Assessment of Performance for a key Indicator of One Health: Evidence based on One Health Index for Zoonoses in Sub-Saharan Africa

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Abstract

**Background:** Zoonoses are public health threats that cause severe damages worldwide and, constitute a key indicator of One Health (OH). The OH approach is being applied for control programmes of zoonotic diseases. In a very recent study, we have developed an evaluation system for OH performance through global OH index (GOHI). This study applied GOHI to evaluate OH performance for zoonoses in sub-Saharan Africa.

**Methods:** Framework for OH index on zoonoses (OHIZ) was constructed including five indicators, 15 sub-indicators and 28 datasets. Publicly available data were referenced to generate OHIZ database which included both qualitative and quantitative indicators for all sub-Sahara African countries (n=48). GOHI algorithm was referred to estimate scores for OHIZ. Indicators weight was calculated by adopting the fuzzy analytical hierarchy process.

**Results:** Overall, five indicators associated with weights were generated as follows: source of infection (23.70%), route of transmission (25.31%), targeted population (19.09%), capacity building (16.77%), and outcomes/case-studies (15.13%). Following the indicators, a total of 37 sub-Sahara African countries aligned with OHIZ validation, while 11 territories were excluded for unfit or missing data. The OHIZ average score of sub-Saharan Africa was estimated at 53.67/100. The highest score was 71.99 from South Africa, while the lowest score was 40.51 from Benin. It is also worth to be mentioned that Sub-Sahara African countries had high performance in many sub-indicators associated with zoonoses, e.g., surveillance and response, vector and reservoir interventions, and natural protected areas, which suggests this region had a certain capacity in control and prevention or responses to zoonotic events.

**Conclusion:** This study reveals that it is possible to perform the OH evaluation for zoonoses in sub-Saharan Africa by OHIZ. Findings from this study provide preliminary research information in advancing knowledge of the evidenced-risks to strengthen strategies for effective control of zoonoses and to support the prevention of zoonotic events.

**Background**

One Health (OH) is an integrated and unifying approach which aims to sustainably balance and optimize the health of people, animals and ecosystems. One Health performance measures the capacity of a country or an area in responding to public health threats [1]. The OH approach implies multidisciplinary efforts with the common goals to achieve better public health outcomes through helping disease prediction, prevention, and preparedness at the interface between humans, animals, and their environments [2].

In 2018, three major international organizations including the World Health Organization (WHO), the United Nations’ Food and Agriculture Organization (FAO), and the World Organization for Animal Health (OIE), put the OH vision into practice by consolidating a formal partnership and strengthening their joint action to combat human-animal-environment health risks [3]. This culminated with the FAO-OIE-WHO (tripartite) zoonoses guide, titled “Taking A Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries” (2018 TZG) which provides principles and best practices to assist countries in achieving sustainable and functional collaboration at the human-animal-environment interface [4]. In May 2021, OH High-Level Expert Panel (OHHLEP) has been launched to address the emergence and spread of zoonotic diseases [5]. The panel aims to advise four international organizations – the FAO, OIE, United Nations Environment Programme (UNEP), and the WHO – on the development of a long-term global plan of action to avert outbreaks of diseases. To that end, 26 international experts have been appointed to kickstart the OHHLEP followed by a joint tripartite (FAO, OIE, WHO) and UNEP statement which advocate to mainstream OH so that they are better prepared to prevent, predict, detect, and respond to global health threats and promote sustainable development [6, 7].

