Measuring Health Sciences Research Capacity in Africa: Mapping The Available Data

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Research

Keywords: health sciences research, Africa, indicators, capacity

Posted Date: March 26th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-321693/v1>

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Abstract

Background: In recent years there have been calls to strengthen health sciences research capacity in African countries. This capacity can contribute to improvements in health, social welfare, and poverty reduction through domestic application of research findings; it is increasingly seen as critical to pandemic preparedness and response. Developing research infrastructure and performance may reduce national economies' reliance on primary commodity and agricultural production, as countries strive to develop knowledge-based economies to help drive macroeconomic growth. Yet efforts to date to understand health sciences research capacity are limited to output metrics of journal citations and publications, failing to reflect the complexity of the health sciences research landscape in many settings.

Methods: We map and assess current capacity for health sciences research across all 54 countries of Africa by collecting a range of available data. This included structural indicators (research institutions and research funding), process indicators (clinical trial infrastructures, intellectual property rights, and regulatory capacities) and output indicators (publications and citations).

Results: While there are some countries which perform well across the range of indicators used, for most countries the results are varied – suggesting high relative performance in some indicators, but lower in others. Missing data for key measures of capacity or performance is also a key concern. Taken as a whole, existing data suggest a nuanced view of current health sciences research landscape on the African continent.

Conclusion: Mapping existing data may enable governments and international organisations to identify where gaps in health sciences research capacity lie, particularly in comparison to other countries in the region. It also highlights gaps where more data are needed. These data can help to inform investment priorities and future system needs.

Introduction

Health sciences research (HSR) has been defined to include basic, clinical, and applied science on human health and wellbeing, as well as the determinants, prevention, detection, treatment, and management of disease.(1–3) To date, the majority of HSR takes place in the global north.(4–6) As of 2018, less than 1% of scientific articles published worldwide each year include at least one author based at an African institution, according to analysis by Elsevier, one of the world's largest publishers of scientific, technical, and medical information.(7)

In the past few years, however, a number of international organizations, including the African Union (8), World Health Organization (9), and World Bank (10), have called for political and economic investment in HSR in Africa. Several high-profile reports have further raised awareness of the so-called 10/90 gap: only a tenth of global expenditure on health research is targeted to issues that affect the poorest 90% of the world's population.(5)

There are two key reasons why investments in HSR in Africa may be particularly important from a developmental perspective. First, the promotion of a strong health science industry can contribute to development goals by reducing national economies' reliance on primary commodity and agricultural production; this can help governments develop knowledge-based economies, which may be important for macroeconomic growth.(11–15) In a seminal 1990 report, the Commission on Health Research and Development (R&D)(4) stated that strengthening research capacity in low- and middle- income countries (LMICs) is “one of the most powerful, cost-effective and sustainable means of advancing health and development” (p.71). Bilateral agencies, such as the United States Agency for International Development and the (former) United Kingdom Department for International Development, have highlighted the important role of science and technology in promoting economic development in LMICs.(16,17)

Second, HSR may contribute to improvements in health, social welfare, and poverty reduction through domestic application of the findings of the research itself.(18–20) The 2013 World Health Report stressed that all nations should be producers, users, and consumers of HSR.(6) Africa is home to nearly one-sixth of the world's population and is estimated to account for about a quarter of the global burden of disease.(21) Yet only a small fraction of global health research currently focuses on diseases which exclusively affect LMICs.(22,23) While there have been developments in the HSR landscape over the past three decades, many LMICs still lack sufficient capacity to build a local evidence base to inform policy and improve population health at a local level.(24–26) The International Vaccines Task Force of the World Bank has highlighted the importance of building research capacity to lower the risk of emergent epidemics.(27)

To date, few academic studies have evaluated the HSR capacity of LMICs. The most widely available indicator of health research capacity is the publication of health-related scientific journal articles. These have been the focus of research in the past, with bibliometric analyses undertaken to map the numbers of African publications related to cardiovascular diseases (28,29), genomics (30), health economic evaluation (31), health policies and systems (32,33), human immunodeficiency virus (34), neglected tropical diseases (35), and public health.(36) Four studies have also examined the total number of African publications on any health-related topic (as indexed in major bibliographic databases).(37–40) Beyond publication outputs, however, researchers have also collected data on investments in health-related R&D (37), clinical trial infrastructures (27,37), healthcare workforce numbers (41), and the numbers of universities and ‘centres of excellence’ (41,42) in African countries to estimate HSR capacity.

