Methods and Applications

Estimating Costs of the HIV Comprehensive Intervention Using the Spectrum Model — China, 2015–2019

Youran Zhang[1]; Lili Wang[1]; Zhen Jiang[2,#]; Hongjing Yan[3]; Xiaoxia Liu[4]; Jing Gu[5]; Guoyong Wang[6]; Xiaosong Cheng[7]; Qiyan Leng[7]; Qisui Long[8]; Zimian Liang[9]; Jing Wang[9]; Liang Liang[10]; Yanchao Qiu[11]; Lin Chen[12]; Hang Hong[13]

ABSTRACT

Introduction: In order to facilitate human immunodeficiency virus (HIV) treatment and prevention, the resource needs for HIV national strategic planning in developing regions were estimated based on Spectrum, the universal HIV cost-effectiveness analysis software.

Methods: Based on the theoretical framework of Spectrum, the study developed a cost measurement tool for HIV, and calculated the cost of HIV prevention and control in 6 sampled cities in China during 2015–2019 using the Spectrum model.

Results: From 2015 to 2019, the average annual costs for HIV prevention and control for Shijiazhuang, Yantai, Ningbo, Zhenjiang, Foshan, and Wuxi cities were 46.78, 47.55, 137.49, 24.73, 74.37, and 58.30 million Chinese yuan (CNY), respectively. The per capita costs were 4.37, 6.73, 17.33, 7.77, 17.56, and 8.91 CNY, respectively. In terms of the cost structure, the ratio of preventive intervention funds to therapeutic intervention funds (antiviral treatment) varied in sampled cities.

Discussion: Developing comprehensive and systematic HIV fund calculation methods can provide a research basis for rational resource allocation in the field of HIV.

INTRODUCTION

As China is striving to meet the Joint United Nations Programme on HIV/AIDS (UNAIDS) 90-90-90 targets, tracking and estimating resource needs is critical in informing financial decisions for human immunodeficiency virus (HIV) prevention and control programs.

Comprehensive HIV prevention and treatment covers various target populations, such as the general population, high-risk groups, infected persons, and a series of service providers including social organizations, community health institutions, CDCs, and hospitals. Sources of funding for prevention and treatment programs include the central government, local government, charitable funds, cooperation projects, and out-of-pocket payments from individuals. The diversity of service objectives, service providers, and funding sources leads to many uncertainties in regional HIV cost calculations.

Based on the theoretical framework of the international HIV cost-effectiveness analysis software Spectrum (1–2), our group developed a cost measurement and investigation tool for HIV (3) and calculated the cost of HIV prevention and control from the perspective of service suppliers. This was established by collecting and investigating the size of various populations, the actual coverage of various HIV interventions, and the unit cost of services. We estimated the cost of comprehensive HIV intervention in Shijiazhuang City from 2015 to 2019 (4). Then, based on this, we measured the HIV intervention costs of 6 cities in eastern China and compared the total costs and the composition change of HIV comprehensive intervention among these cities.

METHODS

The eastern cities of China are economically developed areas with dense populations in the secondary and tertiary sectors, large population mobility, many groups at high risk for HIV, and have better HIV intervention coverage and epidemiological records. Overall, 5 cities in eastern China including Shijiazhuang, Yantai, Ningbo, Foshan, and Wuxi (hereafter, these cities will be abbreviated as S, Y, N, F, and W, respectively) were selected according to 2 conditions: the total population was more than 3 million and the number of newly reported cases of HIV infection was more than 200 each year. In order

to increase the representativeness of urban samples, the research group added Zhenjiang City (in this paper will be abbreviated as Z; located in Jiangsu Province, the same as Wuxi City) with a population of 3 million and 50 newly reported cases of HIV infection each year.

Data was collected on population size, prevention of mother-to-child transmission (PMTCT), antiretroviral treatment (ART), population comprehensive prevention coverage and cost measurement, and program support. CDCs, designated treatment hospitals, and maternal and child health centers provided relevant quantitative data. If some unit costs were missing in one sampled city, we adopted the average value of available cities. If there were outliers (where the unit cost was drastically different from that

in other cities), we used the average value of the cities with reasonable values. The coverage of each HIV intervention service in each city collected in this study was completely subject to the results reported and checked by the six cities.

There were three sub-modules, including Demographic Model (Demproj), AIDS Impact Model (AIM), and Resource Needs Model (RNM), used for comprehensive evaluation of HIV interventions under Spectrum. DemProj Module was used to perform demographic projections by age and sex according to past fertility, mortality, and migration rates. The AIM Module was used to estimate HIV prevalence. RNM was used to generate cost estimates of various interventions (5). The employed coverages and unit costs were part of our previous work.