Zoonoses, a core issue in OH, are infections that are naturally transmitted between human beings and other vertebrates, which can spread from food, water or environment directly. Zoonoses alone represent 60% of world known infectious diseases, with a high proportion (70%) of pathogens coming from wildlife hosts [8]. With the acceleration of globalization,
zoonotic emerging and re-emerging infectious diseases seriously harm human and health, husbandry development, and food security [9]. Throughout the history, several epidemics and pandemics have been associated with zoonotic origins, with rapid spatial and temporal spread worldwide. These include, but not limited to: the bubonic plague in the 14th century, the 1918 influenza pandemic, acquired immune deficiency syndrome (AIDS) since 1959, severe acute respiratory syndrome (SARS) in 2003, middle east respiratory syndrome (MERS) in 2012, and the novel coronavirus disease (Covid-19) in 2019 [10]. According to pathogen types, zoonoses are classified as bacterial zoonoses, e.g., tuberculosis and brucellosis; viral zoonoses, e.g., AIDS and rabies; helminth zoonoses, e.g., schistosomiasis and echinococcosis; protozoa zoonoses, e.g., malaria and leishmaniasis; fungal zoonoses; rickettsia zoonoses; chlamydia zoonoses; mycoplasmosis; and exceptions like the mad cow disease [11]. Zoonoses have different ways of transmission, including animals bite or scratch, by air, aerosol or dust particles, sexual contact or mother-to-child transmission, and other ways including oral transmission, animal or environmental indirect transmission [10]. Severe zoonoses are threatening to life security, public health and economical construction, globally. For examples, tuberculosis, leishmaniasis, and echinococcosis are major zoonotic diseases with high prevalence and disability-adjusted life years (DALYs) which were 1 829 729 478 and 47 030 118 for tuberculosis, 4 575 092 and 696 703 for leishmaniasis, and 900 005 and 122 457 for cystic echinococcosis, respectively, according to the global burden diseases (GBD) report in 2019.

The development degree of a country or area has great significance for its governance capacity of zoonoses. Developed countries have huge advantages in medical treatment, public health, economic construction, scientific research input and social welfare that most developing settings lack [9]. Sub-Saharan Africa has long been regarded as a low-economy region with low- and middle-income countries. This would have been reflected in weak responses capacity/ability to zoonotic events [12, 13]. In addition, global climate change, deforestation, and husbandry development, accelerate risks for zoonotic diseases, especially in sub-Sahara African settings [14, 15]. According to the GBD, in 2020, sub-Saharan Africa alone recorded prevalence and DALYs of 257 082 412 and 17 547 387, respectively, for tuberculosis, and were estimated at 168 633 396 and 43 197 058, respectively, for malaria.

One Health initiatives on zoonoses including governance capacity in surveillance and research activities have been carried in many countries/territories across the Africa continent [16]. In Kenya and Uganda, a global disease detection division [17] and a multi-disciplinary platform [18], respectively, have been established for zoonoses control and prevention under the OH approach. In the horn of Africa (Ethiopia, Kenya, Uganda, Sudan, South Sudan, Somalia, Djibouti and Eritrea) and in Chad, Côte d’Ivoire, and Mali, international cooperation on the OH approach has been established for capacity building to support zoonoses control and prevention [19, 20]. However, such activities lacked of efficient inter-departmental collaboration mechanisms or, few outcomes were adequate to be implemented in local communities [18, 21].

In this study, we formulated indicators for zoonoses and applied OH principals [22, 23] to data retrieved from publicly available repositories to systematically analyze OH index for zoonoses in sub-Saharan Africa. In addition, five major zoonotic diseases of public health importance worldwide including tuberculosis, COVID-19, echinococcosis, leishmaniasis, and rabies [24] were selected as case-studies for assessment. Findings from these aforementioned studies suggest imperative needs of the OH approach not only to consolidate existing achievements, but also to implement integrative strategies in the control programmes of zoonotic events in sub-Saharan Africa.

**Methods**

OH principals were applied to evaluate OH performance for zoonoses in sub-Saharan Africa. This study defines OH index on zoonoses (OHIZ) as an indicator to assess the capacity of a country/territory in responding to or preventing zoonotic events associated with holistic health of human-animal-environmental interface. Figure 1 shows the schematic of the construction steps of OH performance assessment for zoonoses, which included formulation of OHIZ, selection of indicators, database building, and OHIZ calculation.
Formulation of OHIZ and selection of indicators associated with zoonoses

Selection of OHIZ database for zoonoses was based on seven principals as reported by Zhang and colleagues [23]. These data include: fit to corresponding indicators of zoonoses; originated from authoritative sources with global or local zoonotic data; is available from public open sources with clear method of collecting; cover a sufficient number of countries/territories; cover recent temporal period and are can be updated annually; are measured with an established and unified method and peer-reviewed across countries/territories for single indicators; describe the status of zoonoses in the indicators at country-level.

