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China's application of the One Health approach in addressing public health threats at the human-animal-environment interface: Advances and challenges

Jing-Shu Liu [a,b,1], Xin-Chen Li [a,b,1], Qi-Yu Zhang [a,b,1], Le-Fei Han [a,b], Shang Xia [c], Kokouvi Kassegne [a,b], Yong-Zhang Zhu [a,b], Kun Yin [a,b], Qin-Qin Hu [a,b], Le-Shan Xiu [a,b], Xiang-Cheng Wang [a,b], Odel Y. Li [c,d], Min Li [a,b], Zheng-Bin Zhou [c], Ke Dong [a,b], Lu He [a,b], Shu-Xun Wang [a,b], Xue-Chen Yang [a,b], Yan Zhang [a,b], Xiao-Kui Guo [a,b], Shi-Zhu Li [a,b,c,*,2], Xiao-Nong Zhou [a,b,c,*,2], Xiao-Xi Zhang [a,b,*,2]

[a] School of Global Health, Chinese Center for Tropical Diseases Research, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China
[b] One Health Center, Shanghai Jiao Tong University-The University of Edinburgh, Shanghai 200025, China
[c] National Institute of Parasitic Diseases at Chinese Center for Disease Control and Prevention (Chinese Center for Tropical Diseases Research), NHC Key Laboratory of Parasite and Vector Biology, WHO Collaborating Centre for Tropical Diseases, Shanghai 200025, China
[d] Shanghai Legislative Research Institute, Shanghai 200003, China

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ABSTRACT

Background: Due to emerging issues such as global climate change and zoonotic disease pandemics, the One Health approach has gained more attention since the turn of the 21st century. Although One Health thinking has deep roots and early applications in Chinese history, significant gaps exist in China's real-world implementation at the complex interface of the human-animal-environment.

Methods: We abstracted the data from the global One Health index study and analysed China's performance in selected fields based on Structure-Process-Outcome model. By comparing China to the Belt & Road and G20 countries, the advances and gaps in China's One Health performance were determined and analysed.

Findings: For the selected scientific fields, China generally performs better in ensuring food security and controlling antimicrobial resistance and worse in addressing climate change. Based on the SPO model, the "structure" indicators have the highest proportion (80.00%) of high ranking and the "outcome" indicators have the highest proportion (20.00%) of low ranking. When compared with Belt and Road countries, China scores above the median in almost all indicators (16 out of 18) under the selected scientific fields. When compared with G20 countries, China ranks highest in food security (scores 72.56 and ranks 6th), and lowest in climate change (48.74, 11th).

Conclusion: Our results indicate that while China has made significant efforts to enhance the application of the One Health approach in national policies, it still faces challenges in translating policies into practical measures. It is recommended that a holistic One Health action framework be established for China in accordance with diverse social and cultural contexts, with a particular emphasis on overcoming data barriers and mobilizing stakeholders

Abbreviations: GBD study, global burden of disease study; DALYs, disability-adjusted life years; SARS, Severe acute respiratory syndrome; COVID-19, Coronavirus disease 2019; BCE, before the Common Era; GOHI, global One Health index; G20, The Group of Twenty; B&R, Belt & Road; AMR, antimicrobial resistance; FAHP, fuzzy analytical hierarchy process; SPO, Structure-Process-Outcome; BRI, Belt and Road Initiative; AI, artificial intelligence; PM2.5, atmospheric particulate matter (PM) that has a diameter of less than 2.5 micro-metres; PM10, atmospheric particulate matter (PM) that has a diameter of less than 10 micro-metres; RNAS+, the Regional Network for Asian Schistosomiasis and Other Helminth Zoonoses.

* Corresponding authors at: School of Global Health, Chinese Center for Tropical Diseases Research, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China.

E-mail addresses: lisz@chinacdc.cn (S.-Z. Li), zhouxn1@chinacdc.cn (X.-N. Zhou), zhangxiaoxi@sjtu.edu.cn (X.-X. Zhang).

[1] Jing-Shu Liu, Xin-Chen Li and Qi-Yu Zhang contributed equally to this work.

[2] Joint corresponding authors.

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both domestically and globally. Implementation mechanisms, with clarified stakeholder responsibilities and incentives, should be improved along with top-level design.

1. Introduction

In the 21st century, China's rapid economic development has made it the second-largest economic body in the world. However, this growth has caused several public health threats, including severe air pollution, food additive overuse, and antibiotic abuse due to the lack of holistic thinking between human, animal, and environmental health. According to the Global Burden of Disease (GBD) study, around 1 million premature deaths were attributed to air pollution in 2015 and 21.8 million disability-adjusted life years (DALYs) were lost in China [1]. As such, Chinese policymakers are proactively promoting development in One Health to confront these threats.

Zoonotic diseases like severe acute respiratory syndrome (SARS) and coronavirus disease 2019 (COVID-19) raised international awareness of the One Health approach to resolving complex health threats [2]. The One Health concept has deep roots in ancient Chinese philosophy. Early in the Warring States Period (475–221 BCE), Taoism believed that man and nature have the same origin and advocated for the peaceful coexistence of humans and nature [3]. It promoted treating humans, animals, plants, and the environment as a single entity for sustainable development, forming the cultural origin of China's One Health development. Since the 1950s, China has implemented cross-sectoral strategies in its national schistosomiasis control programme with sectoral cooperation and community participation and the concurrent treatment of humans and animals was promoted, as well as environmental modification to control snail hosts. These strategies consistent with the One Health concept have contributed to the control and elimination of schistosomiasis in southern China [4]. Another example is that in the early days of the People's Republic of China, epidemic diseases and medicine shortages prompted the central government to launch the Patriotic Health Campaign. Through a community-based anti-epidemic movement, this campaign targeted the "four pests" (rats, flies, mosquitoes, and grain-eating sparrows) which spread infectious pathogens [5]. This long and comprehensive public health movement in China is considered innovative. These are representative of successful regional applications, indicating that the One Health approach implemented in China has made great achievements in advancing society.

