onesmus W. Gachuno, MBChB⁸; Nancy Mongweli, MBChB⁹; John Kinuthia, MBChB^{8,9}; Daniel Katuashi Ishoso, MD¹⁰; Emmanuella Amoako, MD¹¹; Elizabeth Agyare, MBChB¹²; Evans K. Agbeno, MBBS, MPH¹³; Aishatu Mohammed Jibril, MBBS¹⁴; Asara M. Abdullahi, MBBS¹⁵; Oma Amadi, MBBS¹⁶; Umar Mohammed Umar, MD¹⁷; Birhanu T. Ayele, PhD; MSc¹⁸; Rhoderick N. Machekano, PhD, MPH¹⁸; Peter S. Nyasulu, PhD¹⁸; Michel P. Hermans, MD, PhD¹⁹; John Otokoye Otshudiema, MD, MPH²⁰; Christian Bongo-Pasi Nswe, MD^{5,21}; Jean-Marie N. Kayembe, MD, PhD²²; Placide Mbala-Kingebeni, MD, PhD²³; Jean-Jacques Muyembe-Tamfum, MD, PhD²³; Hellen Tukamuhebwa Aanyu, MBChB²⁴; Philippa Musoke, MBChB, PhD²⁵; Mary Glenn Fowler, MD²⁶; Nelson Sewankambo, MBChB, MMed, MSc²⁷; Fatima Suleman, BPharm, PhD²⁸; Prisca Adejumo, RN, PhD²⁹; Aster Tsegaye, PhD, MSc³⁰; Alfred Mteta, MD, PhD³¹; Emilia V. Noormahomed, MD, PhD³²; Richard J. Deckelbaum, MD, MD, FRCP³³; Alimuddin Zumla, MD, PhD, FRCP³⁴; Don Jethro Mavungu Landu, MD, PhD, MPH^{5,21}; Léon Tshilolo, MD, PhD^{7,35,36}; Serge Zigabe, MD³⁷; Ameena Goga, PhD^{38,39}; Edward J. Mills, PhD, MSc^{40,41}; Lawal W. Umar, MBBS¹⁴; Mariana Kruger, MMed, FCP Paed, M Phil, PhD⁴; Lynne M. Mofenson, MD^{*42}; Jean B. Nachega, MD, PhD, MPH, FAAS^{*43,44,45}; for investigators in the AFREhealth COVID-19 Research Collaboration on Children and Adolescents

*Contributed equally as senior authors

1. Pediatric and Adolescent HIV Unit and International Research Center of Excellence, Institute of Human Virology Nigeria, Abuja, Nigeria
2. Institute of Human Virology and Department of Pediatrics, University of Maryland School of Medicine, Baltimore, MD, USA
3. Department of Pediatrics and Child Health, School of Medical Sciences, University of Cape Coast, Cape Coast, Ghana
4. Department of Pediatrics and Child Health, Stellenbosch University, Cape Town, South Africa
5. Department of Public Health, Centre Interdisciplinaire de Recherche en Ethnopharmacologie, Faculty of Medicine, Université Notre-Dame du Kasayi, Kananga, Democratic Republic of Congo
6. Department of Pediatrics and Child Health, School of Clinical Medicine, College of Health Sciences, University of KwaZulu Natal, Durban, South Africa
7. Faculty of Medicine, University of Lubumbashi, Lubumbashi, Democratic Republic of the Congo
8. Department of Obstetrics and Gynecology, University of Nairobi, Nairobi, Kenya
9. Department of Research and Programs and Department of Reproductive Health, Kenyatta National Hospital, Nairobi, Kenya
10. Community Health Department, Kinshasa School of Public Health, University of Kinshasa, Kinshasa, Democratic Republic of the Congo
11. Department of Pediatrics, Cape Coast Teaching Hospital, Cape Coast, Ghana
12. Department of Microbiology, School of Medical Sciences, University of Cape Coast and Cape Coast Teaching Hospital, Cape Coast, Ghana
13. Department of Obstetrics & Gynecology, School of Medical Sciences, University of Cape Coast and Cape Coast Teaching Hospital, Cape Coast, Ghana
14. Department of Pediatrics, College of Health Sciences, Ahmadu Bello University and Ahmadu Bello University Teaching Hospital, Zaria, Nigeria
15. Department of Medicine, College of Health Sciences, Ahmadu Bello University and Ahmadu Bello Teaching Hospital, Zaria, Nigeria.
16. Department of Pediatrics, Asokoro District Hospital, Abuja, Nigeria
17. Department of Internal Medicine, Asokoro District Hospital, Abuja, Nigeria
18. Division of Epidemiology and Biostatistics, Department of Global Health, Faculty of Medicine and Health Sciences, Stellenbosch University Cape Town, South Africa
19. Department of Endocrinology and Nutrition, Cliniques Universitaires St-Luc, Brussels, Belgium
20. World Health Organization Health Emergencies Program, COVID-19 Response, Democratic Republic of the Congo
21. Faculty of Public Health, Université Moderne de Kinkole, Kinshasa, Democratic Republic of the Congo
22. Department of Medicine, Faculty of Medicine, University of Kinshasa, Kinshasa, Democratic Republic of the Congo