Accordingly, three elements (indicators) of infectious diseases were included in the OHIZ framework and were referred to as: source of infection, route of transmission, and targeted population. Given that the OH approach covers areas of policy support, scientific research, and infrastructure construction, indicator termed as capacity building, was also set. A further indicator referred to as outcomes (case-studies), was added to form a five-indicator panel for OHIZ. Indicators that did not meet the OHIZ principals were excluded. Sub-indicators were conceived following the above-mentioned indicators and information from previous studies [10, 11, 25, 26]. In addition, zoonotic diseases of public health importance, e.g., tuberculosis, COVID-19, echinococcosis, leishmaniasis, and rabies were selected and associated with the outcome indicator as cases-studies. The panel of indicators framework was thereafter developed into a set of 15 sub-indicators (Table 1).

Building of OHIZ database

The panel of indicators were classified into qualitative and quantitative indicators according to the database sets that were consulted. Data collection were applied to qualitative indicators, while data were retrieved for quantitative indicators [22, 23, 27]. During OHIZ data collection, qualitative data were labelled as “0” for “data not found” and as “1” for “data found”.

OHIZ database building referred to internationally published authoritative database. A total of 28 comprehensive sets of OHIZ data were identified, including 13 datasets retrieved from the WHO database [28], three datasets from the OIE-WHAIS and the FAO-Emergency Prevention System for Animal Health (EMPRES) database [29], four datasets from to the World Bank (WB) database [30], four from the global health security (GHS) index [31], and four from the GBD database of global health data exchange (GHDx) [32, 33]. Details on data sources are listed in Additional file 1. After the OHIZ database was generated, all data were checked with consistency and rationality, and unfit data were excluded.

Calculation and validation of OHIZ

OHIZ algorithm from the robust global One Health index (GOHI) algorithm system that was reported very recently [22, 23], was use to estimate OHIZ. Indicators weight was determined by adopting the fuzzy analytical hierarchy process (FAHP) [34], following by fuzzy comparison matrix formation [22, 23] (Additional file 1). For indicators with values of “0” or “1”, appropriate measures were taken to correct bias from over-polarization.

According to the WB classification criteria for countries and regions, there are 47 countries/territories in sub-Saharan Africa. OHIZ was analyzed for all the sub-Sahara African countries (n = 47). Criteria of data of the same indicators from three similar countries was used to excluded biased data or countries with missing data. When there were more than 160 missing data for an indicator, the indicator was excluded. When there were more than 50% missing data for a country, the country was excluded from the final list. A total of 37 sub-Sahara African countries were retained for the OHIZ. These include: Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Cote d’Ivoire, Dem. Republic of Congo, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.
Results