Each of these studies can help to understand individual aspects of HSR capacity in African countries, yet no single piece of information can fully capture the degree of capacity in a country or region. There remains a need for analyses which attempt to collect and analytically combine data on multiple indicators to provide a more comprehensive analysis of HSR capacity across the continent.

Background

2.1 The importance of knowledge economies

Development has been conceptualized as a process that creates growth, progress, positive change and/or the addition of physical, economic, environmental, social and demographic components.(43,44) Science and innovation, if well-utilized, may play a core role in realizing sustainable development.(1,45) As seen from the experiences of many industrialized nations, scientific research and linked innovations have been core to economic and social advancement over the past two centuries – be it medical innovations such as vaccines and antibiotics, or industrial innovations in manufacturing, communications, and computation.(46–48)

More recently, questions have been asked as to whether scientific research supports development, or whether it represents a product of development in itself. (49,50) Both these positions have their justifications. In terms of science resulting in development, it is research and knowledge generation, linked with subsequent innovation and application of that knowledge, that can be seen as critical to overcoming key development challenges in LMICs.(49) Therefore, the need to invest in capacity for mobilizing and using science and innovation can be viewed as an essential component of strategies for promoting sustainable development.(51–53) This argument appears to underpin the inclusion of research within the Sustainable Development Goals. Goal 3.B specifically focusses on health research for LMIC needs, calling for “supporting the development of research and development of vaccines and medicines for health conditions which affect LMICS”; goals 9.5 and 12.A call for increased scientific, technical and research capacity more generally in developing countries.(54)

Many calls for the creation of so-called ‘knowledge economies’ are linked to thinking of research activity as an end goal of development. It has been argued that the conceptualization of an *economy* of knowledge reproduces a growth and market-oriented rationale for knowledge production, accumulation, and diffusion which has particularly influenced the international aid, education, and development agenda.(55,56) For example, the OECD(11) defines knowledge-based economies as those “which are directly based on the production, distribution and use of knowledge and information” (p. 7). The World Bank identifies four dimensions of the knowledge economy: economic and institutional regime, education and skills, information and communication infrastructure, and an innovation system – with the agency going so far as to create a Knowledge Economy Index (KEI) as an indicator of a country’s ‘preparedness’ for a knowledge economy.(57)

Asongu and colleagues(58) found the overall trends in African countries’ performance between 1996 and 2010 differed across the World Bank’s KEI dimensions: with Tunisia leading in education, the Seychelles in information and communication technology, South Africa in innovation, and Botswana and Mauritius in institutional regime. Oluwatobi and colleagues(59) have argued that the potential for knowledge production and innovation in Sub-Saharan Africa is mitigated by the level of human capital and quality of institutions. Overall, quality education and strong institutions are held to be imperative for the transformation into a knowledge economy.(59–61) Both educational and economic institutions may create enabling structures for developing knowledge and innovation and for economic growth, but their influence varies according to institutional arrangements, income, and development levels in countries.(61–63) In particular, education plays a vital role in strengthening human capital, which directly influences the ability to create, absorb, transform, disseminate, and use of knowledge and innovation.(59,64–66) Education and training emphasizing the value of traditional knowledge and culture also strengthens human capital to innovate contextually relevant solutions for local development problems.(58,63,67)

2.2 The contribution of health sciences research

Within the broader remit of science for development, health sciences research is vital in its own specific way. There are global examples where health research leads to collective human benefit, development of medical treatments, or better understanding of health risks of activities such as tobacco smoking. At a national level, however, HSR can also specifically generate evidence that is useful for public service planning and program implementation. Local health research is typically seen to provide policy-relevant information, including disease trends, risk factors, outcomes of interventions, patterns of care, as well as health systems and services costs and outcomes.(68)

Authors such as Grant and Buxton have gone so far as to develop a framework to estimate the value that HSR provides to countries.(69) Included as benefits in the framework are cost reduction in the delivery of existing services; improvements in service delivery processes; increased effectiveness of health services; increased population health and equity (achieved through improved allocation of resources, better targeting and accessibility); and contribution to a healthy workforce.