In recent years, the Chinese government has made significant efforts in formulating policies, investing funds, and advancing technologies, emphasizing the importance of human-nature harmony. China has improved a series of national-level plans to address pressing issues such as zoonotic infectious diseases control, antimicrobial resistance, and climate change, which have been integrated into the National Strategy of Sustainable Development and Healthy China [6]. Within academia, a Chinese consortium on One Health was established in 2021 [7], several symposiums on One Health were held in China, and more research centres for One Health were established in universities, research institutions, and the Chinese Centre for Disease Control and Prevention [8]. However, significant gaps still exist in the real-world practice of implementing the One Health approach in China.

To catalogue the current state and identify gaps and research priorities in One Health development, our research team developed the global One Health index (GOHI) for the assessment of One Health capacity at a global level in 2022. The four main functions of GOHI are: (i) to assist in the early detection of gaps in health practices, (ii) to deepen the understanding of the close relationship between human, animal, and environmental health and optimise decision-making on health-related issues, (iii) to help countries and regions understand deficiencies and gaps in the development of One Health, and (iv) to promote the determination of priorities for international cooperation [9].

Therefore, based on the results of the GOHI pilot studies [10–12], we reviewed the performances of China in comparison with the G20 and Belt & Road (B&R) countries to shed light on the advances and challenges of China in constructing a One Health system. Our review also provides evidence for determining the priorities of policy design to cope with the public health threats at the complex human-animal-environment interface in China.

2. Material and methods

In our previous study of the GOHI, a cell-like framework was generated to conduct the construction of the index (See Fig. A.1 in Appendix A). Four levels of metrics were developed, including category indicators, key indicators, indicators, and sub-indicators (see Table B.1 in Appendix B for the list of GOHI metrics we analysed in this study). A fuzzy analytical hierarchy process (FAHP) was adopted to determine the weights of indicators. For normalization, we scaled each sub-indicator using its highest and lowest values. The weighted sum of the scores of the lower-level indicators was derived from the following equation to obtain the scores of the upper-level indicators.

$$\text{Indicator score}_{ih} = \sum_{1_h}^{m_h} S_{ij_h} \times W_{j_h}, \sum_{1_h}^{m_h} W_{j_h} = 1$$

where m denotes the total number of the sub-indicators under the h-th indicator, j_h denotes the j-th sub-indicator under the h-th indicator, S_{ij_h} denotes the score of the j_h-th sub-indicator in the i-th country and W_{j_h} denotes the weight of the j_h-th sub-indicator. See more details of the methodology of GOHI in Appendix A.

We abstracted the scores and indicators from the GOHI study and analysed China's performance in selected scientific fields including zoonotic diseases, food security, antimicrobial resistance (AMR) and climate change. The selection of these issues for analysis follows our previous work on the framework of the global One Health index [10], which is also consistent with the six action tracks proposed in One Health Joint Plan of Action (2022–2026) launched by the Quadripartite [13].

In this study, we identified China's advances and challenges in One Health practice from different perspectives, based on the scores of China and other countries included in GOHI.

In order to shed light on the overall landscape of China's One Health development in selected scientific fields, we reviewed China's rankings among all involved countries (146 in total) in 4 key indicators, 18 indicators and 58 sub-indicators, which have also been categorized into four divisions based on quartiles (tier 1–4).

Adapting Structure-Process-Outcome (SPO) model [14], we classified the 18 indicators of GOHI (C3.4 – C5.3) into three categories of structure, process and outcome, based on the rules:

(i) Structure indicators are those measuring the resource input, regulation and policy, physical environment and social preparedness for One Health applications.
(ii) Process indicators are those measuring the effectiveness of carrying out the One Health intervention measures and implementation strategies.
(iii) Outcome indicators are those measuring the effectiveness of the One Health intervention measures and implementation strategies (see Table B.2 in Appendix B for details on classifications).

China's performances in these three categories have been compared based on the percentages of indicators in which China ranks in tier 1 and tier 4. This comparison informs our understanding of China's capacity

building for the lifecycle of One Health promotion and implementation.

The Belt and Road Initiative (BRI) aims to promote connectivity and cooperation globally through policy coordination, infrastructure connectivity, unimpeded trade, financial integration and closer people-to-people ties [15]. Under this initiative, China has expanded co-operations with countries in economics, health [16], climate change [17], etc. Comparing the GOHI scores of B&R countries with that of China contributes to identifying the priorities for further international cooperation in One Health development. Therefore, we visualized the indicator' scores of China and other B&R countries in four scientific fields. Furthermore, we calculated the deviations of China's scores from the median scores of B&R countries among different indicators and presented the list of indicators with largest deviations. See Table B.3 in Appendix B for the country list of B&R countries.

Evidence has proven that social, economic factors play important roles in promoting health [18]. Our GOHI pilot study also found that many developed countries performed well in One Health development [11]. Hence, we compared the performance of China in sub-indicators with developed countries in G20 to identify China's weakness in practicing and implementing One Health approach, with analysis providing cues to understand the underlying causes of One Health disparities. See Table B.4 in Appendix B for the country list of G20 countries.

3. Results

3.1. Overview of China's rankings in selected scientific fields

In a previous study, our team showed that China's GOHI total score is 56.34 and that it ranks 21st out of 146 countries. Fig. 1 shows that all the four key indicators rank in tier 1. Among the eighteen indicators, eleven are in tier 1, two in tier 2, three in tier 3, and two in tier 4. Those ranked in tier 1 are mainly from food security (4/11) and AMR (4/11), while those ranked in tier 4 are all from climate change, indicating that China performs generally better in ensuring food security and controlling AMR. See Table B.5 in Appendix B for China's score and ranking of each indicator in four scientific fields.