TABLE 1. Average annual coverage of HIV interventions in 6 cities from 2015–2019 (in person-time).

HIV intervention	S	Y	N	Z	F	W
Prevention						
Priority populations						
Youth focused interventions	3,150	0	46,369	243	32,330	1,426
Female sex workers and clients	2,131	1,538	18,646	2,985	10,641	6,072
Male sex workers and clients	62	0	0	0	0	0
Cash transfers	N/A	N/A	N/A	N/A	N/A	N/A
Injecting drug users	0	0	0	992	0	0
MSM	4,315	3,409	8,131	1,247	23,205	7,660
Community mobilization	255,351	196,606	376,180	857,149	199,889	171,267
Service delivery						
Condom provision	N/A	N/A	N/A	N/A	N/A	N/A
STI management	617	564	5,911	67	8,859	1,096
VCT	21,198	13,519	16,379	6,739	4,631	4,860
PrEP	0	0	0	0	0	0
PMTCT	2	1	4	1	4	5
Mass media	829,720	1,255,575	839,149	97,008	207,673	N/A
Health care						
Blood safety	294,311	595,350	N/A	N/A	N/A	74,229
PEP	0	67	552	0	0	0
Safe injection	N/A	N/A	N/A	N/A	N/A	N/A
Universal precautions	54,781	41,293	32,593	14,703	30,786	34,260
Care and treatment services						
ARV therapy	1,379	673	3,251	815	1,982	398
Non-ART care and prophylaxis	608	371	626	153	527	696

Note: N/A indicates missing data. The 6 cities include Shijiazhuang, Yantai, Ningbo, Zhenjiang, Foshan, and Wuxi, abbreviated as S, Y, N, Z, F, and W, respectively.
Abbreviations: HIV=Human immunodeficiency virus; MSM=Men who have sex with men; STI=Sexually transmitted infections; VCT=Voluntary counseling and testing; PrEP=Pre-exposure prophylaxis; PMTCT=Prevention of mother-to-child transmission; PEP=Post-exposure prophylaxis; ARV=AIDS-related virus; ART=Antiretroviral therapy.

RESULTS

Table 1 showed that for 2015–2019, routine HIV interventions in cities S, Y, N, Z, F, and W mainly included youth, female sex workers, and men who have sex with men (MSM) focused interventions, community mobilization, condom provision, sexually transmitted infection (STI) management, voluntary counseling and testing (VCT), PMTCT, mass media, blood safety, safe injection, universal precautions, and antiretroviral therapy (ARV). The coverage related to the interventions of condom promotion, blood safety, and safe injection was unavailable because their administration departments involved other departments, such as local Family Planning Department, blood bank, and hospital.

In order to make the costs more comparable, the gross domestic product (GDP) deflators of the six cities were obtained by referring to the regional GDP index (Supplementary Table S1, available in http://weekly.chinacdc.cn/). The 2019 GDP deflator was adopted to modify the projected costs. Then, the total and average annual cost of each intervention for each city was calculated.

There was an imbalance in the total costs and per-capita of HIV funds among cities (Table 2). From 2015 to 2019, the average annual costs of S, Y, N, Z, F, and W were 46.78 million Chinese yuan (CNY), 47.55 million CNY, 137.49 million CNY, 24.73 million CNY, 74.37 million CNY, and 58.30 million CNY, respectively. The per capita costs were 4.37 CNY, 6.73 CNY, 17.33 CNY, 7.77 CNY, 17.56 CNY, and 8.91 CNY, respectively. City N had the largest cost input in all service categories including priority population, service delivery, health care, treatment services and program support. City N reached 17.37 CNY per capita, city F reached 17.56 CNY per capita, and city S reached 4.37 CNY per capita. We plotted the three categories of cost results (prevention, treatment, and program support) displayed by Spectrum and calculated the cost ratio of preventive and therapeutic interventions.