Finally, HSR evidence has also been argued to improve the health policymaking process itself by identifying new issues for the policy agenda, informing decisions about policy content and direction, and through evaluations of policy impact.(70) In many ways, these examples capture the benefits widely seen to follow from a system of evidence-informed policymaking, whereby a more systematic and robust use of research evidence in decision making is seen to improve planning effectiveness and efficiency to serve the broader social good.(18,71)

Health sciences research input and output by national governments are not uniform, with significant disparities between regions or income levels, and also across countries within the same region or at similar levels of income.(72,73) On the African continent, for example, Tanzania and Lesotho had similar levels of GDP (per capita USD 2,365 and USD 2,494 respectively in 2013); however, the percentage of GDP invested in research in Tanzania was more than 3 times higher than in Lesotho (0.28 v. 0.08) while the number of publications per million inhabitants was nearly 50 times higher, at 770 in Tanzania compared to 16 in Lesotho.(74)

One of the most critical contextual determinants of HSR outputs is historical evolution of research systems. For those African nations subject to colonial rule, for instance, modern forms of research were often developed in service to the economic interests of the colonising power. The focus of research thus centred on key exports such as agriculture, forestry and mining related activity, with little interest in HSR to benefit local populations.(75,76) After independence, HSR remained embryonic, with governments often choosing to invest in economies based on the commercialisation of cash products and natural resources rather than in the development of research and technology.(77) Moreover, countries which have experienced conflict, instability, and other socio-political crises, have had to direct resources towards reconstruction and peacekeeping investments, rather than towards scientific research and innovation.(78)

For some nations, the catalyst for investment and development of HSR has only been through the emergence of health crises—new diseases such as HIV/AIDS and Ebola, or the rising incidence of tuberculosis and plague.(79) (Ministère de la santé publique, 2015; MTN, 2017). Outbreaks have also at times inspired new policies calling for investment in HSR by global organisations such as the World Health Organization (WHO) and UNESCO.(80,81) These calls for investment have allowed for a more open dialogue and progress on conceptualising the importance of health research, even within low income African states—with several governments now committed to investing in scientific research in connection with a country's economic and sustainable development priorities.(82–84) Despite these shifts, such as the Bamako initiative, WHO's efforts to regionalise research efforts, and signs of increased attention to domestic HSR, key drivers of research and research funding in the health sector remain exogenous to African states. Indeed, funding largely reflects global HSR priorities, with limited options for investigator-initiated research on local health concerns.

2.3 How can we measure health sciences research?

While there is a strong case that HSR in LMICs is important at national and global levels – for improving health, preventing epidemic spread, supporting health policy and systems, and as an influential factor of national development more broadly – there is no single framework or consensus method to assess HSR capacity across countries. Indicators for measuring and monitoring HSR generally include standard output indicators of knowledge production and innovation, such as scientific journal articles per million inhabitants or patents per million inhabitants (57), and input and process indicators of health research and development. Such process indicators can include gross domestic research and development expenditure on health as a percentage of GDP (GERD), number of clinical trials per million inhabitants, research grants, and full-time equivalent health researcher per million inhabitants.(37) From the perspective of decision-makers in national agencies, these indicators of knowledge production and human resources for research are helpful for benchmarking performance against regional and global comparators and for informing policy and strategy to strengthen research and development.(85)

Researchers and international organisations have attempted to compile indicators and measure HSR capacity in different ways. For example, the WHO has created a Global Observatory on Health Research and Development which aims to “consolidate, monitor, and analyse relevant information on health research and development activities”.(86) This uses a logic model perspective to assessing HSR, tracking a range of indicators to monitor health R&D inputs, processes, and outputs as identified and defined by Røttingen and colleagues.(37) While these indicators are useful for monitoring and benchmarking the state of HSR and development activities, funding, and performance at the national level, they do not provide information to assess overall capacity of national health research systems as a set of “people, institutions and processes” for HSR. Moreover, there are incomplete or missing data for many of these indicators.

A second approach takes a systems perspective to assessing HSR capacity, recognising that research and development funds and personnel represent but two components of a nation's HSR capacity. In this vein, Pang and colleagues(19) defined a national health research system within a conceptual framework of four functions: stewardship, financing, creating and sustaining resources, and producing and using research. This framework has been operationalised under the Research for Health unit at the WHO Regional Office for Africa and used to assess the evolution of national health research systems, with data collected from individual researchers for health focal points in 2003, 2009, and 2014.(87–90) These key informants within national Ministries of Health and other institutions replied to survey questions about whether HSR policies, institutions, or other resources were currently in place in the country (e.g. national health research policy, national research ethics committee, national health research institute, national budget line for health research)(87).