3.2. The pattern of China's rankings in the indicators based on the SPO model

Based on the SPO model, five indicators have been classified into the structure category, eight classified as process, and five classified as outcome. Table 1 shows that, compared to other categories, structure indicators make up the highest proportion (80.00%) in tier 1 (the denominator is the total number of indicators in the corresponding category), and outcome indicators make up the highest proportion (20.00%)

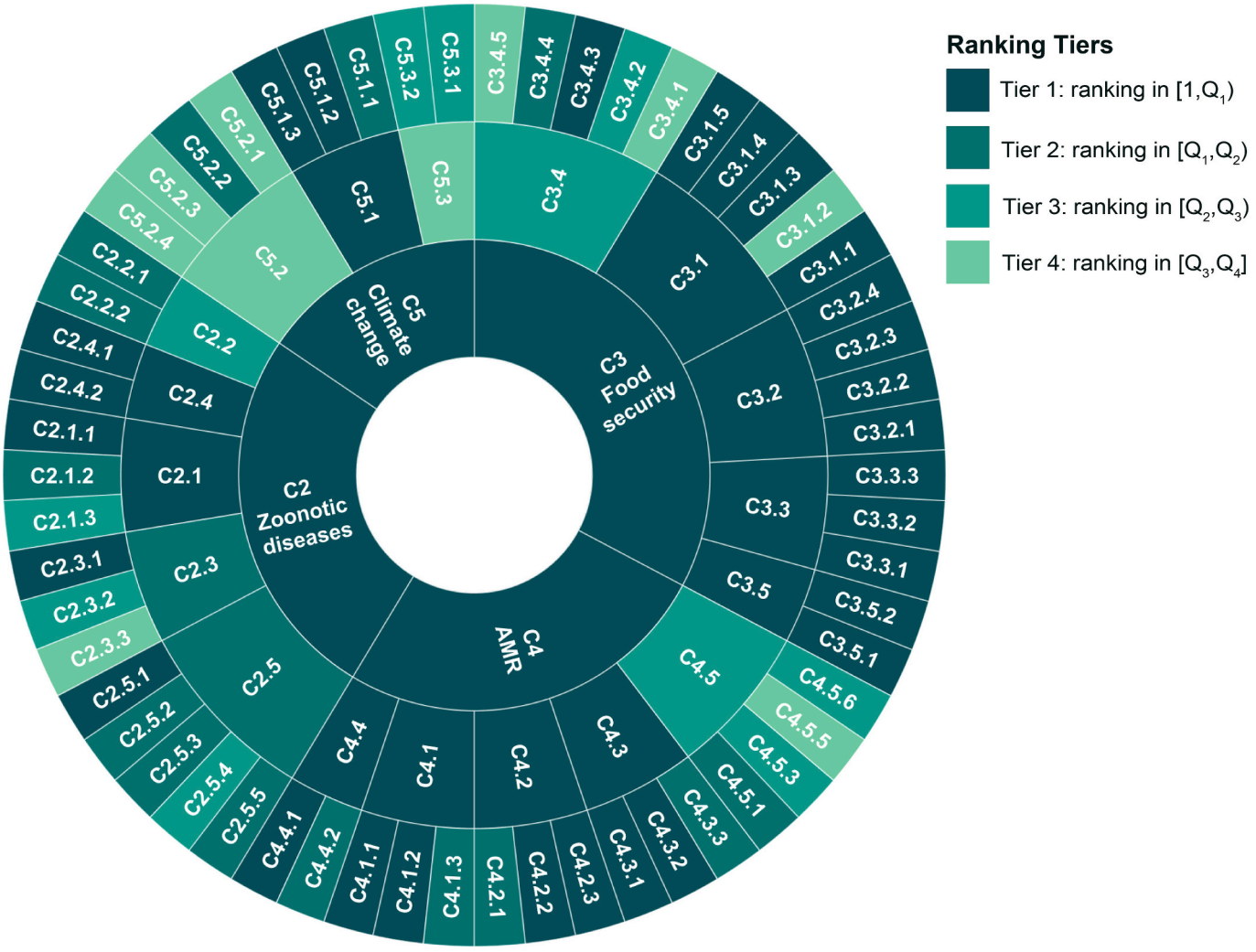

Fig. 1. China's rankings in selected scientific fields (zoonotic diseases, food security, antimicrobial resistance, climate change) across all indicators of the global One Health index (GOHI) among 146 countries. China's rankings were divided into four quantiles. Tier 1 represents rankings of 1st ~ 36th, tier 2 represents rankings of 37th ~ 72nd, tier 3 represents rankings of 73rd ~ 108th and tier 4 represents rankings of 109th ~ 146th (for detailed rankings of China see Table B.5 in Appendix B). Four key indicators: C2, C3, C4, C5. 18 indicators: C2.1 ~ C5.3. 58 sub-indicators: C2.1.1 ~ C5.3.2.

Table 1
The percentages of indicators in which China ranks in tier 1 and tier 4 based on the SPO (Structure-Process-Outcome) category.

Category	Total [a]	Tier 1		Tier 4	
		Number	Percentage (%) [b]	Number	Percentage (%) [c]
Structure	5	4	80.00	0	0.00
Process	8	5	62.50	1	12.50
Outcome	5	2	40.00	1	20.00

Note: [a] Total number of the indicators within each category; [b] Percentages of the indicators in which China ranks in tier 1 within each SPO (Structure-Process-Outcome) category. [c] Percentages of the indicators in which China ranks in tier 4 within each SPO (Structure-Process-Outcome) category.

in tier 4.

3.3. Comparative analysis of China's One Health performance among B&R countries

Compared to the B&R countries, China scores above the median in the majority of indicators (16 out of 18) under the selected scientific fields (Fig. 2).

Meanwhile, China's scores have the largest deviation above the median value of the B&R countries (Table 2) in the following aspects:

- In the field of zoonoses: leishmaniasis control and immunization coverage;
- In the field of food security: surveillance system building, high-tech use, and foodborne disease control;
- In the field of AMR control: technical promotion, raising awareness, and optimisation;
- In the field of climate change: knowledge building, intervention strategy, and policy response.

China's scores have the largest deviation below the median value of the B&R countries in the following aspects:

- In the field of zoonoses: rabies control;
- In the field of food security: food economics;
- In the field of AMR control: selected antibiotics resistance;
- In the field of climate change: air condition, greenhouse gas emissions, and fossil energy use.

See Table B.6 in Appendix B for China's score and deviation to the median score of B&R countries for each sub-indicator.