Figure 1 showed that the comparable per capita cost of HIV finance increased steadily during 2015–2019 in all 6 cities. City N started at a high level and continued improving rapidly. The total cost ratio of prevention to treatment in 6 cities decreased from 0.79 in 2015 to 0.58 in 2019. The 6 cities had different manifestations in the cost changes for prevention and treatment interventions: 1) fluctuating: in city Y, the funds for prevention and treatment were in a stable fluctuating state. The ratio of prevention/treatment expenditure was around 1.8–1.4; 2) rapid increase in ARV: in city N, the investment of preventive intervention funds was stable, the cost of ARV funds increased from 24.79 million CNY in 2015 to 69.51 million CNY in 2019, and the ratio of prevention to treatment funds showed a rapid downward trend (from 1.25 in 2015 to 0.50 in 2019); 3) steady increase in ARV: in city Z, F, and W, the investment of preventive intervention funds was stable, the cost of ARV funds increased steadily, and the ratio of prevention/treatment funds showed a steady downward trend (from 0.88, 0.92, and 0.54 in 2015 to 0.59, 0.72, and 0.42 in 2019); 4) synchronous growth type: in city S, prevention and treatment funds maintained a synchronous growth trend (from 0.13 in 2015 to 0.20 in 2019).

DISCUSSION

A mature model with standardized data collection and information processing can generate more reliable estimates. Through standardized reports, the research results are reliable for decision-makers (6–7). Particularly, it may help to reasonably estimate the resources needed to expand, maintain, or replicate successful interventions at a local or national level.

Multiple data collection sources and incomplete information greatly increased the complexity of HIV disease-tracking modeling. Data reported by different departments and institutions may often conflict with each other. Developed jointly by the United Nations Programme on HIV/AIDS and other national teams, Spectrum software can estimate the cost of HIV/AIDS based on the mathematical model established by regional HIV/AIDS epidemic data and intervention program coverage (8). This provides a tool to calculate and compare HIV funds among subnational regions in China.

Our research reflected that HIV prevention and control funds continued to grow, but there was a regional imbalance in sampled cities. Based on the data of 2019, the comparable HIV intervention total cost in 6 cities adjusted by the GDP deflator showed an upward trend, indicating that each city had continuously increased investment in HIV prevention and control. In the most economically developed provinces, Guangdong and Zhejiang, the HIV prevention and control costs of the sampled cities were significantly higher than those of other cities.

TABLE 2. Costs of HIV interventions in 6 cities from 2015–2019 (in million CNY).

Cost for HIV Intervention	S	Y	N	Z	F	W
Prevention	7.29	27.90	33.96	8.95	30.26	16.15
Priority populations	0.96	2.61	14.80	0.88	14.61	4.76
Youth focused interventions	0.19	0.00	2.54	0.04	2.83	0.12
Female sex workers and clients	0.04	0.02	1.96	0.01	0.53	0.62
Male sex workers and clients	0.00[*]	0.00	0.00	0.00	0.00	0.00
Cash transfers	0.00	0.00	0.00	0.00	0.00	0.00
Injecting drug users	0.00	0.00	0.00	0.59	0.00	0.00
MSM	0.41[†]	0.37	0.85	0.07	1.23	0.98
Community mobilization	0.32	2.23	9.45	0.17	10.01	3.03
Service delivery[§]	1.59	4.78	12.15	2.96	6.89	1.54
Condom provision[§]	204.54	30.45	18.09	5.72	139.80	111.72
STI management	0.40	0.30	7.21	0.03	6.10	0.56
VCT	0.94	4.28	4.82	2.86	0.36	0.98
Male circumcision	0.00	0.00	0.00	0.00	0.00	0.00
PrEP	0.00	0.00	0.00	0.00	0.00	0.00
PMTCT[§]	8.37	0.08	0.76	0.18	1.51	0.04
Mass media	0.26	0.20	0.12	0.07	0.43	0.00
Health care[§]	4.74	20.51	7.01	5.11	8.76	9.85
Blood safety[§]	110.40	35.55	N/A	N/A	N/A	6.02
PEP	0.00	0.17	0.15	0.00	0.00	0.00
Safe injection	N/A	N/A	N/A	N/A	N/A	N/A
Universal precautions	4.74	20.34	6.86	5.11	8.76	9.85
Care and treatment services	37.16[†]	17.58	50.90	13.06	36.95	34.67
ARV therapy	17.06[†]	8.47	33.58	7.77	18.47	9.43
Non-ART care and prophylaxis	20.10[†]	9.10	17.32	5.30	18.48	25.25
Program support[§]	2.32	2.08	52.64	2.71	7.16	7.48
Enabling environment	0.00	0.00	0.00	0.00	0.00	0.00
Program management	1.28	0.71	44.40	0.80	0.93	5.19
Research	0.00	0.00	0.00	0.00	0.00	0.00
Monitoring and evaluation	0.04	0.07	0.00	0.07	0.12	0.41
Strategic communication	0.00	0.00	0.00	0.00	0.00	0.00
Logistics	0.06	0.37	5.92	0.41	3.08	0.83
Program-level HR	0.81	0.85	2.28	1.34	2.30	0.90
Training	0.13	0.07	0.04	0.10	0.73	0.15
Laboratory equipment[§]	1.36	2.8	3.01	27.11	30.97	N/A
Total millions of CNY[§]	46.78	47.55	137.49	24.73	74.37	58.30
Total populations	10,699,314	7,065,362	7,936,082	3,183,832	4,235,791	6,543,320
Per capita HIV intervention cost (CNY)	4.37	6.73	17.33	7.77	17.56	8.91
Cost ratio of prevention to treatment	0.20	1.59	0.67	0.69	0.82	0.47