In applying this approach, Kirigia and colleagues(88) analysed trends between 2003 and 2014 to show that although there have been positive gains across many functions, there are still considerable gaps in many African countries. For example, fewer than half of the countries in Sub-Saharan Africa have an official health research policy, a national strategic health research plan, a law regulating HSR, or a budget line for HSR within the health budget; and only about half of them have a national health research institute or council, a health research programme at the Ministry of Health, or a health research management forum. Public financing for HSR is also typically measured to be very low, with minimal progress towards the goal of 2% of the national health expenditure allocated to HSR. Instead, most funds for HSR come from external sources such as international organisations, NGOs, or multilateral/bilateral partners. Within the systems approach, Kirigia and colleagues attempted to quantify the performance and capacity of national HSR systems in the African national health research systems barometer.(89) Based on their operationalisation of Pang et al.(19) framework, with 4 main functions and 17 sub-functions, Kirigia et al. calculate an index for each sub-function and propose a score for the region, and for each country and function using the 2014 survey data.(89) According to Kirigia et al, the weakest elements of African health research systems are human resources for HSR, government spending on HSR, publications in peer-reviewed journals, and research institutions to conduct HSR.(89)

Overall, there have been a variety of attempts to identify various elements of HSR activity, performance, and capacity in Africa. Some have assessed R&D potential, measured funding inputs, or identified gaps in national HSR systems. These efforts shed light on where strengths and weaknesses lie, but currently do not provide a comprehensive review and synthesis of data on which to comparatively evaluate HSR knowledge and innovation, HSR and development activities, and HSR systems at the national level across Africa.

The aim of this paper is thus to develop this work by collecting and aggregating data on a range of variables to consider HSR activity, performance, and capacity in all African countries. We propose a framework for evaluating a country's capacity for HSR based on publicly available data sources. This framework incorporates and expands on indicators from previous studies. Using this framework, we present data on HSR capacity in each of the 54 UN-recognised African states to map current capacity across the region for health sciences research – providing one of the first analyses to systematically outline the contribution of African countries to HSR across such a wide range of indicators.

Methods

3.1 Data collection

We reviewed data for each of the 54 UN-recognised states in Africa. This excluded any foreign departments (e.g., Mayotte), regions (e.g., Réunion), or territories (e.g., Saint Helena) located in Africa, as well as the disputed territory of Western Sahara. We collected population and gross domestic product (GDP) data from the World Bank(91) for each of these states to be able to benchmark our findings against broader development metrics.

We sought to identify a range of indicators which could help measure the HSR capacity in each country. We used the indicators selected by the World Health Organization Global Observatory on Health R&D database as a starting point, which comprised gross expenditure on R&D (GERD) as a proportion of GDP, health researchers per million inhabitants, number of institutions, and official development assistance for the medical research and basic health sectors as a proportion of gross national income.(92) We then supplemented this with others measures of HSR capacity which we identified through discussions between authors and members of a project oversight committee[1], including bibliographic data, data on clinical trial infrastructures, regulatory environment, intellectual property rights, and research funding. All data were acquired between June and September 2018.

To classify and conceptualise the various indicators available, we followed the Donabedian(93) model of health care quality measurement to categorise our indicators into one of three types: structural, process, and output measures related to HSR. Structural measures capture inputs into the system and thus comprised metrics such as workforce numbers, budget allocation to R&D, and numbers of organisations, regulations, and guidelines on human subject protections. Process measures are indicators of ongoing HSR activities, including numbers of clinical trials registered and patent applications. Finally, output measures capture the outputs of research activities including numbers of peer-reviewed publications and citations for these publications.

3.2 Structural Indicators

1. R&D expenditures and personnel

Data on R&D expenditure and personnel were obtained from the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (2016, or the most recent available year).(92) We collected data on the number of full-time equivalent staff in the following categories: (i) R&D personnel (per million inhabitants), (ii) researchers (per million inhabitants), and (iii) researchers with doctoral or equivalent degrees (as a proportion of total number of researchers). From the same database, we also collected data on gross domestic expenditure on R&D in '000s current purchasing power parity (PPP) \$; these figures were also shown as a proportion of GDP and per capita. Whenever possible, we collected expenditure and personnel data specific to medical and health sciences.

2. Research institutions

We collected data on the number of universities in each country from the website <https://univ.cc/>; which compiles a list based in part on information from the International Association of Universities.(94) We recognise that there may be limitations affecting the quality of data from this source, so we also identified the number of African universities listed on the most recent global university rankings of three influential publishers: Quacquarelli Symonds Limited (QS World University Rankings) (95), Times Higher Education (THE World University Rankings) (96), and Shanghai Ranking Consultancy (Academic Ranking of World Universities).(97) Whilst this may not be comprehensive, it allows an indication of the number of institutions across the continent.