3.4. Comparative analysis of China's One Health performance among G20 countries

The scores and rankings of key indicators in all G20 and B&R

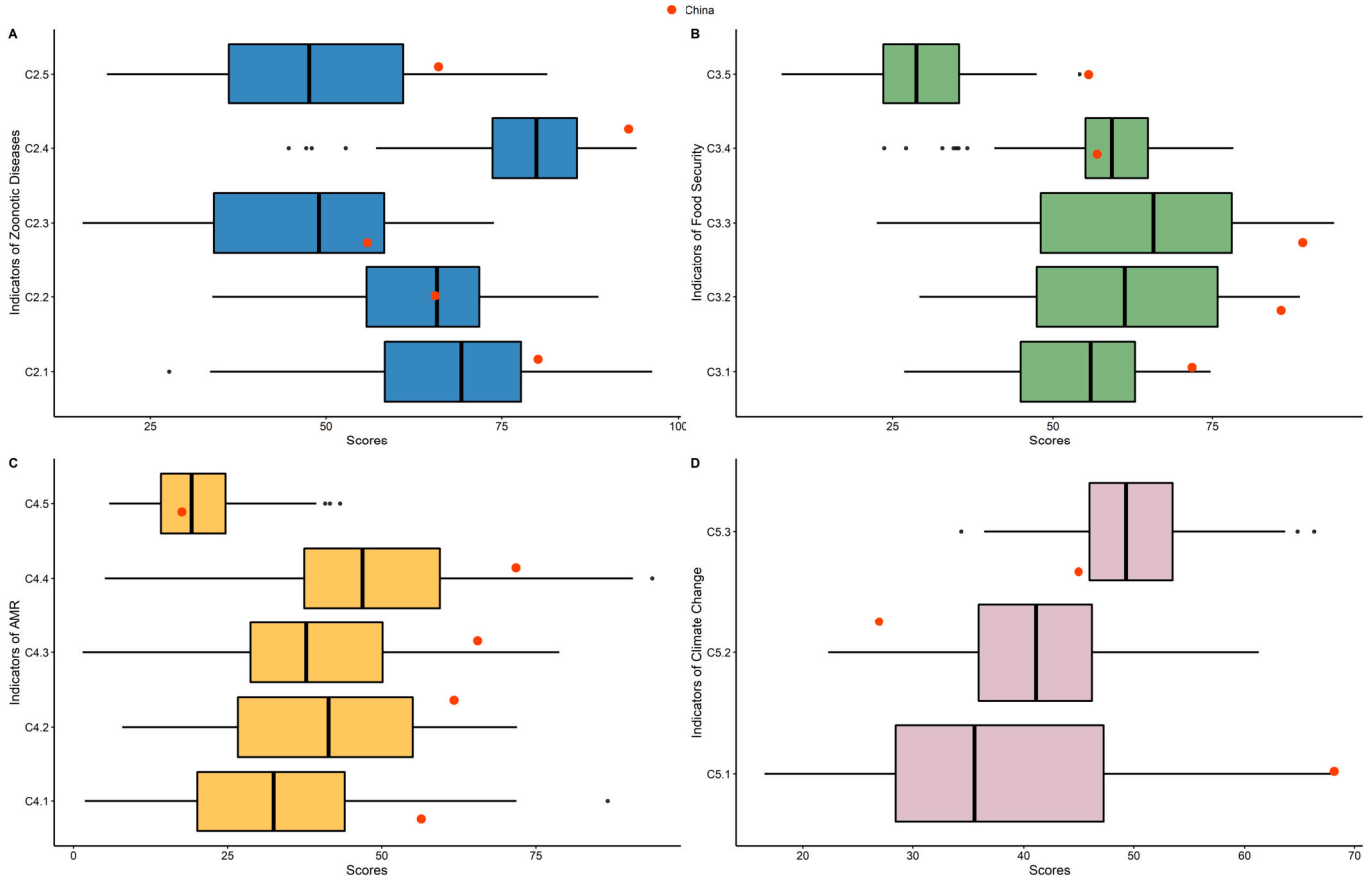

Fig. 2. The indicators' score distribution of China and other B&R countries in four scientific fields. The red points represent the score of China. The x-axis is the score of each indicator; the y-axis is the code of each indicator. See Fig. B.1 and B.2 in Appendix B for the score distributions of key indicators and sub-indicators for China and other B&R countries. (A) Indicators' score distributions in zoonotic diseases. (B) Indicators' score distributions in food security. (C) Indicators' score distributions in AMR. (D) Indicators' score distributions in climate change. C2.1 Source of infection, C2.2 Route of transmission, C2.3 Targeted population, C2.4 Capacity building, C2.5 Outcomes (Case-Studies), C3.1 Food demand and supply, C3.2 Food safety, C3.3 Nutrition, C3.4 Natural and social circumstances, C3.5 Government support and response, C4.1 AMR surveillance system, C4.2 AMR laboratory network and coordination capacity, C4.3 Antimicrobial control and optimisation, C4.4 Improve awareness and understanding, C4.5 AMR rate for important antibiotics, C5.1 Government response, C5.2 Climate change risks, C5.3 Health outcome. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
List of sub-indicators with the largest deviations above or below the median GOHI scores of B&R countries.

Scientific fields	Sub-indicators		Score (1)	Median of B&R (2)	Deviation to median [a] (3)
Zoonotic diseases	Largest deviation above median	C2.5.1 COVID-19 [b]	82.80	41.90	40.91
		C2.5.3 Leishmaniasis	98.59	65.37	33.23
		C2.3.1 Vaccine coverage	99.35	75.44	23.92
	Largest deviation below median	C2.3.2 Population coverage and intervention costs	44.61	46.01	−1.40
		C2.3.3 Inhabitants below 5 m above sea level [c]	31.83	44.73	−12.90
		C2.5.4 Rabies	32.62	47.60	−14.98
Food security	Largest deviation above median	C3.2.2 Food control and surveillance	92.31	28.06	64.26
		C3.2.4 Foodborne illness burden	89.71	55.87	33.85
		C3.5.2 Training and artificial intelligence (AI) agriculture performance score	50.00	16.67	33.33
	Largest deviation below median	C3.1.2 Food loss and waste	50.75	59.05	−8.30
		C3.4.1 Famine warning	77.85	86.68	−8.83
		C3.4.5 Food price indicators	46.09	55.28	−9.19
Antimicrobial resistance	Largest deviation above median	C4.2.2 Technical promotion score in AMR	93.75	43.75	50.00
		C4.4.1 Raising awareness and understanding	100.00	50.00	50.00
		C4.3.2 Optimisation of antimicrobial use	83.33	34.72	48.61
	Largest deviation below median	C4.2.1 National AMR capacity	37.52	36.44	1.08
		C4.5.6 Quinolone-resistance for *Klebsiella pneumoniae*, *Escherichia coli*, *Acinetobacter baumannii*	19.60	25.55	−5.95
		C4·5·5 Aminoglycosides-resistance for *Klebsiella pneumoniae* and *Acinetobacter baumannii*	13.27	24.84	−11.57
Climate change	Largest deviation above median	C5.1.2 Climate knowledge system	99.30	50.94	48.36
		C5.1.3 Climate intervention strategy	70.12	31.53	38.60
		C5.1.1 Climate policy	45.00	20.00	25.00
	Largest deviation below median	C5.2.1 Air condition	11.42	20.67	−9.25
		C5.2.4 Greenhouse gas emissions	38.70	53.11	−14.41
		C5.2.3 Energy use	22.52	51.85	−29.33