OHIZ indicators and datasets

This study identified 28 datasets for zoonoses under 15 sub-indicators and five OHIZ indicators, which were all associated with weights (Table 1). Among the five indicators, route of transmission scored the highest (25.31%) weight, followed by source of infection (23.70%), targeted population (19.09%), and capacity building (16.77%). Outcomes (case-studies) weighted only 15.13%. Weight for sub-indicators were also estimated according to the weight calculation. For examples, in source of infection, strategy and regulation sub-indicator weighted 41.32%; in route of transmission, vector and reservoir interventions sub-indicator was estimated at 54.85%; in targeted population, population coverage and cost of interventions sub-indicator weighted 39.43%; in capacity building, sub-indicator of health promotion for zoonoses was 56.86%; and in outcomes (case-studies), COVID-19 sub-indicator weighted 25.42%, out of three, two, three, two, and five sub-indicators under each of indicators, respectively. Meanwhile, weight for datasets were attributed averagely (Table 1).
| Indicator | Weight (%) | Sub-indicator | Weight (%) | Dataset | Weight (%) |
|-----------|------------|---------------|------------|---------|------------|
| Source of infection | 23.70 | Strategy and regulation | 41.32 | National guideline for surveillance/control | 35.00 |
| Source of infection | | | | National legislation on animal reservoirs | 35.00 |
| Source of infection | | | | Zoonoses capacity score | 30.00 |
| Surveillance and response | 33.36 | General surveillance | 33.33 | |
| Surveillance and response | | Vector control | 33.33 | |
| Surveillance and response | | Wildlife reservoirs control | 33.33 | |
| Sanitation | 25.32 | Basic sanitation services | 100 | |
| Route of transmission | 25.31 | Detection | 45.15 | Laboratory testing for zoonotic reservoirs (vectors and animals) | 100 |
| Route of transmission | | Vector and reservoir interventions | 54.85 | Policy adoption of insecticide-treated mosquito nets | 33.33 |
| Route of transmission | | | | Policy adoption of indoor residual spraying | 33.33 |
| Route of transmission | | | | Prevention chemotherapy coverage of zoonoses | 33.33 |
| Targeted Population | 19.09 | Vaccination regulation | 28.98 | Vaccination strategy and regulation vaccination | 100 |
| Targeted Population | | Population coverage and cost of interventions | 39.43 | Proportion of population having basic drinking water and sanitation facilities | 50.00 |
| Targeted Population | | | | Costs directed to chemotherapy/vaccination of humans | 50.00 |
| Targeted Population | | Inhabitants below 5 meters above sea level | 31.60 | Number of inhabitants below 5 meters above sea level | 100 |
| Capacity Building | 16.77 | Health promotion for zoonoses | 56.86 | Legislation of zoonosis educational activities | 16.66 |
| Capacity Building | | | | Prevention and control of zoonoses | 16.66 |
| Capacity Building | | | | National plan for zoonoses vaccine | 16.66 |
| Capacity Building | | | | Zoonotic events and human-animal interface | 16.66 |
| Capacity Building | | | | Early warning for zoonoses | 16.66 |
| Capacity Building | | | | Emergency/surveillance system | 16.66 |
| | | Natural protected areas | 43.14 | Proportion of natural protected areas | 100 |

HD, Human DAILYs
Sub-Saharan Africa scored an average performance for OHIZ

A total of 37 sub-Saharan African countries was qualified for OHIZ score evaluation, after 10 countries that did not meet inclusion criteria were excluded. Countries score for sub-indicators are showed in Figs. 2B, C. The average score of sub-Saharan African countries was 53.67, while they had better scores in sub-indicators of surveillance and response, vector and reservoir interventions, natural protected areas, and leishmaniasis control. Figure 2A showed the 37 countries/territories with different shades of red color which reflected ranges of score. Amongst, South Africa had the highest score (71.99), suggesting that the country scored the highest OH performance for zoonoses. In other words, such a performance suggests its strong capacity in responding to or preventing zoonotic events. South Africa, Mauritius, Rwanda, Botswana, Mali, Tanzania, Nigeria, Kenya, Cote d’Ivoire, and Ethiopia are top-10 that had better OH performance for zoonoses, while Benin had the lowest score (40.51) (Table 2).

Indicators score of OHIZ in the sub-Saharan African countries

Sub-Saharan African countries performed best in indicator of capacity building for zoonoses (76.80 ± 8.25), overall. Indicator scores obtained for route of transmission, source of infection, and outcomes (case-studies) were 60.64 ± 12.43, 55.41 ± 12.52, and 35.27 ± 10.03, respectively (Fig. 3A). The OHIZ score for indicator of targeted population (33.33 ± 28.87) was the lowest, overall, while it was not in normal distribution across the region. Following the indicators, South Africa got the highest score (89.03), while Benin got the lowest performance capacity (27.66) in responding to or preventing source of infection (Fig. 3B). For performance capacity in responding to or preventing route of transmission, the highest score was performed by Togo (81.15) and the lowest score was attributed to Cabo Verde (33.79) (Fig. 3C). Mali scored highest (70.39) in performance capacity for targeted population indicator, while Benin scored lowest (15.29), (Fig. 3D). For performance in capacity building for zoonoses, Sierra Leone ranked first (90.23), while the lowest score was identified in Chad (57.75) (Fig. 3E). In terms of outcomes (case-studies) for zoonoses, Mauritius had the highest performance (69.13) in responding to or preventing tuberculosis, COVI-19, echinococcosis, leishmaniasis, and rabies, collectively; whereas the Chad ranked lowest (18.86) (Fig. 3F). Details are provided in Table 2.