We further collected data on the number of institutional review boards(98) and WHO Collaborating Centres(99) in each country, and noted whether or not there exists a national ethics committee(100) and national public health institute.(101)

3. Research funding

We collected data on international funding awarded to researchers in each country (2008-2017) from the ten largest public and philanthropic funders of health research globally (listed in order of size)(102): (1) U.S. National Institutes of Health, (2) European Commission, (3) U.K. Medical Research Council, (4) French National Institute of Health and Medical Research, (5) U.S. Department of Defense (including the Congressionally Directed Medical Research Program), (6) Wellcome Trust, (7) Canadian Institutes of Health Research, (8) Australian National Health and Medical Research Council, (9) Howard Hughes Medical Institute, and (10) German Research Foundation.

The data were collected from each funder website. As we are seeking to understand current capacity, we only counted funding allocated to researchers based at institutions in African countries. We excluded funding for research projects in which the principal investigators were based at non-African institutions, even if these projects included collaborators, field sites, or locations of research in Africa.

All amounts were reported in 2018 U.S. dollars based on consumer price index adjustments to account for inflation. Foreign currencies were converted to dollars based on the yearly average exchange rates published by the World Bank.(91)

3.3 Process Indicators (clinical trial infrastructures, intellectual property rights, and regulatory capacities)

Data on the numbers of clinical trials and records, as of 4 August 2018, were extracted from the WHO International Clinical Trials Registry Platform (ICTRP) (103) and US National Institutes of Health database (ClinicalTrials.gov).(104) ClinicalTrials.gov indexes trials of new investigational drugs, whereas the ICTRP indexes data from several sources, including the European Union Clinical Trials Register, ClinicalTrials.gov, International Standard Randomised Controlled Trial Number register, and Pan African Clinical Trial Registry. A full list of data providers can be found on the ICTRP website.(103) The ICTRP registry accepts all types of clinical research studies (e.g., trials of public health interventions).

We also collected information on the number of organisations, regulations, and guidelines on human subjects protections in each country. These data, which are collected annually by the US Department of Health and Human Services (105), reflect protections in each of the following categories: “general (ie, applicable to most or all types of human subjects research)”, “drugs and devices”, “clinical trial registries”, “research injury”, “social-behavioural research”, “privacy/data protection”, “human biological materials”, “genetic”, and “embryos, stem cells, and cloning”. We used the 2018 edition of the compilation of protections.(105)

Finally, we collected data from the World Intellectual Property Organization on the numbers of patents issued to residents in each country (2016, or most recent available year).(106)

3.4 Output Indicators (publications and citations)

To systematically collect publication data, we searched Scopus, the world’s largest abstract and citation database of peer-reviewed literature.(107) Scopus was chosen as it includes a larger volume of non-English language journals than many other major bibliographic databases (e.g. Web of Science).(107) We searched for any articles published in the following Scopus subject areas: health sciences (medicine, nursing, veterinary, dentistry, health professions) and life sciences (agricultural and biological sciences, biochemistry, genetics and molecular biology, immunology and microbiology, neuroscience, and pharmacology, toxicology and pharmaceuticals). We included the following types of publications: articles, in press, books, chapters, and conference papers.

We searched for articles published with at least one author based at an institution in each of the 54 countries, using the “Affiliation country” field in Scopus. We searched the names of each country in English, French, and Portuguese, as well as variant spellings of country names. We restricted the searches to publications published in the ten-year period from 2008 to 2017. The search strategy, including the country names, can be found in **Appendix 1**.

For each country, we extracted data on the number of publications with at least one author based in the country, as well as the number of publications first authored by a local researcher. We also collected citation data for all articles. For publications published in the five-year period from 2013 to 2017, we collected data on the proportion of publications with international, institutional, and national collaborators; these data were unavailable for articles published before 2013. These data were obtained in SciVal, a research information tool developed by Elsevier to synthesise bibliometric data from Scopus.

Results

4.1 Descriptive statistics

Appendix 2: Table 1 presents the bibliometric data collected in Scopus and SciVal. The total number of outputs (with at least one author from an African state) published between 2008 and 2017 ranged from 25 in Sao Tome and Principe to 63,171 in South Africa. On a per-capita basis, the Seychelles had 3,568 publications per thousand population, while South Sudan had only 0.007 publications per thousand people. The absolute number of citations for published outputs ranged from 335 in Sao Tome and Principe to 243,026 in Kenya[1]. Three quarters (43/54) publications included international authors, yet a small share of total publications were first authored by researchers based in each country.

Appendix 2: Table 2 shows the data on clinical trial infrastructures and intellectual property rights. The number of clinical trials indexed in the World Health Organization’s International Clinical Trials Registry Platform ranged from 0 in Cape Verde to 4,341 in South Africa. The number of patent applications by residents (2016, or last available year) ranged from 1 in Botswana, Djibouti, and Tanzania to 2,783 in South Africa.