Note: [a] (3) = (1)–(2); [b] Data of COVID-19 in GOHI study is the reported infection number and vaccination coverage of the disease in 2021; [c] C2.3.3 Inhabitants below 5 m above sea level is not included in this discussion.

countries are shown in the Appendix B (Table B.4 and B.5). To precisely locate the gaps of China, we compare the scores of China and the best scores of G20 countries at the sub-indicators level.

China's smallest gaps to the best among the G20 countries (Fig. 3) are in following aspects:

- In the field of zoonoses: immunization coverage (score: 99.35, difference: 0.00), natural environment (100.00, 0.00), and COVID-19 control (82.80, 0.00);
- In the field of food security: food productivity (83.85, 0.00), foodborne disease control (89.71, 0.00), and high-tech use (50.00, 0.00);
- In the field of AMR control: antimicrobial consumption control (66.67, 0.00), national action plan formulation (62.50, 0.00), and awareness raising (100.00, 0.00);
- In the field of climate change: knowledge building (99.30, 0.00), intervention strategy (70.12, 0.00), and occurrence of extreme weather (42.83, 5.78).

China has considerable gaps to the best among G20 countries in these aspects:

- In the field of zoonoses: rabies (32.62, 67.38), tuberculosis control (57.28, 42.72), and living condition (31.83, 52.37);
- In the field of food security: value-added agriculture (46.18, 53.82), food loss and waste (50.75, 45.73), and food economics (46.09, 29.92);
- In the field of AMR control: surveillance of antimicrobials in the environment (20.92, 71.96), training for professionals (43.75, 50.00), and resistance to important antimicrobials (19.60, 46.92);
- In the field of climate change: policy response (45.00, 45.00), fossil energy use (22.52, 34.52), and air condition (11.42, 30.47).

4. Discussion

4.1. China's progress in improving top-level design on One Health implementation

Our results show that when classified using the SPO model, China performs better in structure indicators than process and outcome indicators. Combining this with literature review, we found that China had some advantages in top-level design on One Health implementation.

Firstly, China has made efforts to tackle zoonotic diseases, through policies, funds and technologies. It has enacted the *Infectious Diseases Prevention Law* and established special programmes for serious zoonotic diseases. The average annual growth rate of the Chinese government's budget for major infectious diseases between 2016 and 2020 was 3.31% [19] (excluding budget for COVID-19). In addition to promulgating and enhancing the *Wildlife Protection Law* and *the Animal Epidemic Prevention Law*, China has also enacted surveillance systems for both livestock and wildlife [20] to improve animal health.

Secondly, China has been addressing food security issues, including reduced arable land, growing food demand, and insufficient food surveillance. Policies such as the *National Agricultural Sustainable Development Plan* (2015–2030) and the *Food Safety Law* have been implemented, encouraging strategies like returning crop residues to fields, utilising organic fertilisers, and strict surveillance of food additive use. To reduce the massive amount of food waste, a national "clean your plate" promotion has been in place since 2013, followed by the *Anti-Food Waste Law* from 2021.

Thirdly, China has put extensive effort into controlling antibiotics, resulting in a decrease in antibiotic usage among hospitalised patients from 59.40% in 2011 to 36.00% in 2019 [21]. This achievement followed years of controlling clinical antibiotics between 2011 and 2013. In 2014, China has implemented the *National Action Plan to Contain Antimicrobial Resistance*, which was the first to resolve AMR problems from a holistic perspective. It stressed the importance of regulations in healthcare and agriculture, intersectoral collaboration with clear