Note: N/A indicates missing data. The 6 cities include Shijiazhuang, Yantai, Ningbo, Zhenjiang, Foshan, and Wuxi, abbreviated as S, Y, N, Z, F, and W, respectively.
Abbreviations: HIV=Human immunodeficiency virus; CNY=Chinese yuan; MSM=Men who have sex with men; STI=Sexually transmitted infection; VCT=Voluntary counseling and testing; PrEP=Pre-exposure prophylaxis; PMTCT=Prevention of mother-to-child transmission; PEP=Post-exposure prophylaxis; ARV=AIDS-related virus; ART=Antiretroviral therapy; HR=Human resource.
* The cost of male sex workers and clients in city S was not 0, but 2,654 CNY.
† The unit cost of this indicator in city S was quite different from the other cities, therefore, the average value of other cities filled in the unit cost had been taken.
§ To ensure the comparability of total costs in all cities, i.e., all sub cost items in 6 cities were the same, the total costs in this study did not include the costs of condom provision, PMTCT, blood safety, and laboratory equipment.
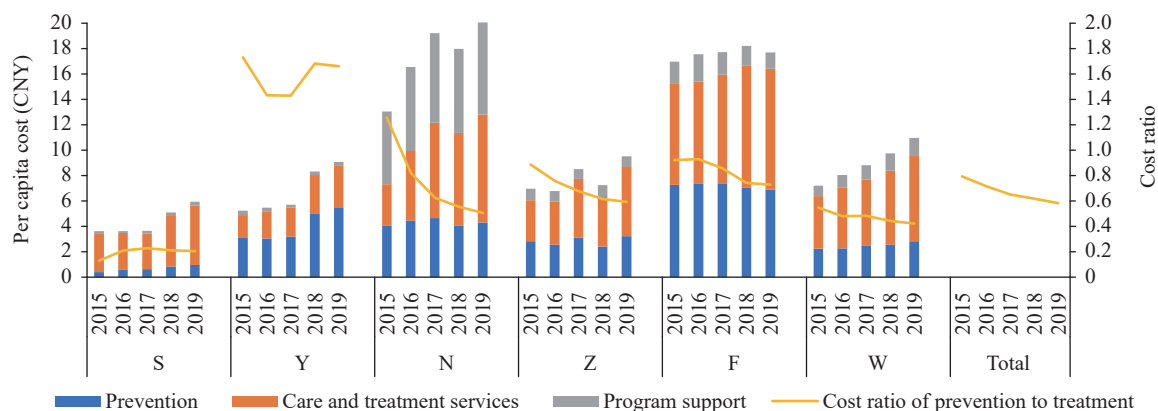
FIGURE 1. Per capita cost and cost ratio of prevention to treatment of 6 cities from 2015 to 2019.
Note: The 6 cities include Shijiazhuang, Yantai, Ningbo, Zhenjiang, Foshan, and Wuxi, abbreviated as S, Y, N, Z, F, and W, respectively.
Abbreviation: CNY=Chinese yuan.

Our research suggested that it is necessary to explore the correlation among preliminary work indicators, fund allocation, and subsequent intervention coverage and quality in the future. Differentiating reasonable and unreasonable factors of regional resource allocation will help to provide evidence for equitable and efficient resource allocation (9).

The distribution structure of funds for prevention and treatment must be balanced. With the continuous scaling-up of ARV, post-exposure prophylaxis (PEP), pre-exposure prophylaxis (PrEP), and other proven effective therapeutic interventions, investment in this area has increased rapidly worldwide. From 2015 to 2019, it was determined that HIV funding in these 6 cities was mainly due to the rapid growth of ARV costs. Evidence from the past 40 years indicated that scientific innovation, research, funding, activism, and policies were all central components of HIV messaging in ending HIV (10). It is necessary to simulate the list of prioritized interventions with high cost-effectiveness combined with the local population size, characteristics and HIV epidemic trend. An optimized HIV resource reallocation model may provide a reference for future intensive HIV investments (11–14).