Appendix 2: Tables 3 and 4 present R&D personnel and spending, respectively. Based on data from 2016, or the nearest available year, the number of researchers per million inhabitants ranged from 7 in the Democratic Republic of Congo to 1,965 in Tunisia; the proportion of researchers with doctoral or equivalent degrees ranged from 10% in Malawi to 72% in Cape Verde. The gross expenditure on R&D as a share of GDP ranged from 0.01% in Madagascar to 0.8% in South Africa. The proportion of gross expenditure on R&D that went to the medical and health sciences ranged from 0% in Lesotho to 30% in Swaziland.

Appendix 2: Table 5 presents data on regulatory capacities. About half the countries had a national public health institute (27/54) and national ethics committee (25/54). The number of institutional review boards ranged from 0 in several countries to 30 in South Africa. **Table 6** shows the amount of funding awarded to researchers in each country (2008-2017) from ten large organisations.

Table 7 presented in combines our main indicators into a single table.

While there are some high-achievers across the board, for most states the results are varied – suggesting high relative performance in some indicators, but lower in others (or lacking data). For example, Libya is a relatively high achiever for publications, first author publications and number of research institutions, but lags behind this success with the number of clinical trials conducted within the country. Conversely, Burundi has low numbers of publications, first author publications, number of clinical trials and GERD as a % of GDP, but performs relatively well in number of research institutions.

Table 7. Indicators Framework for all 54 Sovereign African States

Country	GDP (million, current US\$,2016)*	Population (thousand,2016)**	GDP per capita (current US\$, 2016)	# of publications per 1 million inhabitants	# of first author publications per 1 million inhabitants	# of trials per 1 million inhabitants	# of universities per 1 million inhabitants	GERD a % of GDP
Algeria	159,049	40,606	3,917	198.07	159.41	4.06	0.76	0.066
Angola	95,335	28,813	3,309	15.48	4.16	0.56	0.59	
Benin	8,583	10,872	789	223.23	107.25	4.97	0.37	
Botswana	15,581	2,250	6,924	784.80	335.96	41.33	3.56	0.537
Burkina Faso	11,693	18,646	627	166.47	71.65	9.98	0.11	0.221
Burundi	3,007	10,524	286	23.09	6.37	1.81	0.86	0.121
Cameroon	32,218	23,439	1,375	254.83	143.18	4.82	0.55	
Cape Verde	1,617	540	2,998	229.82	35.21	0.00	12.97	0.072
Central African Republic	1,756	4,595	382	72.48	29.82	2.83	0.22	
Chad	9,601	14,453	664	14.05	3.81	0.83	0.07	0.315
Comoros	617	796	775	76.67	16.34	3.77	1.26	
Democratic Republic of the Congo	35,382	78,736	449	19.50	7.73	1.10	0.20	0.016

Country	GDP (million, current US\$,2016)*	Population (thousand,2016)**	GDP per capita (current US\$, 2016)	# of publications per 1 million inhabitants	# of first author publications per 1 million inhabitants	# of trials per 1 million inhabitants	# of universities per 1 million inhabitants	GER a % GDF
Djibouti	1,727	942	1,833	64.73	31.84	4.24	1.06	
Egypt	332,791	95,689	3,478	634.28	N/A	38.78	0.49	0.70
Equatorial Guinea	10,685	1,221	8,747	93.33	9.82	4.91	0.82	
Eritrea	2,608	4,475	583	34.42	12.07	1.34	0.22	
Ethiopia	72,374	102,403	707	96.93	64.74	1.84	0.30	0.60
Gabon	14,214	1,980	7,179	607.64	225.28	31.82	1.01	0.57
Gambia	965	2,039	473	576.40	178.07	58.38	1.47	0.13
Ghana	42,690	28,207	1,513	248.34	130.50	8.44	0.92	0.37
Guinea	8,200	12,396	662	124.80	33.72	2.50	0.32	
Guinea- Bissau	1,165	1,816	642	183.40	61.13	34.15	N/A	
Ivory Coast	36,373	23,696	1,535	110.65	66.38	3.04	0.30	
Kenya	70,529	48,462	1,455	294.79	125.27	13.19	1.03	0.78
Lesotho	2,291	2,204	1,040	84.40	29.04	9.98	0.45	0.04
Liberia	2,101	4,614	455	55.92	9.75	5.42	0.22	
Libya	34,699	6,293	5,514	240.42	116.79	3.02	1.91	
Madagascar	10,001	24,895	402	80.30	27.32	1.08	0.24	0.01
Malawi	5,433	18,092	300	190.25	66.55	17.52	1.16	