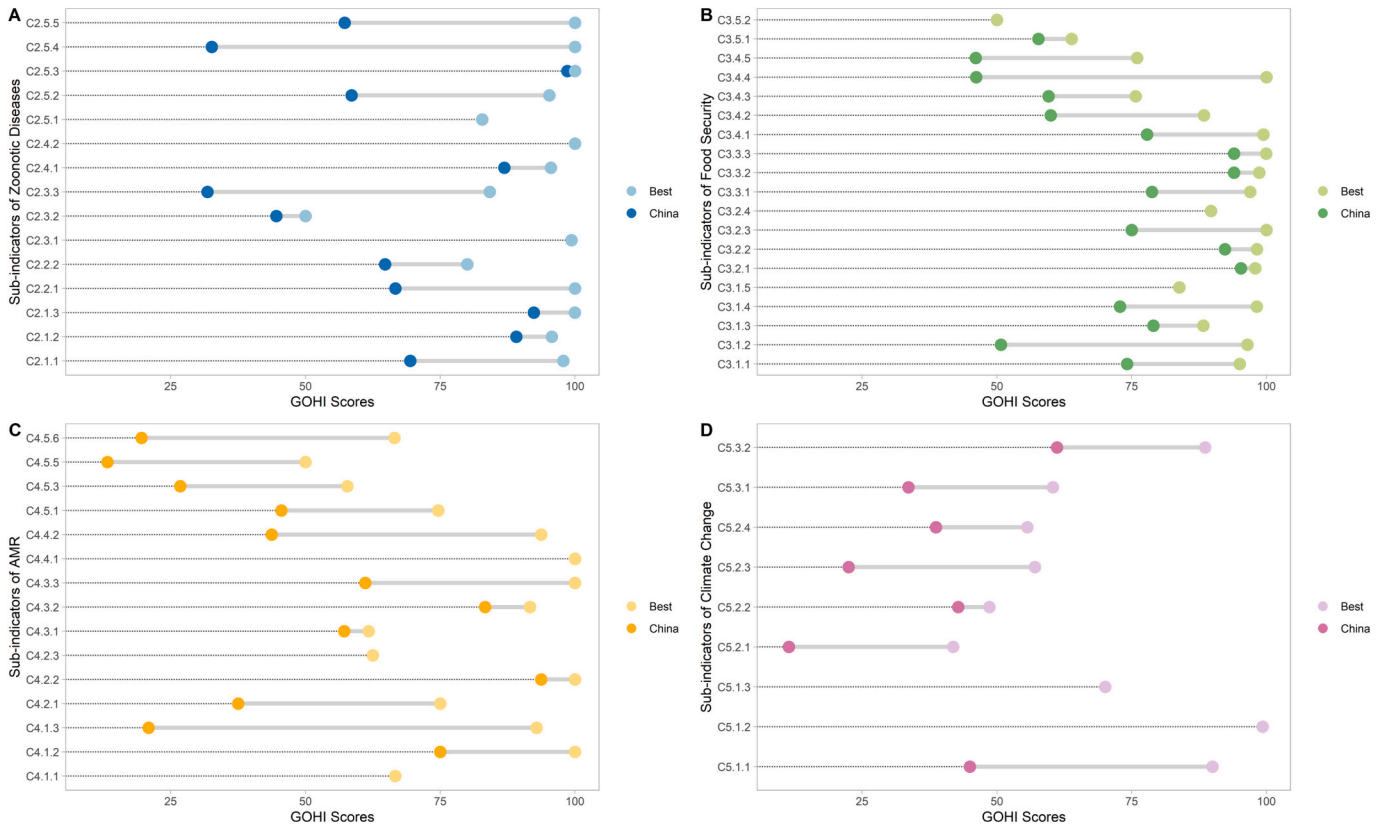

Fig. 3. The gap between the score of China and the best score of the G20 countries in sub-indicators of the global One Health index (GOHI). The x-axis is the score of each sub-indicator; the y-axis is the code of each sub-indicator, and the codebook is shown in Table B.1. The dark colour represents the score of China, and the light colour represents the best score of the G20 countries. (A) The gap between the score of China and the best score of the G20 countries in zoonotic diseases. (B) The gap between the score of China and the best score of the G20 countries in food security. (C) The gap between the score of China and the best score of the G20 countries in AMR. (D) The gap between the score of China and the best score of the G20 countries in climate change.

responsibilities, and management of environmental pollution.

Finally, China has confronted multiple climate-related problems and taken various measures. It has implemented the *National Program on Climate Change* (2007), the *Work Plan for Controlling Greenhouse Gas Emissions during the 12th Five-Year Plan Period* (2012), the *Action Plan on Prevention and Control of Air Pollution* (2013), and the *National Plan on Climate Change 2014–2020* (2014), etc. From 2013 to 2017, air pollution control actions have decreased PM2.5 annual average concentrations by 33.30% and PM10 by 27.80% [22]. The Chinese government has also pledged to reach the peak of carbon emissions by 2030 and carbon neutrality by 2060 to fulfil due responsibilities. So far, China's 2020 carbon emission intensity has dropped 18.80% from 2015 [23].

4.2. China's challenges in translating policies using One Health practice

According to our results, China lags behind G20 countries in controlling diseases such as rabies, improving sanitation, increasing added value in agriculture, optimising food production chains, monitoring animal and environmental antimicrobials, controlling air pollution and fossil energy use, etc.

China has encountered difficulties in translating policies into implementation strategies, leading to poorer performance in process and outcome indicators than in structure indicators. The reasons are multifaceted. Firstly, although China has a top-level design for several One Health issues, it lacks specific implementation mechanisms. For instance, although plans have been made for managing stray animals in China, little has been done to immunise and maintain sanitation of these animals, especially in rural areas [24], hindering the control of zoonotic diseases like rabies. Moreover, a dedicated government body for coordinating One Health affairs has not been launched yet in China, nor has a comprehensive and transparent shared data environment been established.

Secondly, China has a vast territory with significant variation between regions. Insufficient application of new ideas, technologies, and models in underdeveloped regions causes governance shortfalls in these areas. Although the current veterinary antibiotics policy is effective in some large-scale farms, supervision is lacking in small-scale farms operated by self-employed farmers in rural areas and many of them continue to use banned antibiotics [25]. The added value of China's agricultural production is low, indicating that China needs to enhance technological and management innovations in food production and processing, especially in less-developed regions. Financial incentives, such as environmental taxes and ecological compensation mechanisms have been underused to balance the economic and One Health development.

Moreover, there is a lack of public education and social awareness of One Health in China, the value of which is highlighted in the definition of One Health [2]. China imminently needs to foster a social culture that values animals and the environment.

4.3. China's opportunities ahead in enhancing partnerships for One Health development

The lessons from COVID-19 teach us that in an interconnected world, no country can survive a global health crisis alone without international cooperation and coordination. China has always actively participated in global health governance. Driven by international frameworks such as the BRI, in-depth international cooperation will present China and other countries with new solutions to One Health problems.

Firstly, China has been dedicated to achieving scientific

breakthroughs through international technical cooperation. After being certified for malaria elimination in June 2021, China has actively promoted its experience in Tanzania [26] and other areas in need. China has also established the Regional Network for Asian Schistosomiasis and Other Helminth Zoonoses (RNAS+) [27] with Philippines and other countries.

Secondly, China assists One Health products supply with international production and commerce. Under the B&R Strategic Cooperation Agreement, it has signed agricultural cooperation agreements with 86 co-construction countries in 2021, adding the possibility of establishing cooperative mechanisms for food security. China's free trade agreements with numerous countries have stimulated agricultural production and trade, as the average tariff level on Chinese agricultural products in 2018 was only 15.20%, a quarter of the global average [28].

Finally, with its growing economy, China's overseas development assistance has grown by 25.00% per year since 2010, reaching $7 billion by 2013 [29]. China has assisted a number of low- and middle-income countries through direct financial support, basic facilities, medical equipment, and human resources [30].