Sub-indicators score of OHIZ in the sub-Saharan African countries

The average capacity in strategy and regulation to respond to and prevent source of infection for sub-Saharan African countries was scored 39.55 for national guideline for surveillance/control, while it was 17.24 and 80.64 for national...
legislation on animal reservoirs and zoonoses capacity score, respectively. In addition, the average scores of sub-Sahara African countries in surveillance and response to source of infection, were 85.83 for general surveillance, 80.84 for vector control, and 69.59 for wildlife reservoirs control; while in sanitation, the average capacity was estimated at 40.32 for basic sanitation services (Fig. 4B).

The average score for detection in responding to and preventing route of transmission for laboratory testing for zoonotic reservoirs (vectors and animals) in sub-Sahara African countries was 45.05. The average score for policy adoption of insecticide-treated mosquito nets was 90.93, that for policy adoption of indoor residual spraying was 85.68, and that for prevention chemotherapy coverage of zoonoses was 43.81, in terms of capacity of vector and reservoir interventions (Fig. 4C).

Sub-Saharan African scored 67.46 for costs directed to chemotherapy/vaccination of humans and 41.79 for proportion of population having basic drinking water and sanitation facilities in terms of capacity performance for population coverage and cost of interventions; while the average score was 37.52 for vaccination strategy and regulation vaccination in capacity of vaccine for target population (Fig. 4D).

The average scores of sub-Sahara African countries in capacity building were 57.42 for legislation of zoonosis educational activities, 75.49 for zoonoses prevention and control, 77.35 for zoonoses vaccine national plan, 54.59 for zoonotic events and the human-animal interface, 48.39 for zoonotic early warning, and 65.77 for emergency/surveillance system in health promotion for zoonoses; while the it was 94.77 for proportion of natural protected areas in terms of natural protected areas building (Fig. 4E).

OH index for the five zoonotic diseases that were assessed in this study, revealed the highest score of human DALYs of leishmaniasis (66.15), followed by those of echinococcosis (42.20), rabies (19.19), and tuberculosis (17.31). However, the capacity of sub-Sahara African countries in responding to and preventing COVID-19 scored an average of vaccination coverage estimated at 47.69 and that of infectious number at 34.56 (Fig. 4F).
Table 2: Indicator scores of OH performance on zoonoses in sub-Saharan Africa. Ranks included 37 sub-Sahara African countries.