Country	GDP (million, current US\$, 2016)*	Population (thousand, 2016)**	GDP per capita (current US\$, 2016)	# of publications per 1 million inhabitants	# of first author publications per 1 million inhabitants	# of trials per 1 million inhabitants	# of universities per 1 million inhabitants	GERD a % GDI
Mali	14,035	17,995	780	93.97	27.51	9.45	0.06	0.3
Mauritania	4,739	4,301	1,102	52.78	19.30	2.33	0.23	
Mauritius	12,168	1,263	9,631	583.31	319.75	26.91	1.58	0.1
Morocco	103,606	35,277	2,937	341.61	269.70	5.41	0.79	0.7
Mozambique	11,015	28,829	382	60.04	18.80	3.36	0.55	0.3
Namibia	10,948	2,480	4,415	413.76	135.90	2.82	1.61	0.3
Niger	7,528	20,673	364	38.89	13.45	1.64	0.05	
Nigeria	404,653	185,990	2,176	166.80	139.00	1.84	0.65	0.2
Republic of the Congo	7,834	5,126	1,528	179.68	68.48	10.14	0.20	
Rwanda	8,376	11,918	703	127.46	45.14	8.14	0.92	
Sao Tome and Principe	343	200	1,715	125.06	20.01	10.00	N/A	
Senegal	14,684	15,412	953	237.94	114.13	6.68	0.65	0.7
Seychelles	1,427	95	15,075	3580.48	602.03	31.69	21.12	0.2
Sierra Leone	3,737	7,396	505	71.66	13.79	5.27	0.41	
Somalia	6,217	14,318	434	5.10	1.68	0.98	1.12	

Country	GDP (million, current US\$, 2016)*	Population (thousand, 2016)**	GDP per capita (current US\$, 2016)	# of publications per 1 million inhabitants	# of first author publications per 1 million inhabitants	# of trials per 1 million inhabitants	# of universities per 1 million inhabitants	GERD GDP
South Africa	295,456	56,015	5,275	1127.74	N/A	77.50	0.45	0.798
South Sudan	9,015	12,231	737	0.00	0.00	0.16	0.25	
Sudan	95,584	39,579	2,415	93.31	49.67	1.79	0.96	0.298
Swaziland	3,721	1,343	2,770	403.54	148.16	16.38	0.74	0.270
Tanzania	47,340	55,572	852	138.85	56.99	7.79	0.40	0.529
Togo	4,400	7,606	578	121.48	73.89	2.10	0.13	0.271
Tunisia	42,063	11,403	3,689	1800.54	1502.90	37.36	1.67	0.599
Uganda	24,079	41,488	580	198.85	84.27	15.69	0.46	0.170
Zambia	21,064	16,591	1,270	166.23	51.89	15.79	0.48	0.278
Zimbabwe	16,620	16,150	1,029	186.06	81.73	11.76	0.93	
* Except Djibouti (2015), Eritrea (2011), Libya (2011), and South Sudan (2015) Source: World Bank		** Except Eritrea (2011) Source: World Bank		Note: put two N/A (South Africa and Egypt) as highest category			Note: put two N/A as lowest category	Split 1

Figures 1 through 10—and the corresponding tables under each figure—explore associations between various metrics and GDP (gross and per capita). In general, there was a strong linear relationship between GDP and the various indicators.

Limitations

There are a few limitations to this study. First, there is no single indicator for accurately ascertaining HSR. Accordingly, we used a variety of available metrics that serve as proxy indicators. Thus, there is a risk that these proxies do not capture the full landscape we sought to map. For example, we have not accounted for broader financing and infrastructure which contributes to health sciences research – such as buildings, routine access to electricity, primary and secondary education attainment, etc. Each of these, alongside others, contribute to a country's capacity for HSR, and yet such indicators may not demonstrate impact of HSR and can be difficult to disaggregate.

Second, there was a lack of data for several indicators. The most comprehensive data sources were for publications and clinical trials, but many other categories of data were missing results for numerous countries. In some data categories, there were issues of reliability and comparability between sources. Furthermore, while we aimed to collect data from 2007-2017 across indicators, some data points come from before this time frame if more recent data were not available. This included data on patent applications and human resources, as we deemed it to be better to include data outside the period to get a fuller picture of the HSR landscape.