23. National Institute of Biomedical Research (INRB) and Department of Medical Microbiology and Virology, Faculty of Medicine, University of Kinshasa, Kinshasa, Democratic Republic of the Congo
24. Department of Pediatrics, Mulago Hospital, Kampala, Uganda
25. Department of Pediatrics and Child Health, College of Health Sciences, Makerere University, Kampala Uganda
26. Department of Pathology, Johns Hopkins University School of Medicine, Baltimore, MD, USA
27. School of Medicine, College of Health Sciences, Makerere University, Kampala, Uganda
28. Discipline of Pharmaceutical Sciences, University of KwaZulu Natal, Durban, South Africa
29. Department of Nursing, University of Ibadan, Ibadan, Nigeria
30. Department of Medical Laboratory Sciences, College of Health Sciences, Addis Ababa University, Ethiopia
31. Kilimanjaro Christian Medical University College, Moshi, United Republic of Tanzania
32. Faculty of Medicine, Eduardo Mondlane University, Maputo, Mozambique
33. Department of Pediatrics, Columbia University Irving Medical Center, New York, NY, USA
34. Division of Infection and Immunity, Centre for Clinical Microbiology, University College London, and NIHR Biomedical Research Centre, UCL Hospitals NHS Foundation Trust, London, UK
35. Department of Pediatrics, Official University of Mbuji-Mayi, Kinshasa, Democratic Republic of the Congo.
36. Sickle Cell Disease Research Center et le Centre de Formation et d'Appui Sanitaire, Centre Hospitalier Monkole, Kinshasa, Democratic Republic of the Congo
37. Hôpital Provincial Général de Référence de Bukavu, Département de Pédiatrie, Service de Néonatalogie, Université Catholique de Bukavu, Bukavu, Democratic Republic of the Congo
38. South African Medical Research Council, Cape Town, South Africa
39. Department of Pediatrics and Child Health, University of Pretoria, Pretoria, South Africa
40. Department of Real World & Advanced Analytics, Cytel, Vancouver, Canada
41. Department of Health Research Evidence and Impact, Faculty of Health Sciences, McMaster University, Hamilton, Canada
42. Elizabeth Glaser Pediatric AIDS Foundation, Washington DC, USA
43. Department of Medicine and Centre for Infectious Diseases, Stellenbosch University Faculty of Medicine and Health Sciences, Cape Town, South Africa
44. Departments of Epidemiology & International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA
45. Department of Epidemiology, Infectious Diseases and Microbiology, and Center for Global Health, University of Pittsburgh, Pittsburgh, PA, USA

Address for Correspondence:

Jean B. Nachega, M.D., Ph.D., M.P.H., D.T.M & H., F.A.A.S.

Stellenbosch University Faculty of Medicine and Health Sciences

Professor Extraordinary, Department of Medicine and Centre for Infectious Diseases

Francie van Zijl Drive, Parow 7505, Clinical Building, 3rd Floor, Room No. 3149

Cape Town, South Africa

Tel: +27 21 938 9119; E-mail: jnachega@sun.ac.za

Summary:

Robust data on epidemiology, clinical manifestations, and outcomes of child and adolescent COVID-19 in African countries are lacking. Cross-country collaborations are critical for obtaining data to understand the effects of COVID-19 on health outcomes among younger populations in these settings.

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ABSTRACT

Globally, there are prevailing knowledge gaps in the epidemiology, clinical manifestations, and outcomes of SARS-CoV-2 infection among children and adolescents; however, these gaps are especially wide in African countries. The availability of robust age-disaggregated data is a critical first step in improving knowledge on disease burden and manifestations of COVID-19 among children. Furthermore, it is essential to improve understanding of SARS-CoV-2 interactions with comorbidities and co-infections such as HIV, tuberculosis, malaria, sickle cell disease and malnutrition, which are highly prevalent among children in sub-Saharan Africa. The African Forum for Research and Education in Health (AFREhealth) COVID-19 Research Collaboration on Children and Adolescents is conducting studies across Western, Central, Eastern, and Southern Africa to address existing knowledge gaps. This consortium is expected to generate key evidence to inform clinical practice and public health policy-making for COVID-19, while concurrently addressing other major diseases affecting children in African countries.

Key words: SARS-CoV-2, COVID-19, Children, Neonates, Adolescents, Africa

Global Epidemiology of COVID-19 Among Children

There continues to be a global upsurge of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection and associated novel coronavirus disease (COVID-19). As of January 31, 2021, the World Health Organization (WHO) reported more than 102 million confirmed cases and 2.2 million deaths globally [1]. The African Region has recorded nearly 2.6 million cases and over 62,000 deaths due to COVID-19 [1]. However, there is a significant knowledge gap with respect to COVID-19 epidemiology among children. To date, available data indicates that children and adolescents 0-19 years of age (hereafter referred to as 'children') constitute a relatively small proportion of COVID-19 cases worldwide. Systematic reviews based on data largely from China, the United States (US), Spain, and other European and Asian countries report that children comprise 1 to 5% of all COVID-19 cases reported [2-4]. A recent meta-analysis of 107 datasets from 47 studies in 23 countries estimated a 3.4% SARS-CoV-2 general seroprevalence globally; prevalence in children was reported at 2.3% [5]. It is worth noting that the meta-analysis reported significantly high heterogeneity ($I^2=99.4\%$) for the overall estimate, and the pediatric data was based on 11 datasets, with only one dataset from an African country - Kenya [5].