| Country     | Zoonoses Score | Source of infection Score | Route of transmission Score | Targeted population Score | Capacity building Score | Outcomes (case-studies) Score |
|-------------|----------------|---------------------------|------------------------------|---------------------------|-------------------------|-------------------------------|
| South Africa| 71.99          | 89.03                     | 77.66                        | 67.30                     | 67.75                   | 46.45                         |
| Mauritius   | 68.02          | 80.14                     | 61.47                        | 62.24                     | 66.34                   | 49.13                         |
| Rwanda      | 65.93          | 68.80                     | 72.30                        | 59.25                     | 82.17                   | 41.18                         |
| Botswana    | 65.55          | 77.03                     | 64.66                        | 60.35                     | 76.39                   | 43.62                         |
| Mali        | 63.46          | 69.07                     | 60.31                        | 70.39                     | 86.78                   | 25.40                         |
| Tanzania    | 60.64          | 61.00                     | 68.12                        | 79.95                     | 15.36                   | 35.26                         |
| Nigeria     | 59.97          | 62.72                     | 65.86                        | 53.84                     | 76.46                   | 26.84                         |
| Kenya       | 59.45          | 58.14                     | 74.20                        | 57.09                     | 71.19                   | 26.84                         |
| Cote d'Ivoire| 58.86        | 65.15                     | 71.89                        | 46.52                     | 68.12                   | 32.55                         |
| Ethiopia    | 57.83          | 49.12                     | 66.86                        | 57.48                     | 88.58                   | 22.77                         |
| Togo        | 55.98          | 47.13                     | 80.15                        | 23.16                     | 85.07                   | 38.59                         |
| Burkina Faso| 55.88         | 54.94                     | 74.86                        | 35.42                     | 83.94                   | 20.31                         |
| Seychelles  | 55.50          | 73.29                     | 41.77                        | 25.13                     | 83.80                   | 58.01                         |
| Cameroon    | 54.69          | 54.80                     | 63.39                        | 38.41                     | 82.70                   | 29.49                         |
| Mozambique  | 54.68          | 55.04                     | 70.31                        | 17.65                     | 90.03                   | 35.51                         |
| Madagascar  | 53.63          | 60.71                     | 56.96                        | 27.16                     | 81.28                   | 39.75                         |
| Guinea      | 53.58          | 55.41                     | 67.46                        | 21.94                     | 86.79                   | 30.65                         |
| Dem. Rep. Congo | 52.78   | 61.70                     | 41.41                        | 57.50                     | 76.88                   | 25.18                         |
| Senegal     | 52.44          | 62.95                     | 69.79                        | 24.82                     | 62.84                   | 30.25                         |
| Namibia     | 52.12          | 53.41                     | 52.73                        | 34.36                     | 80.42                   | 40.14                         |
| Zimbabwe    | 52.06          | 51.17                     | 74.09                        | 15.29                     | 74.89                   | 37.68                         |
| Uganda      | 52.02          | 44.37                     | 77.60                        | 27.27                     | 73.52                   | 28.62                         |
| Ghana       | 51.42          | 55.01                     | 55.59                        | 33.93                     | 77.86                   | 31.57                         |
| Sudan       | 50.91          | 54.08                     | 42.12                        | 36.37                     | 85.69                   | 40.47                         |
| Malawi      | 50.56          | 51.59                     | 47.95                        | 42.43                     | 74.73                   | 36.80                         |
| Sierra Leone| 49.19          | 42.09                     | 56.60                        | 21.10                     | 90.23                   | 37.85                         |
| Niger       | 49.15          | 49.81                     | 69.45                        | 27.58                     | 67.23                   | 21.32                         |
| Lesotho     | 48.35          | 44.61                     | 52.52                        | 30.72                     | 79.64                   | 34.81                         |
| Gabon       | 47.28          | 58.38                     | 41.18                        | 27.50                     | 64.46                   | 46.02                         |
### Discussion

This study used a new-established evaluation system—OHIZ to assess OH performance for zoonoses through scores of indicators, and provided essential guidance and reference in zoonotic events prevention and control in sub-Saharan Africa.

The OHIZ datasets built in this study referred to relatively complete data for zoonoses, from international organizations and authoritative databases, such as WHO, OIE-WHAIS, FAO-EMPRES, WB, and GHS, GBD. Following the very recently developed assessment tool for OH performance [22, 23], we used indicators based on guidelines for OH and zoonoses, and generated OHIZ datasets that fit to research approaches for zoonoses from a global and holistic view.

The algorithm used for OHIZ in this study, referred to the GOHI algorithm system [34], which provided scores for 37 sub-Saharan African countries out of the 48. A total of 11 countries/territories excluded from this study were of low quality or presented with insufficient data for OHIZ calculation [23]. However, such an exclusion suggests that publicly available data that would reflect application of the OH approach for zoonoses control and prevention are needed.