Third, for the output indicators, it is important to note that research is not always published in peer-reviewed journals, and therefore limiting the analysis to bibliometrics from SciVal could miss research published in other sources and formats. Scopus does not index all journals published in African states. And for some countries, including Democratic Republic of Congo, Republic of Congo, South Sudan and Sudan, the indexing of affiliation countries on journal articles is incomplete. Our approach also does not include research published outside of peer-reviewed journals, including government or non-governmental literature policy reports, open data sets, software, or other grey literature.

Fourth, we were unable to find a consistent data source across the African continent to measure government budget allocation to HSR. Instead, we used GERD as a proxy; this captures investments in R&D, which is not disaggregated by health sciences. Similarly, when measuring the number of universities in each state, we were not able to ascertain whether these universities undertake research or those which solely offer degrees or training in health sciences.

Fifth, these metrics are all aggregated at the national level, and thus this crude analysis fails to reveal the sub-national interaction. This may not only produce analysis revealing particular “hubs” of excellence, but it may also reveal institutional capacity or individual capacities which form key components of the national landscape.

Discursive Conclusion

We have sought to assess current capacity for health sciences research across Africa, based on a subset of proxy indicators for which we had more complete data. In doing so we contribute to quantifying current strengths and lack of capacity in the African health sciences research landscape.

Our findings have raised a number of points for consideration:

There are some unsurprising high performers across the variety of indicators South Africa, Egypt, Tunisia, which score highly across broader development metrics, perform well in health sciences research also. However, it is worth noting that it is not simply the level of development (GDP) or international or national financing for HSR (GERD and international research funding) that leads to a success in HSR. States which have had major donor investment in HSR (per capita), including Uganda and The Gambia have not necessarily emerged as top performers across the range of proxy indicators used. Whilst current level of economic development does not appear to play a significant role in a country's health sciences research capacity per se. our analysis shows clear correlation between GDP and a range of individual metrics (see Figures 1-10), although this is not suggesting causality.

There are several possible explanations for results such as these. One explanation might be that that reliance of donor funding has limited the sustainability of the health research sector when these collaborations end(108,109), or lacked significant improvements in broader infrastructures within the national system. Alternatively, international arrangements may result in research agendas set by the global north, which could imply that they either reflect the need of the funding location(110,111), a focus on spotlight issues(112) or so-called ‘parachute research’, any of which may be limited in improving health research outcomes in the host location. The importance of local research development, however, has been highlighted as vital to building a knowledge economy and addressing domestic health concerns, as in country researchers have the best understanding of the national agenda and cultural context which increased the likelihood of evidence uptake by policymakers.(24,113)

Secondly, we recognise that the experience of conflict, or post-conflict reconstruction, can have profound impact on health sciences research capacity. It is unsurprising, perhaps that the lowest performers, South Sudan, Somalia, Democratic Republic of Congo have all been or continue to be engaged in domestic conflict. Importantly we have not included metrics of conflict into our analyses, so this remains speculative. Yet, this is not conclusive, as other locations which have recently been engaged in conflict or political strife have fared better across a range of indicators, such as Sudan, Nigeria and Central African Republic.

Thirdly, we recognise (as per the limitations) that using these indicators to measure performance does not capture the nuance of what is occurring within each system, and the progress that systems are making more holistically. For example, these metrics are not able to infer political commitment to HSR, the relative importance of the HSR landscape globally, how these systems have developed, where the success stories are and where barriers remain to solidifying knowledge economies. They are also unable to infer the historical contexts which led to the development of these systems, whether rooted in colonial science or post-colonial investments, each of which will lead to different looking HSR environments.

Our hope is that with this mapping exercise, governments will be able to identify where their gaps in HSR lie, particularly in comparison to their regional counterparts, and this may offer meaningful analysis for investment priorities and future system needs.

Declarations

- **Ethics approval and consent to participate**

Not applicable

- **Consent for publication**

Not applicable

- **Availability of data and materials**

All data generated or analysed during this study are included in this published article [and its supplementary information files].

- **Competing interests**

The authors declare that they have no competing interests

- **Funding**

Funding for this research was provided by Wellcome Trust under a commissioned project “Building the Case for Investment in Health Sciences Research in Africa”

- **Authors' contributions**

CW and JP conceptualised and developed the research, CW drafted the manuscript. OW collected and analysed the data. CJ, PA, RM and JT all contributed to the manuscript draft and conversations reflected in the analysis. All authors have approved the final manuscript.

- **Acknowledgements**

We thank Aaron Hedquist and Emily Canner for their research assistance with finalising this manuscript.

- **Authors' information (optional)**

Not applicable

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