The WHO's COVID-19 global surveillance data from January through July 2020 indicated that most confirmed cases reported are in the 25-64 year age group, with only 3.7% reported among children under age 15 years [6]. However, 72% of cases in this database were reported from the Americas and Europe. Evidence from primarily high-income countries with higher proportions of older populations may not be valid for the younger populations in low- and middle-income countries. The age distribution of cases partly reflects the

population's age structure and the age-dependent probability of being tested. While data from high-income countries show that younger individuals are less likely to develop symptomatic disease than older adults, there are additional factors in Africa, such as the health effects of food insecurity and high prevalence of communicable diseases, which may counteract potential age-related protective factors for disease [7]. Of concern is that the WHO COVID-19 Situation Reports have not consistently included age-disaggregated data, and the WHO-African region has not provided such data on their public website to date.

Given the limited data available to estimate pediatric COVID-19 burden, UNICEF re-analyzed country-level data from the Max Planck Institute for Demographic Research (MPIDR) on SARS-CoV-2 infection among children under age 20 years [8]. Since not all countries routinely report COVID-19 data by standard age group and sex, the MPIDR team redistributed unknown age group measures to standardized 5-year age groups using the 2019 World Population Prospects, with reference to the year 2020. Using available age-disaggregated data from 87 countries (which account for 54% of global SARS-CoV-2 infections), they estimated that as of November 2020, children accounted for 11% of reported COVID-19 cases [8]. The proportion of confirmed positive cases in children < 20 years old varied widely between countries, ranging from 1.1% to 30%. Of these cases, 68% were among 10- to 19-year-old patients, and 32% among the 0 to 9-year-old group. In sub-Saharan Africa (SSA), the volume and detail of available pediatric COVID-19 data remain inadequate at both country and regional level, and many knowledge gaps and research questions so far remain unanswered (**Table 1, Figure 1**).

Clinical Manifestations and Outcomes of COVID-19 among Children

There is an expanding pool of data on the manifestations and clinical outcomes of COVID-19 among children. So far, most of this data is from China, followed by the US, Spain, the UK, and other European and Asian countries [2-4, 9, 10]. Overall, reported disease severity has been lower, and clinical outcomes (including case fatality rates) better among children, compared to adults. A recent meta-analysis by Li et al. included 96 studies involving >7,000 children with confirmed COVID-19; the mean age of children across 49 studies with age-disaggregated data was 6.48 years (95% CI 5.20-7.75) [10]. The most common presenting symptoms were fever (47%) and cough (42%), while 23% of children had no symptoms at presentation. The prevalence of severe/critical disease was 7% among children <5 years and 3% for those ≥5 years old, with an overall mortality rate of 1% [10]. Data shown here should be interpreted with caution, as the number and size of datasets used for the analyses varied across different pediatric age groups and by inclusion criteria.

There are few reports on COVID-19 in children from SSA. The largest cohort reported to date is from South Africa, comprising 159 children <13 years old with PCR-confirmed SARS-CoV-2 infection presenting to Tygerberg Hospital, Cape Town, between April and July 2020 [11]. Children in this South African cohort were relatively young (median age 48 months), but this is likely due to data collection being limited to those under age 13 years. Of the 159 children, 81 (50.9%) were symptomatic, with cough (88.9%, 72/81) and fever (61.7%, 50/81) predominating symptomatology at presentation. A total of 51 children (32.1%) required hospital admission for symptomatic care. Lower respiratory tract infection (pneumonia) was

the most common reason for admission (41.2%), particularly for children less than 3 months old (68.8%). Multisystem Inflammatory Syndrome in Children temporally related to COVID-19 (MIS-C) was diagnosed in three children. Intensive care admission was required for 11 of 51 children admitted (21.6%), out of which four required mechanical ventilation. Median length of hospital stay was five days, and despite severity, there were no deaths among children admitted in intensive care; there was one death in a five-week-old HIV-exposed, uninfected infant, which was determined secondary to sepsis and not directly due to COVID-19.

MIS-C, also known as Pediatric Multisystem Inflammatory Syndrome temporally associated with COVID-19 (PIMS), is a newly recognized severe manifestation of SARS-CoV-2 infection that mimics Kawasaki disease and toxic shock syndrome [12]. The earliest reports of MIS-C/PIMS were from Italy in May 2020 [13], the United Kingdom (UK) [14] and the US [15] in June 2020. MIS-C has rarely been described among the relatively large Chinese COVID-19 pediatric cohorts to date [10]; however, this may be due to many reports predating the recognition of this syndrome. MIS-C has begun to be reported from SSA, with the largest case series to date (N=23) from South Africa; mean age was 6.6 years, 80% were Black, and all survived [16]. In a separate report, four South African children with confirmed SARS-CoV-2 infection were initially diagnosed with acute appendicitis; three had an appendectomy and were subsequently diagnosed with MIS-C, and one was managed non-surgically with no MIS-C diagnosis [17]. Besides the South African cohorts described [11, 16, 17], the mention of MIS-C is notably absent from the few small SSA studies reporting COVID-19 manifestations and/or outcomes among children e.g. from Ethiopia [18], Nigeria [19, 20],

Ghana [21], the Democratic Republic of the Congo (DRC) [22], and Sierra Leone [23]. This may be due to the under-recognition of MIS-C and its potential to manifest among African children. In the US and the UK, Black children have been reported to have significantly higher SARS-CoV-2 test positivity rates and higher rates of severe COVID-19/MIS-C than their non-Black counterparts [24-27]. Furthermore, in a well-characterized cohort of 766 hospitalized COVID-19 patients in DRC, in-hospital mortality among 34 children <20 years old (11.4%) was unexpectedly high, and second only to that of the ≥60-year age-group (32.0%) [22] with no clear explanation. This DRC study's small pediatric sample size and the possible effects of unmeasured confounding factors, such as the quality and scope of pediatric intensive care, precluded concrete conclusions about excess COVID-19 mortality among children in this setting.