Throughout the OHIZ scores identified by this study, only South Africa exceeded 70 in scores (71.99). Besides, five countries exceeded 60 in scores, and 12 countries were lower than 50 in scores, while the scores of all the countries were normally distributed on the whole (Fig. 2B). South Africa performed best in source of infection indicator and ranked first in height sub-indicators, alongside with scores above average in 22/28 sub-indicators. This suggests that OH initiatives for zoonoses, including capacity in surveillance and research activities are being successfully implemented in the country [21, 35], somehow. Mauritius ranked second behind South Africa for overall scores for zoonoses, with good performances in 3/5 indicators including the selected zoonotic case-studies (rank 1), source of infection (rank 2), and targeted population (rank 3). Such a performance aligns with the results following implementations of the strategic partnership for health security and emergence preparedness by the country in collaboration with the WHO and other international organizations [35]. Countries had inconsistent performances in different indicators and sub-indicators, suggesting implementation of some components of the OH approach to zoonoses, however. For example, Mali, Togo, and Sierra Leone ranked first, fifth, and twenty-sixth for overall scores, respectively. Remarkably, they got the highest score (first rank) for indicators of source of infection (Mali), route of transmission (Togo), and targeted population (Sierra Leone). These findings are consistent with (i) the OH project recently established in collaboration with the Swiss Tropical and Public Health Institute to tackle sources of zoonotic infections, e.g., as rabies, in Mali [20]; (ii) improvement in cross-border preparedness and response to zoonotic diseases in Togo [36]; (iii) establishment of a national multisectoral coordination and collaboration mechanisms to prevent, detect, and respond to public health threats in Sierra Leone [37], especially after the bitter experience of the Ebola outbreak response which served as an important catalyst for increased efforts to building the country’s capacity for...
health security and emergence preparedness. Furthermore, Benin ranked first in three sub-indicators and a number of height sub-indicators obtained above average scores, reflecting the country’s better performance in indicators of route of transmission and in zoonotic case-studies than that of South Africa. This suggests that, although its lowest overall score for zoonoses, Benin performed better for zoonotic diseases control, especially in responding better to tuberculosis, COVID-19, echinococcosis, leishmaniasis and rabies than South Africa did.

In the last two decades, human beings were suffered from zoonoses. Zoonoses prevention and control had issues like cross-border transmission and multi-disciplinary integration. The OH approach provides an opportunity to overcome these challenges. Besides, the development of OH between countries need to be synchronized. The OH concept has been raised at the beginning of the 21st century [38, 39] and gained much more attention in recent years [40]. However, OH practices are still ignored at both government and local levels.

This work provided OH performance for zoonoses and promoted awareness of OH by providing reference in OH practice, researches and applications of international assists for sub-Sahara African countries. However, the study was limited by 11 sub-Sahara African countries which presented with unfit or missing data and were excluded.

**Conclusion**

Indicators to assessing OH performance related to zoonoses are manifold, yet they are still not seemingly being embraced in developing countries, especially in the sub-Saharan Africa where zoonoses have the greatest impact. Findings from this study provide preliminary research information in advancing knowledge of the evidenced-risks to strengthen OH strategies for effective control of zoonoses and to support prevention of a next zoonotic event.

**Abbreviations**

AIDS, acquired immune deficiency syndrome  
BDI, Burundi  
BEN, Benin  
BFA, Burkina Faso  
BWA, Botswana  
CAF, Central African Republic  
CCV, cases of COVID-19  
CIV, Cote d’Ivoire  
CMR, Cameroon  
COD, Democratic Republic of Congo  
COVID-19, novel coronavirus disease  
CPV, Cabo Verde  
DALYs, disability-adjusted life years  
DTT, detection
ETH, Ethiopia
FAHP, fuzzy analytical hierarchy process
FAO, United Nations’ Food and Agriculture Organization
GAB, Gabon
GBD, global burden of disease
GHA, Ghana
GHDx, global health data exchange
GHS, global health security
GIN, Guinea
GOHI, global One Health index
HDE, human DALYs of echinococcosis
HDL, human DALYs of leishmaniasis
HDR, human DALYs of rabies
HDT, human DALYs of tuberculosis
HPZ, health promotion for zoonoses
IMS, inhabitants below 5 meters above sea level
KEN, Kenya
LBR, Liberia
LSO, Lesotho
MDG, Madagascar
MERS, middle east respiratory syndrome
MLI, Mali
MOZ, Mozambique
MRT, Mauritania
MUS, Mauritius
MWI, Malawi
NAM, Namibia
NER, Niger
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**Availability of data and materials**

The full study protocol and the datasets, are available, following manuscript publication, upon request from the corresponding author Kokouvi Kassegne (kassegnek@sjtu.edu.cn).

**Authors’ contributions**

Conception and study design: KK. Data collection: H-QZ, S-WF, J-XY, QL, T-GJ, YZ, and KK. Data analysis: H-QZ, J-BX, Z-YG, L-FH, X-XZ, and SX. Supervision: YZ and KK. Writing-original draft: H-QZ, S-WF, and J-XY. Writing-review & editing: J-XS, X-KG and KK.