4.4. Establishment of a holistic One Health action framework in China

We recommend that China should further strengthen capacity building in One Health. Concrete implementation mechanisms, including government and stakeholder responsibilities and incentives, should be improved along with top-level design. While long-term and sustainable investments in funds, personnel, and facilities are required, the following deficiencies need to be overcome.

Firstly, data barriers should be removed by establishing a cross-field database based on comprehensive surveillance systems. Gaps in developing animal and environmental surveillance systems should be addressed, and data-sharing mechanisms should be standardised and transparent to expedite early detection and response to zoonotic disease outbreaks, natural disasters, and other emergencies.

Secondly, governments should tailor strategies to local socioeconomic and cultural contexts, especially for rural areas. Practitioners should consider the feasibility of One Health strategies and carry out cost-effectiveness evaluations for policy-making. Financial mechanisms, including fiscal tools and compensation strategies, should be creatively utilised to lessen the conflicts among stakeholders.

Finally, China lacks nationwide One Health education activities for social transformation from human health to One Health. Many education strategies are available for reference such as the Fukuoka One Health Action Plan [31]. The experiences with public education should be drawn on, such as the promotion of the 2017 "Healthy China 2030" strategy, which has established channels and mechanisms for future education work in constructing a One Health society.

In the latest edition of One Health proposed by the One Health High-Level Expert Panel, "shared and effective governance, communication, collaboration, and coordination" are stressed. Attention should be paid by policymakers to the integrity of the One Health system and avoiding governance fragmentation. Local governments along with stakeholders should overcome regional protectionism and departmentalism, actively collaborate and coordinate across sectors, disciplines, and regions, and improve stakeholder communication [32].

This study summarises the development of One Health in China using GOHI pilot study results. However, two limitations were identified: (i) it lacks time-scale data or analysis at different time points, and (ii) the current study contains only descriptive statistics while mathematical inferential models have not been applied. It is possible to further explore the causes for the current performance through higher-quality data and mathematical models. Additionally, GOHI currently only has national-level data and we expect to introduce provincial-level data in the future to develop a more precise description of China's One Health development.

5. Conclusion

China has taken significant strides to enhance the application of the One Health approach in policy and practice. However, it still faces challenges due to the complexity of eco-environmental changes domestically and globally, particularly at the primary level. It has been suggested that China should further eliminate the governance bottleneck in a systematic redesign for One Health and constructing a holistic One Health framework for social action. A stronger emphasis on communication, coordination, collaboration, and capacity building in practice should be placed on reshaping China's national development and international cooperation strategies for One Health. This would better enable China to confront public health threats at the human-animal-environment interface.

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CRediT authorship contribution statement

Jing-Shu Liu: Conceptualization, Data Curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Xin-Chen Li**: Conceptualization, Data Curation, Formal analysis, Investigation, Validation, Writing - original draft, Writing - review & editing. **Qi-Yu Zhang**: Conceptualization, Data Curation, Formal analysis, Investigation, Validation, Writing - original draft, Writing - review & editing. **Le-Fei Han**: Software, Validation, Writing - review & editing. **Shang Xia**: Software, Validation, Writing - review & editing. **Kokouvi Kassegne**: Validation, Writing - review & editing. **Yong-Zhang Zhu**: Validation, Writing - review & editing. **Kun Yin**: Validation, Writing - review & editing. **Qin-Qin Hu**: Validation, Writing - review & editing. **Le-Shan Xiu**: Validation, Writing - review & editing. **Xiang-Cheng Wang**: Validation, Writing - review & editing. **Odel Y. Li**: Validation, Writing - review & editing. **Min Li**: Validation, Writing - review & editing. **Zheng-Bin Zhou**: Validation, Writing - review & editing. **Ke Dong**: Validation, Writing - review & editing. **Lu He**: Validation, Writing - review & editing. **Shu-Xun Wang**: Validation, Writing - review & editing. **Xue-Chen Yang**: Validation, Writing - review & editing. **Yan Zhang**: Validation, Writing - review & editing. **Xiao-Kui Guo**: Validation, Writing - review & editing. **Shi-Zhu Li**: Supervision, Validation, Writing - review & editing. **Xiao-Nong Zhou**: Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing. **Xiao-Xi Zhang**: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing - original draft, Writing - review & editing.

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Ethical consideration

Not applicable.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Data availability

Data will be made available on request.

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References

[1] A.J. Cohen, M. Brauer, R. Burnett, H.R. Anderson, J. Frostad, K. Estep, et al., Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the global burden of diseases study 2015, Lancet 389 (2017) 1907–1918, https://doi.org/10.1016/S0140-6736(17)30505-6.

[2] WHO, Tripartite and UNEP Support OHHLEP's Definition of "One Health". https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhlep-s-definition-of-one-health, 2021 accessed 22 July 2022.

[3] M.M. Wang, An analysis of the inheritance and sublimation of Taoist thought, Chin. Charact. Cult. (2021) 187–188, https://doi.org/10.14014/j.cnki.cn11-2597/g2.2021.22.083 (in Chinese).

[4] L.D. Wang, H.G. Chen, J.G. Guo, X.J. Zeng, X.L. Hong, J.J. Xiong, et al., A strategy to control transmission of Schistosoma Japonicum in China, N. Engl. J. Med. 360 (2009) 121–128, https://doi.org/10.1056/NEJMoa0800135.

[5] Y. Hu, The patriotic hygiene campaign and the construction of clean new people, in: Hu Yi (Ed.), Rural Health Care Delivery: Modern China from the Perspective of Disease Politics, Springer Berlin Heidelberg, Berlin, 2013, pp. 111–126.

[6] China Daily, Full Text of Xi Jinping's Report at 19th Cpc National Congress. https://www.chinadaily.com.cn/china/19thcpcnationalcongress/2017-11/04/content_34115212.htm, 2017 accessed 6 January 2023.

[7] School of Global Health, Shanghai Jiao Tong University School of Medicine. School of Global Health, Chinese Consortium for One Health (CCOH), 2021. https://www.shsmu.edu.cn/sghen/Consortium/Chinese_Consortium_for_One_Health_CCOH_.htm. accessed 23 December 2022.

[8] Shanghai Jiao Tong University, SJTU and the University of Edinburgh Establish One Health Center. https://dzb.sjtu.edu.cn/En/Data/View/4520, 2020.