A recent systematic review of 443 studies and 145 national reports data by Kitano et al. suggests that children in low- and middle-income countries (LMICs) have poorer COVID-19 outcomes compared to those in higher-income countries [28]. They analyzed data from 3,788 global pediatric COVID-19 deaths, 91.5% of which were reported from LMICs; in fact, 83.5% of reported pediatric cases were in LMICs. COVID-19 case fatality rate was significantly higher among children in LMICs than in higher-income countries (0.24% vs 0.01%, respectively, $p < 0.001$), while intensive care unit admissions were significantly lower, and the highest case fatality rates were among infants less than a year old. The authors additionally noted that 1) many countries failed to report age-disaggregated outcome data for children, 2) there was a lack of national-level data, particularly for children in Africa and the Middle East, and 3) there was a paucity of intensive care unit admission data from LMICs

[28]. It would be important to evaluate pediatric (including neonatal) COVID-19 outcomes in multi-country studies across Africa to augment our understanding of the prevalence of SARS-CoV-2 infection and degree and impact of severe disease in this population (**Table 1, Figure 1**).

Co-Infections and Co-Morbidities in Pediatric COVID-19

Where evaluated for, acute co-infections were commonly identified among children with COVID-19; a 29% co-infection rate was determined in the systematic review by Li et al. [10]. *Mycoplasma* spp, followed by influenza A, influenza B, Epstein-Barr virus, adenovirus, and respiratory syncytial virus were most predominant microorganisms [10]. In a South African cohort (N=159), two (1.3%) children were HIV-infected and 13 (8.2%) were HIV-exposed but uninfected; other pre-existing conditions included sickle cell disease (SCD), aplastic anemia, asthma, prematurity, and tuberculosis [11]. Of note, seven children had a recent or current diagnosis of tuberculosis; two children were on anti-tuberculosis treatment at presentation, and an additional four children received a new tuberculosis diagnosis during admission [11]. Infectious diseases such as HIV, tuberculosis, malaria and non-communicable diseases such as SCD and malnutrition are highly prevalent among children in SSA, and can pose significant diagnosis and disease management challenges at individual and public health level if co-existing with COVID-19 [29]. A meta-analysis by Tsankov et al. determined that children with underlying co-morbidities, such as chronic respiratory disorders (including asthma), immune disorders (including 'immunosuppression' but not HIV), cardiovascular disease, metabolic disorders (including diabetes), obesity, neurologic disorders, hematologic disorders (including SCD), and cancers have significantly more severe COVID-19 manifestations and higher associated mortality [30]. More studies are needed to determine

the impact of co-morbidities common in the SSA region on pediatric COVID-19 outcomes [29] (**Table 1, Figure 1**).

Established Pediatric COVID-19 Research Consortia

In the wake of the COVID-19 pandemic, several countries and regions have established research consortia to generate evidence for policy and practice on prevention and treatment, including among children. The pediatric consortia have leveraged pre-existing networks, e.g., the Pediatric Tuberculosis Network European Trials Group (ptbnet) [31], or have forged new alliances, e.g., the CoviDOMINGO (COVID in South American Children) study group [32]. In SSA, South Africa, which has by far the highest number of COVID-19 cases in Africa, has established the Cape Town MIS-C Team [16] which is part of an ongoing drive to expand in-country MIS-C collaboration. Additionally, the South African COVID-19 in Children Research Network is coordinated by the South African Medical Research Council [33]. Within-country collaborations are needed to generate local evidence to shape national responses for children, while multi-country and intra-regional collaborations will make it possible and easier to rigorously address additional research questions, particularly those with rare outcomes. Pooling data across countries has the advantages of enhancing statistical power and the ability to compare outcomes across sites or settings (increased internal validity), as well as generalizability of the findings to the continent (increased external validity). The African Forum for Research and Education in Health (AFREhealth) [34] has assembled a multi-country team of pediatric and infectious disease clinicians and researchers to address the paucity of pediatric COVID-19 evidence in Africa, starting with SSA. Furthermore, AFREhealth has established a multi-country COVID-19 Research Collaboration group that has prioritized pregnant women and neonates for studies spanning

Western, Central, Eastern, and Southern Africa [35]. These consortia will serve as a ready resource for further prospective and retrospective COVID-19 studies to drive the response at country, regional and/or continental level.

The Problem of Weak Health Information Systems in African Countries

One of the reasons AFREhealth's COVID-19 Research Collaboration on Children and Adolescents was necessary was the relative lack of public health data on pediatric COVID-19 at the SSA country and regional level. Health information systems (HIS) are an essential building block of health systems and allow for rapid review of data for evidence-based decision-making and efficient use of resources. HIS challenges in SSA were well-described prior to the COVID-19 pandemic; an overreliance on household surveys and poor integration of other, key data sources (e.g., civil registration and health facility statistics, especially from the private sector) were noted [36]. To date, measures to strengthen HIS in SSA include the African Health Initiative's Population Health Implementation and Training Partnership, established in 2010 [37]. It focused on strengthening district health systems and improving health planning in five SSA countries. Currently, it is unclear whether and how the partnership is contributing to COVID-19 reporting and decision-making in the respective countries. The importance of national public health agencies and prior experience with outbreaks such as Ebola has been reported, in addition to how ineffective governance and chronically poor HIS have affected prior outbreaks and ongoing COVID-19 responses [38, 39].