**Competing interests**

The authors have no other competing interests to disclose.

**Consent for publication**

Not applicable.

**Ethical approval and consent to participate**

Not applicable.

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Figures

Figure 1

Flow chart for the processes involved in the assessment of OH performance for zoonoses.

Figure 2
OHIZ overall scores of sub-Saharan African countries. (A) Sub-Saharan African countries OHIZ map. (B) OHIZ scores of sub-Saharan African countries. Data statistics included 37 sub-Saharan African countries. (C) Scores trend chart of sub-Saharan African countries for all-level indicators of OHIZ. Sub-indicators are denoted by standing initial as follows: SR, strategy and regulation; SVR, surveillance and response; SNT, sanitation; DTT, detection; VRI, vector and reservoir interventions; VNR, vaccination regulation; PCI, population coverage and cost of interventions; IMS, inhabitants below 5 meters above sea level; HPZ, health promotion for zoonoses; NPA, natural protected areas; CCV, cases of COVID-19; HDE, human DALYs of echinococcosis; HDL, human DALYs of leishmaniasis; HDR, human DALYs of rabies; HDT, human DALYs of tuberculosis.

Figure 3

OHIZ scores density of sub-Saharan African countries. (A) Score density of OHIZ indicators in sub-Saharan Africa. (B-F) Scores of OHIZ indicators across sub-Saharan Africa. Sub-Saharan African countries were ranked from left to right according to indicator scores. ZAF, South Africa; MUS, Mauritius; RWA, Rwanda; BWA, Botswana; MLI, Mali; TZA, Tanzania; NGA, Nigeria; KEN, Kenya; CIV, Cote d’Ivoire; ETH, Ethiopia; TGO, Togo; BFA, Burkina Faso; SYC, Seychelles; CMR, Cameroon; MOZ, Mozambique; MDG, Madagascar; GIN, Guinea; COD, Democratic Republic of Congo; SEN, Senegal; NAM, Namibia; ZWE, Zimbabwe; UGA, Uganda; GHA, Ghana; SDN, Sudan; MWI, Malawi; LSO, Lesotho; GAB, Gabon; ZAM, Zambia; BDI, Burundi; CPV, Cabo Verde; LBR, Liberia; TCD, Chad; CAF, Central African Republic; MRT, Mauritania; BEN, Benin.

Figure 4

Dataset scores of OHIZ in sub-Saharan African countries. (A) Score scatter of OHIZ indicators. Data statistics included 37 sub-Saharan African countries. Indicators are denoted by standing initial as follows: SI, Source of infection; RT, Route of transmission; TP, Target population; CB, Capacity building; CS, Outcomes (case-studies). (B-E) Score scatter of OHIZ datasets. Data statistics included 37 sub-Saharan African countries. Datasets are denoted by standing initial as follows: NGS, National guideline for surveillance/control; NLR, National legislation on animal reservoirs; ZCS, Zoonoses capacity score; GSV, General surveillance; VTC, Vector control; WRC, Wildlife reservoirs control; BSS, Basic sanitation services; LTR, Laboratory testing for zoonotic reservoirs (vectors and animals); PAN, Policy adoption of insecticide-treated mosquito nets; PAS, Policy adoption of indoor residual spraying; PCC, Prevention chemotherapy coverage of zoonoses; VSR, Vaccination strategy and regulation vaccination; PPF, Proportion of population having basic drinking water; CCV, Costs directed to chemotherapy/vaccination of humans; NIL, Number of inhabitants below 5 meters above sea level; LEA, Legislation of zoonosis educational activities; PCZ, Prevention and control of zoonoses; NPV, National plan for zoonoses vaccine; ZEI, Zoonotic events and human-animal interface; EWZ, Early warning for zoonoses; ESS, Emergency/surveillance system; NPA, Proportion of natural protected areas; INC, Infections number of COVID-19; VCC, Vaccination coverage for COVID-19; ECD, Echinococcosis DALYs; LMD, Leishmaniasis DALYs; RBD, Rabies DALYs; TBD, Tuberculosis DALYs.

Supplementary Files

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