[9] X.X. Zhang, J.S. Liu, L.F. Han, G. Simm, X.K. Guo, X.N. Zhou, One health: new evaluation framework launched, Nature. 604 (2022) 625, https://doi.org/10.1038/d41586-022-01108-0.

[10] X.X. Zhang, J.S. Liu, L.F. Han, S. Xia, S.Z. Li, O.Y. Li, et al., Towards a global One Health index: a potential assessment tool for one health performance, Infect. Dis. Povert. 11 (2022) 57, https://doi.org/10.1186/s40249-022-00979-9.

[11] N. Zhou, Z. Cheng, X. Zhang, C. Lv, C. Guo, H. Liu, et al., Global antimicrobial resistance: a system-wide comprehensive investigation using the global One Health index, Infect. Dis. Povert. 11 (2022) 92, https://doi.org/10.1186/s40249-022-01016-5.

[12] H.Q. Zhao, S.W. Fei, J.X. Yin, Q. Li, T.G. Jiang, Z.Y. Guo, et al., Assessment of performance for a key indicator of one health: evidence based on one health index for Zoonoses in sub-Saharan Africa, Infect. Dis. Povert. 11 (2022) 109, https://doi.org/10.1186/s40249-022-01020-9.

[13] WHO, FAO, OIE, UNEP, One Health Joint Plan of Action (2022–2026): Working Together for the Health of Humans, Animals, Plants and the Environment, WHO, Geneva, 2022.

[14] A. Donabedian, Evaluating the quality of medical care, Milbank Quarter. 83 (2005) 691–729, https://doi.org/10.1111/j.1468-0009.2005.00397.x.

[15] Belt and Road Portal, The Belt and Road Initiative Progress, Contributions and Prospects. https://eng.yidaiyilu.gov.cn/p/86739.html, 2019 accessed 20 July 2023.

[16] Y.J. Qian, W. Ding, W.P. Wu, et al., A path to cooperation between China and Mongolia towards the control of echinococcosis under the Belt and Road Initiative, Acta Trop. 195 (2019) 62–67, https://doi.org/10.1016/j.actatropica.2019.04.022.

[17] China Daily, Green BRI to Push Global Low-Carbon Drive. https://eng.yidaiyilu.gov.cn/p/252742.html, 2022 accessed 20 July 2023.

[18] D.G. Vidal, G.M. Oliveira, M. Pontes, R.L. Maia, M.P. Ferraz, Chapter 6 - the influence of social and economic environment on health, in: J.C. Prata, A.I. Ribeiro, T. Rocha-Santos (Eds.), One Health, Academic Press, 2022, pp. 205–229.

[19] National Health Commission Ministry of Finance, Notice on the Release of the Budget for the Prevention and Control of Major Infectious Diseases in 2021. http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/202108/t20210816_3745364.htm, 2021 accessed 22 July 2022.

[20] H. Li, Y. Chen, C.C. Machalaba, H. Tang, A.A. Chmura, M.D. Fielder, et al., Wild animal and zoonotic disease risk management and regulation in China: examining gaps and one health opportunities in scope, mandates, and monitoring systems, One Health-Amsterdam. 13 (2021) 100301, https://doi.org/10.1016/j.onehlt.2021.100301.

[21] WHO, Antimicrobial Resistance. https://www.who.int/china/health-topics/antimicrobial-resistance, 2019 accessed 13 August 2022.

[22] J. Huang, X. Pan, X. Guo, G. Li, Health impact of China's air pollution prevention and control action plan: an analysis of National air Quality Monitoring and mortality data, Lancet Planet Health. 2 (2018) e313–e323, https://doi.org/10.1016/S2542-5196(18)30141-4.

[23] Xinhuanet.com, Full Text: Responding to Climate Change: China's Policies and Actions. https://eng.yidaiyilu.gov.cn/qwyw/rdxw/194163.htm, 2021 accessed 1 August 2022.

[24] W. Yin, J. Dong, C. Tu, J. Edwards, F. Guo, H. Zhou, et al., Challenges and needs for China to eliminate rabies, Infect. Dis. Povert. 2 (2013) 23, https://doi.org/10.1186/2049-9957-2-23.

[25] K. Schoenmakers, How China is getting its farmers to kick their antibiotics habit, Nature. 586 (2020) S60–S62, https://doi.org/10.1038/d41586-020-02889-y.

[26] Y.P. Mlacha, D. Wang, P.P. Chaki, T. Gavana, Z. Zhou, M.G. Michael, et al., Effectiveness of the innovative 1,7-malaria reactive community-based testing and response (1, 7-Mrctr) approach on malaria burden reduction in southeastern Tanzania, Malar. J. 19 (2020) 292, https://doi.org/10.1186/s12936-020-03363-w.

[27] H.M. Li, Y.J. Qian, K. Yang, W. Ding, L.L. Huang, X.J. Ma, et al., Assessment of China's contributions to the Regional Network for Asian Schistosomiasis and other helminth Zoonoses: a questionnaire survey, Glob Health Res Pol. 6 (2021) 7, https://doi.org/10.1186/s41256-021-00186-3.

[28] Xinhua News Agency, China and the World Trade Organization. http://www.gov.cn/zhengce/2018-06/28/content_5301884.htm, 2018 accessed 2022-08-08.

[29] K. Tang, Z. Li, W. Li, L. Chen, China's silk road and global health, Lancet. 390 (2017) 2595–2601, https://doi.org/10.1016/s0140-6736(17)32898-2.

[30] P. Liu, Y. Guo, X. Qian, S. Tang, Z. Li, L. Chen, China's distinctive engagement in global health, Lancet (London, England). 384 (2014) 793–804, https://doi.org/10.1016/S0140-6736(14)60725-X.

[31] Fukuoka Prefeture, Action Plan on One Health Promotion in Fukuoka. https://www.pref.fukuoka.lg.jp/contents/one-health-fukuoka-keikaku.html, 2022 accessed 15 January 2023.

[32] J. He, Z. Guo, P. Yang, C. Cao, J. Xu, X. Zhou, et al., Social insights on the implementation of one health in zoonosis prevention and control: a scoping review, Infect. Dis. Povert. 11 (2022) 48, https://doi.org/10.1186/s40249-022-00976-y.