Private facility data are often not included in national reports, and few countries have highly functioning HIS with transparent data-sharing for COVID-19. Unique issues for children include outright exclusion or poorly age-disaggregated data, both in public health and in

research reports. Research consortia – especially those that are child-focused – can bridge some of these gaps as follows: engaging investigators and/or including data from private clinics and smaller district (versus larger referral) facilities to present more representative findings; incorporating verbal or social autopsy studies to provide or support mortality data that may be unavailable or inadequate; and initiating large-scale primary or secondary data collection from health facilities, especially where (pediatric) data is not being collected, reported, or age-disaggregated by public health agencies.

CONCLUSIONS

Critical knowledge gaps remain about the epidemiology, clinical manifestations, and outcomes of SARS-CoV-2 infection in African children. Prevailing weak HIS further complicate data collection to address these gaps. While available data may be more robust and accessible in higher-income countries outside SSA, knowledge regarding COVID-19 among children is far from adequate, even in those settings. For many reasons, including population demographics, health system infrastructure, potentially genetics and other disease epidemiology, it is difficult to draw comparisons between pediatric COVID-19 data from SSA and those from other geographic regions. It remains, however, that more data are needed from all over the world. Initiatives such as AFREhealth's child-focused, multi-country research consortium and emerging in-country collaborations (e.g., the South African pediatric COVID-19 and MIS-C networks) are important mechanisms for generating evidence and supplementing health information systems to guide public health policy and program decision-making for COVID-19 for children.

NOTES

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DISCLAIMER

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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CONFLICTS OF INTEREST

Disclosures:

*Dr. Sam-Agudu is a clinician-scientist and implementation researcher in Pediatric Infectious Diseases, supported by the NIH National Institute of Child Health and Human Development (NICHD) grant R01HD089866, and by an NIH/Fogarty International Center (FIC) award under

the Adolescent HIV Prevention and Treatment Implementation Science Alliance (AHISA), for the Central and West Africa Implementation Science Alliance (CAWISA).

*Professor Nachege is an infectious disease internist and epidemiologist and Principal Investigator of the NIH/ FIC grant numbers 1R25TW011217-01 (African Association for Health Professions Education and Research); 1R21TW011706-01 (Cardiometabolic Outcomes, Mechanisms, and approach to prevention of Dolutegravir Associated Weight Gain in South Africa); and 1D43TW010937-01A1 (the University of Pittsburgh HIV-Comorbidities Research Training Program in South Africa). He is Chairman of AFREhealth Research committee and serves on the scientific program committee of the American Society of Tropical Medicine and Hygiene (ASTMH), as well as a senior fellow alumnus of the European Developing Countries Clinical Trial Partnership (EDCTP).

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members of the DRC Ministry of Health's COVID-19 Multi-Sectoral Response Committee led by Professor Jean-Jacques Muyembe Tamfum.

*Professor Lawal W. Umar is the Chairman of the Epidemic Response Committee, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria. Dr. Elizabeth Agyare is the Chair of the COVID-19 Committee at Cape Coast Teaching Hospital, Cape Coast, Ghana; and Dr. Umar Mohammed Umar is the Coordinator of the COVID-19 Quarantine and Treatment Center at Asokoro District Hospital, Abuja, Nigeria.

*All other co-authors have no conflicts of interest to declare.

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REFERENCES

1. World Health Organization. WHO Coronavirus Disease (COVID-19) Dashboard. **2020**. Available from: <https://covid19.who.int/>. Accessed: 2021 January 31.
2. Castagnoli R, Votto M, Licari A, et al. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infection in Children and Adolescents: A Systematic Review. *JAMA Pediatr* [Internet]. **2020** Apr 22. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/32320004>. DOI: 10.1001/jamapediatrics.2020.1467.
3. Mantovani A, Rinaldi E, Zusi C, Beatrice G, Saccomani MD, Dalbeni A. Coronavirus disease 2019 (COVID-19) in children and/or adolescents: a meta-analysis. *Pediatr Res* [Internet]. **2020** Jun 17. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/32555539>. DOI: 10.1038/s41390-020-1015-2.
4. Mehta NS, Mytton OT, Mullins EWS, et al. SARS-CoV-2 (COVID-19): What Do We Know About Children? A Systematic Review. *Clinical Infectious Diseases* **2020**; 71(9): 2469-79.
5. Rostami A, Sepidarkish M, Leeflang MMG, et al. SARS-CoV-2 seroprevalence worldwide: a systematic review and meta-analysis. *Clin Microbiol Infect* [Internet]. **2020** Oct 24 PMC7584920]. DOI: 10.1016/j.cmi.2020.10.020.
6. World Health Organization. WHO COVID-19 Situation Report 2020 **2020**. Available from: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200810-covid-19-sitrep-203.pdf?sfvrsn=aa050308_4 Accessed: 2020 December 16.
7. Post LA, Argaw ST, Jones C, et al. A SARS-CoV-2 Surveillance System in Sub-Saharan Africa: Modeling Study for Persistence and Transmission to Inform Policy. *J Med Internet Res* **2020**; 22(11): e24248.
8. UNICEF. Averting a lost COVID generation: A six-point plan to respond, recover and reimagine a post-pandemic world for every child. **November 2020**. Available from: <https://www.unicef.org/media/86881/file/Averting-a-lost-covid-generation-world-childrens-day-data-and-advocacy-brief-2020.pdf>. Accessed: 2020 December 16.
9. Ma X, Liu S, Chen L, Zhuang L, Zhang J, Xin Y. The clinical characteristics of pediatric inpatients with SARS-CoV-2 infection: A meta-analysis and systematic review. *J Med Virol* [Internet]. **2020** Jun 19 PMC7323441]. DOI: 10.1002/jmv.26208.
10. Li B, Zhang S, Zhang R, Chen X, Wang Y, Zhu C. Epidemiological and Clinical Characteristics of COVID-19 in Children: A Systematic Review and Meta-Analysis. *Front Pediatr* **2020**; 8: 591132.
11. van der Zalm MM, Lishman J, Verhagen LM, et al. Clinical experience with SARS CoV-2 related illness in children - hospital experience in Cape Town, South Africa. *Clin Infect Dis* [Internet]. **2020** Nov 10 PMC7717210]. DOI: 10.1093/cid/cia1666.
12. Africa Centres for Disease Control and Prevention. Health Advisory: Multisystem Inflammatory Syndrome in Children and Adolescents Temporally Related to COVID-19 **2020**. Available from: <https://africacdc.org/download/multisystem-inflammatory-syndrome-in-children-and-adolescents-temporally-related-to-covid-19/>. Accessed: 2020 December 11.