This study was subject to some limitations. First, in the current tool, the costs were classified according to intervention services, which was different from the actual situation. For example, the provision of condoms involved multiple departments. It was difficult to collect multi-source data and may have resulted in underestimating related costs. In future studies, cost measurement tools consistent with the implementation will be more operable and more accurate. Second, the current cost measurement tools were still difficult to distinguish between the quantity and quality of HIV interventions and quantify each dimension. For example, there are great differences between the number of people receiving standardized STI management coverage and the number of people receiving STI treatment. This study estimated the cost according to the former indicators, which may have underestimated the total expenditure of STI treatment and management. The distinction and quantification of the "quality" and "quantity" of HIV intervention will increase the accuracy of cost estimation in the next step.

Corresponding author: Jiangzhen, jiangzhen@chinaaids.cn.

1 School of Health Service Management, Anhui Medical University, Hefei City, Anhui Province, China; 2 Division of Prevention and intervention, National Center for AIDS and STD Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing Municipality, China; 3 Jiangsu Provincial Center for Disease Control and Prevention, Nanjing City, Guangxi Zhuang Autonomous Region, China; 4 Zhenjiang Center for Disease Control and Prevention, Zhenjiang City, Jiangsu Province, China; 5 Wuxi Center for Disease Control and Prevention, Wuxi City, Jiangsu Province, China; 6 Shandong Provincial Center for Disease Control and Prevention, Jinan City, Jiangsu Province, China; 7 Yantai Center for Disease Control and Prevention, Yantai City, Shandong Province, China; 8 Guangdong Provincial Center for Disease Control and

Prevention, Guangzhou City, Guangdong Province, China; [9] Foshan Center for Disease Control and Prevention, Foshan City, Guangdong Province, China; [10] Hebei Provincial Center for Disease Control and Prevention, Shijiazhuang City, Hebei Province, China; [11] Shijiazhuang Center for Disease Control and Prevention, Shijiazhuang City, Hebei Province, China; [12] Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou City, Zhejiang Province, China; [13] Ningbo Center for Disease Control and Prevention, Ningbo City, Zhejiang Province, China.

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SUPPLEMENTARY TABLE S1. GDP deflator of 6 cities from 2015–2019.

City	Year	Gross regional product (Current year price, Unit: 100 million CNY)	Regional GDP index	Regional GDP deflator
S	2015	5,440.60	100.00	1.23
	2016	5,857.80	106.80	1.24
	2017	6,460.90	114.49	1.24
	2018	6,082.60	122.96	1.12
	2019	5,809.90	131.20	1.00
Y	2015	6,086.49	100.00	1.02
	2016	6,455.84	107.70	1.01
	2017	6,762.00	114.59	1.01
	2018	7,184.43	121.81	0.99
	2019	7,653.45	128.51	1.00
N	2015	8,295.35	100.00	0.91
	2016	8,972.83	107.20	0.92
	2017	10,146.55	115.67	0.92
	2018	11,193.14	123.77	1.00
	2019	11,985.12	132.18	1.00
Z	2015	3,088.47	100.00	0.97
	2016	3,435.73	109.30	0.99
	2017	3,847.79	117.17	0.99
	2018	3,847.79	120.80	1.00
	2019	4,077.32	127.81	1.00
F	2015	8,107.60	100.00	1.00
	2016	8,756.31	107.91	1.00
	2017	9,382.16	116.51	1.00
	2018	9,976.72	123.92	0.99
	2019	10,751.02	132.47	1.00
W	2015	8,681.37	100.00	0.97
	2016	9,340.16	107.50	0.97
	2017	10,313.07	115.46	0.97
	2018	11,202.98	124.00	1.01
	2019	11,803.32	132.18	1.00

Note: Data source: Statistical Yearbook of 6 cities; Shijiazhuang Statistical Yearbook in 2020 (*1*); Yantai Statistical Yearbook in 2020 (*2*); Ningbo Statistical Yearbook in 2020 (*3*); Zhenjiang Statistical Yearbook in 2020 (*4*); Foshan Statistical Yearbook in 2020 (*5*); and Wuxi Statistical Yearbook in 2020 (*6*).
Abbreviations: GDP=Gross domestic product; CNY=Chinese yuan.

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