13. Verdoni L, Mazza A, Gervasoni A, et al. An outbreak of severe Kawasaki-like disease at the Italian epicentre of the SARS-CoV-2 epidemic: an observational cohort study. *Lancet* (London, England) **2020**; 395(10239): 1771-8.
14. Whittaker E, Bamford A, Kenny J, et al. Clinical Characteristics of 58 Children With a Pediatric Inflammatory Multisystem Syndrome Temporally Associated With SARS-CoV-2. *JAMA* **2020**; 324(3): 259-69.
15. Dufort EM, Koumans EH, Chow EJ, et al. Multisystem Inflammatory Syndrome in Children in New York State. *N Engl J Med* **2020**; 383(4): 347-58.
16. Webb K, Abraham DR, Faleye A, McCulloch M, Rabie H, Scott C. Multisystem inflammatory syndrome in children in South Africa. *Lancet Child Adolesc Health* **2020**; 4(10): e38.
17. Lishman J, Kohler C, de Vos C, et al. Acute Appendicitis in Multisystem Inflammatory Syndrome in Children With COVID-19. *The Pediatric Infectious Disease Journal* [Internet]. **2020**; 39(12):[e472-e3 pp.]. Available from: https://journals.lww.com/pidj/Fulltext/2020/12000/Acute_Appendicitis_in_Multisystem_Inflammatory.40.aspx. DOI: 10.1097/inf.0000000000002900.
18. Gebremariam BM, Shienka KL, Kebede BA, Abiche MG. Epidemiological characteristics and treatment outcomes of hospitalized patients with COVID-19 in Ethiopia. *The Pan African Medical Journal* **2020**; 37(Suppl 1): 7.
19. Adedeji IA, Abdu YM, Bashir MF, et al. Profile of children with COVID-19 infection: a cross sectional study from North-East Nigeria. *Pan Afr Med J* **2020**; 35(Suppl 2): 145.
20. Ibrahim OR, Suleiman BM, Sanda A, et al. COVID-19 in children: a case series from Nigeria. *Pan Afr Med J* **2020**; 35(2): 53.
21. Ashinyo M, Duti V, Dubik S, et al. Clinical characteristics, treatment regimen and duration of hospitalization among COVID-19 patients in Ghana: a retrospective cohort study. *Pan Afr Med J* **2020**; 37(1).
22. Nachege JB, Ishoso DK, Otokoye JO, et al. Clinical Characteristics and Outcomes of Patients Hospitalized for COVID-19 in Africa: Early Insights from the Democratic Republic of the Congo. *Am J Trop Med Hyg* [Internet]. **2020** Oct 2; 103(6):[2419-28 pp.]. DOI: 10.4269/ajtmh.20-1240.
23. Adetola H, Ishola D, Afolabi M, et al. Clinical presentations and management of COVID-19 infected children seen in a district health facility in Kambia, northern Sierra Leone. *Pan Afr Med J* **2020**; 37(1): 38.
24. Bandi S, Nevid MZ, Mahdavinia M. African American children are at higher risk of COVID-19 infection. *Pediatr Allergy Immunol* **2020**; 31(7): 861-4.
25. Bailey LC, Razzaghi H, Burrows EK, et al. Assessment of 135 794 Pediatric Patients Tested for Severe Acute Respiratory Syndrome Coronavirus 2 Across the United States. *JAMA Pediatr* [Internet]. **2020** Nov 23. DOI: 10.1001/jamapediatrics.2020.5052.
26. Fernandes DM, Oliveira CR, Guerguis S, et al. SARS-CoV-2 Clinical Syndromes and Predictors of Disease Severity in Hospitalized Children and Youth. *J Pediatr* [Internet]. **2020** Nov 13 PMC7666535]. DOI: 10.1016/j.jpeds.2020.11.016.
27. Swann OV, Holden KA, Turtle L, et al. Clinical characteristics of children and young people admitted to hospital with covid-19 in United Kingdom: prospective multicentre observational cohort study. *BMJ* [Internet]. **2020** Aug 27; 370:[m3249 p.]. DOI: 10.1136/bmj.m3249.

28. Kitano T, Kitano M, Krueger C, et al. The differential impact of pediatric COVID-19 between high-income countries and low- and middle-income countries: A systematic review of fatality and ICU admission in children worldwide. *PLoS One* **2021**; 16(1): e0246326.
29. Coker M, Folayan MO, Michelow IC, Oladokun RE, Torbunde N, Sam-Agudu NA. Things must not fall apart: the ripple effects of the COVID-19 pandemic on children in sub-Saharan Africa. *Pediatric Research* [Internet]. **2020**. Available from: <https://doi.org/10.1038/s41390-020-01174-y>. DOI: 10.1038/s41390-020-01174-y.
30. Tsankov BK, Allaire JM, Irvine MA, et al. Severe COVID-19 Infection and Pediatric Comorbidities: A Systematic Review and Meta-Analysis. *Int J Infect Dis* [Internet]. **2020** Nov 20 PMC7679116]. DOI: 10.1016/j.ijid.2020.11.163.
31. Götzinger F, Santiago-García B, Noguera-Julián A, et al. COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. *Lancet Child Adolesc Health* **2020**; 4(9): 653-61.
32. Antúñez-Montes OY, Escamilla MI, Figueroa-Uribe AF, et al. COVID-19 and Multisystem Inflammatory Syndrome in Latin American Children: A Multinational Study. *The Pediatric Infectious Disease Journal* **2021**; 40(1): e1-e6.
33. The South African Medical Research Council. Research Collaboration on COVID-19 in Children. **2020**. Available from: <https://www.samrc.ac.za/intramural-research-units/covid-19-children> Accessed: 2020 December 20.
34. Omaswa F, Kiguli-Malwadde E, Donkor P, et al. Medical Education Partnership Initiative gives birth to AFREhealth. *Lancet Glob Health* **2017**; 5(10): e965-e6.
35. Nachega JB, Sam-Agudu NA, Budhram S, et al. Effect of SARS-CoV-2 Infection in Pregnancy on Maternal and Neonatal Outcomes in Africa: An AFREhealth Call for Evidence through Multicountry Research Collaboration. *Am J Trop Med Hyg* [Internet]. **2020** Dec 28. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/33372651>. DOI: 10.4269/ajtmh.20-1553.
36. Mbondji PE, Kebede D, Soumbey-Alley EW, Zielinski C, Kouvididila W, Lusamba-Dikassa P-S. Health information systems in Africa: descriptive analysis of data sources, information products and health statistics. *J R Soc Med* **2014**; 107(1 suppl): 34-45.
37. Mutale W, Chintu N, Amoroso C, et al. Improving health information systems for decision making across five sub-Saharan African countries: Implementation strategies from the African Health Initiative. *BMC Health Services Research* **2013**; 13(2): S9.
38. Khan MS, Dar O, Erondu NA, et al. Using critical information to strengthen pandemic preparedness: the role of national public health agencies. *BMJ Glob Health* **2020**; 5(9).
39. Lal A, Ashworth HC, Dada S, Hoemeke L, Tambo E. Optimizing Pandemic Preparedness and Response Through Health Information Systems: Lessons Learned From Ebola to COVID-19. *Disaster Med Public Health Prep* **2020**: 1-8.

Table 1. Areas of Specific Interest/Concern and Research Questions for Pediatric SARS-CoV-2/COVID-19 Research in Africa			
		Areas of Specific Interest/Concern	Key Research Questions
1	Epidemiology	<ul style="list-style-type: none"> Country- and regional-level geographic differences in pediatric COVID-19 prevalence in Africa Major differences in demographic profiles among countries, with younger populations in SSA vs HIC Role of children in SARS-CoV-2 transmission and SARS-CoV-2 viral loads in children Very limited testing among children in Africa 	<ul style="list-style-type: none"> ➤ What is the burden of SARS-CoV-2 among children in African countries? ➤ What are the dynamics of SARS-CoV-2 acquisition and transmission patterns among SSA children in the community and in schools?
2	Clinical Manifestations and Disease Severity	<ul style="list-style-type: none"> Asymptomatic and mild disease commonly reported among children in HIC [3, 4, 9, 10] MIS-C in children is uncommon but can be severe, reported primarily in HIC [13,14,15] Few reports from Africa; MIS-C reported only from South Africa to date [16, 17] 	<ul style="list-style-type: none"> ➤ What are the clinical features of SARS-CoV-2/COVID-19 in African children and do they differ from those in HIC? ➤ What factors, including acute and chronic disease co-morbidities, are associated with severe disease among children in Africa? ➤ Is MIS-C being seen or recognized in African children, and do characteristics and outcomes differ compared to children from HIC?
3	Communicable Disease Comorbidities	<ul style="list-style-type: none"> High prevalence of HIV, TB, malaria, respiratory infections among children in SSA vs HIC [29] Limitations in SARS-CoV-2 testing and diagnostics for pneumonia make it difficult to differentiate from other infectious respiratory diseases [29] 	<ul style="list-style-type: none"> ➤ Are specific co-infections highly prevalent in SSA countries associated with more severe COVID-19 in children? [29] ➤ Does SARS-CoV-2 infection result in poor outcomes of co-infection in African children with such coinfections? [29]
4	Non-Communicable Disease Comorbidities	<ul style="list-style-type: none"> Obesity associated with disease severity in HIC, no data on malnutrition High prevalence in SSA: <ul style="list-style-type: none"> ○ Sickle Cell Disease (SCD) ○ Hypertension, cardiovascular disease ○ Diabetes ○ Asthma ○ Malignancies ○ Often undiagnosed mental health conditions Poverty-related issues such as crowding, poor housing, household air pollution 	<ul style="list-style-type: none"> ➤ How does nutritional status of children (malnutrition, obesity) affect risk of disease severity in SSA children? [29] ➤ What is the impact of SCD on risk and outcomes of COVID-19 disease among children in SSA? [29] ➤ How do cardiovascular, metabolic, and other comorbidities impact the risk and outcomes of COVID-19 in African children? ➤ How do housing density, crowding and household air pollution affect risk of SARS-CoV-2 infection in children in SSA? ➤ What is the prevalence of depression and stigma experienced among children with COVID-19, or in the context of the COVID-19 pandemic in Africa?
5	Outcomes	<ul style="list-style-type: none"> In HIC children, disease less severe than in adults but limited SSA data suggests possible high rates of hospitalization/higher need for intensive care for younger children with COVID-19 (South Africa) [17] and possible increased mortality among adolescents (DRC) [22] Longer-term consequences (e.g., cardiac, neurologic) post-recovery are being observed primarily among adults in HIC 	<ul style="list-style-type: none"> ➤ How do outcomes in African children with COVID-19 disease differ from adults (and from children in HIC)? ➤ What are the independent factors that may impact pediatric outcomes of COVID-19 in Africa? ➤ What are the healthcare system-related vs. individual factors that may impact outcome? ➤ What are the long-term consequences of SARS-CoV-2/COVID-19 in African children?
6	Treatment and Prevention (including Vaccines)	<ul style="list-style-type: none"> Intensive care/respiratory support may be less available in SSA Limited availability of treatment drugs (e.g., remdesivir, monoclonal antibody) in SSA vs HIC Role of BCG in COVID-19 acquisition, prevention, and severity 	<ul style="list-style-type: none"> ➤ What are key low cost and effective intensive care interventions that improve outcome of children with severe COVID-19 in SSA? ➤ Is BCG vaccination potentially protective against COVID-19? ➤ What is COVID-19 vaccine efficacy and safety in children vs. adults in Africa? ➤ How to prioritize vaccine access for children in Africa? [29]

		<ul style="list-style-type: none"> • Lack of randomized controlled trial data and access to COVID-19 treatments and vaccines effective for children [29] 	
7	Scope and Quality of Health System for Management of COVID-19 Children in Africa	<ul style="list-style-type: none"> • Access to SARS-CoV-2 PCR/antigen and antibody testing in SSA limited, particularly for children • Access to higher-level ancillary COVID-19 tests e.g., D-dimer, IL-6, IL-10, troponin, brain natriuretic peptide • Access to basic care (e.g., oxygen) at primary, secondary and tertiary hospital level of care; lack of intensive care and mechanical ventilation facilities • Lower quality of care contributing to excess mortality 	<ul style="list-style-type: none"> ➤ What low cost, highly sensitive molecular antigen and antibody tests can be made available for broader testing of children in SSA? ➤ How could access to critical ancillary tests be expanded, especially for children with MIS-C or other severe COVID-19 manifestations? ➤ How does differential access to, and quality of healthcare impact clinical pediatric COVID-19 outcomes within (e.g., urban vs rural) and across African countries? [28] ➤ Is there excess COVID-19 mortality among SSA children vs HIC children, and is this associated with quality of healthcare? [35]

SSA: Sub-Saharan Africa; HIC: High-Income Countries; MIS-C: Multisystem Inflammatory Syndrome in Children and Adolescents, temporally related to COVID-19
 TB: tuberculosis; DRC : Democratic Republic of the Congo; BCG: Bacille Calmette-Guérin tuberculosis vaccine; IL: interleukin

Figure Legends

Figure 1. Known or hypothetical factors associated with COVID-19 in adults and children and potential effects on health outcomes in African children

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Figure 1

Known or Hypothetical Factors Associated with COVID-19 Outcomes in African Children

- Age
- Malnutrition
Undernutrition
Obesity
- Prevalent co-infections in Africa:
HIV, TB, malaria, other viruses/parasites
- Prevalent non-communicable disease comorbidities in African children:
Sickle cell disease, congenital & rheumatic heart disease, hypertension, diabetes, asthma, mental health, malignancies
- Limited access to care (including routine childhood vaccines), household air pollution
- Limited health system infrastructure



Child-Specific Factors

- Effect of age on expression of cell-entry enzymes (e.g., ACE-2)
- Innate/adaptive immune maturation
- Immunization status (e.g., BCG)
- Age-related response to vaccines
- Maternal infection: vertical infection? SARS-CoV-2 antibodies in exposed-infant?

Effect on COVID-19 Disease Outcomes ?

- Symptoms of infection
- Hospital admission
- Length of hospital stay
- ICU admission
- Need for mechanical ventilation
- Mortality
- Long-term outcomes of infection
- Response to COVID-19 vaccines

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