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Preplanned Studies

Macroelements Intake in Chinese Adults — 10 PLADs, China, 2022–2023

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Summary

What is already known about this topic?

The Chinese Nutrition and Health Surveillance in 2015–2017 reported that among adults aged 18–59 years, the average daily intake was 328.3 mg of calcium, 251.8 mg of magnesium, 5,681.4 mg of sodium, and 1,474.1 mg of potassium. For adults aged 60 years and above, the corresponding intakes were 333.2 mg, 242.5 mg, 5,412.1 mg, and 1,392.6 mg per day, respectively.

What is added by this report?

Based on the China Development and Nutrition Health Impact Cohort Survey (2022–2023) across 10 provincial-level administrative divisions (PLADs), the median daily intakes among Chinese adults were calcium (288.3 mg), magnesium (228.9 mg), sodium (4,182.4 mg), and potassium (1,397.6 mg), with a median Na/K ratio of 3.0. The study revealed that 96.1% of adults had calcium intake below the estimated average requirement (EAR), 64.4% had magnesium intake below the EAR, 81.9% had potassium intake below the adequate intake (AI), and 89.4% had sodium intake above the PI-NCD. Urban residents demonstrated generally better macroelement intake patterns compared to rural residents.

What are the implications for public health practice?

There is an urgent need for effective policies and interventions to enhance diet quality through increased consumption of dairy products, fruits, and vegetables, thereby improving calcium, magnesium, and potassium intake while reducing sodium intake and the sodium-to-potassium ratio among Chinese adults. Priority should be given to improving the nutritional status of rural residents and reducing urban-rural disparities.

Calcium, magnesium, sodium, and potassium are essential macroelements for human health. While China has implemented comprehensive policies to enhance nutritional and health status, understanding current macroelement intake patterns among Chinese adults remains crucial. This study analyzed adults participating in the China Development and Nutrition Health Impact Cohort Survey (2022–2023), which continues the China Health and Nutrition Survey (CHNS). Using consecutive 3-day 24-hour dietary recall combined with household weighing methods, we calculated intake levels of calcium, magnesium, sodium, and potassium. Results revealed median daily intakes of 288.3, 228.9, 4,182.4, and 1,397.6 mg/d for these macroelements, respectively, with a median Na/K ratio of 3.0. Analysis showed that 96.1% of adults had calcium intake below the estimated average requirement (EAR), 64.4% had magnesium intake below the EAR, 81.9% had potassium intake below the adequate intake (AI), and 89.4% exceeded the Prevention of non-communicable diseases intake level (PI-NCD) for sodium. Urban areas consistently demonstrated better macroelement intake patterns compared to rural areas. These findings indicate the need for a comprehensive approach encompassing enhanced nutrition education, promotion of healthy eating habits, strengthened food supply chains, and improved access to nutritious foods to elevate overall nutrition status and reduce urban-rural disparities.

This study utilizes data from the China Development and Nutrition Health Impact Cohort Survey (2022–2023), which builds upon the CHNS, an ongoing large-scale, longitudinal cohort study initiated in 1989 (*1*). The study population comprises Chinese adults from 10 provincial-level administrative divisions (PLADs, including Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guizhou, and Shaanxi provinces; and Guangxi Zhuang Autonomous Region). Exclusion criteria included individuals with implausible energy intake (<600 or >4,000 kcal/d for females, <800 or >5,000 kcal/d for males), implausible macroelements intake (<1% or >99%), and pregnant or lactating women. The study protocol was approved by the institutional review board of the National Institute for Nutrition and

Health, China CDC (ethics approval code 2022-024), with all participants providing written informed consent prior to participation.

Dietary intake data were collected through consecutive 3-day 24-hour dietary recalls (2 workdays and 1 weekend day) using face-to-face interviews at participants' homes. Household weighing methods were employed to measure the consumption of cooking oils and condiments during the corresponding 3-day period. Macroelement intake calculations were based on the *China Food Component Table*. According to the Dietary Reference Intakes for China 2023 (DRIs 2023) (*2*), population-level nutrient inadequacy was assessed by calculating the proportion of individuals with daily calcium or magnesium intake below the EAR or daily potassium intake below the AI. For sodium, the proportion of individuals exceeding the proposed intakes for preventing non -communicable chronic diseases (PI-NCD) was calculated to assess chronic disease risk. Age-specific EAR, AI, and PI-NCD values are presented in Supplementary Table S1(available at https://weekly.chinacdc.cn/).

Given the non-normal distribution of macroelement intake, statistical analyses employed the Kruskal-Wallis test to evaluate differences in median intake across age groups, while the Wilcoxon rank sum test compared median intake between genders and urban-rural areas. Mean±standard deviation values were reported to facilitate comparison with other studies. The chi-square test was used to compare proportions between different groups. All statistical tests were two-tailed, with significance set at $P<0.05$. Analyses were conducted using R (version 4.4.0, R Foundation for Statistical Computing, Vienna, Austria), and figures were generated using both R and Microsoft Office Excel 2019 MSO (version 2406, Microsoft Corporation, Santa Rosa, California, USA).

This study included 8,912 participants with a mean age of 55.9 years. Table 1 demonstrates that Chinese adults in 2022–2023 had median daily intakes of 288.3 mg calcium, 228.9 mg magnesium, 4,182.4 mg sodium, and 1,397.6 mg potassium, with a median Na/K ratio of 3.0. Urban residents exhibited significantly higher intakes of calcium (311.4 mg/d), magnesium (234.3 mg/d), and potassium (1,467.6 mg/d) compared to rural residents (278.0, 226.2, and 1,359.9 mg/d, respectively). Additionally, urban residents maintained a significantly lower Na/K ratio than their rural counterparts (2.8 *vs*. 3.1).

As shown in Figure 1, the prevalence of inadequate intake was widespread among adults: 96.1% fell below the EAR for calcium, 64.4% below the EAR for magnesium, and 81.9% below the AI for potassium. Furthermore, 89.4% exceeded the PI-NCD for sodium intake. Urban areas consistently demonstrated better nutritional status, with significantly lower proportions of inadequate intake across all macroelements compared to rural areas ($P<0.001$ for calcium, sodium, and potassium; $P=0.027$ for magnesium).

As shown in Figure 2, analysis of Na/K ratios revealed that only 5.7% of Chinese adults maintained the optimal ratio of ≤1, while 49.8% exhibited ratios >3. Urban-rural disparities were evident, with urban areas showing a significantly higher proportion of adults achieving the optimal Na/K ratio ≤1 (7.8% *vs*. 4.7% in rural areas) and a lower proportion with ratios >3 (45.4% *vs*. 51.9% in rural areas) ($P<0.001$).

DISCUSSION

Our research reveals that the intake of calcium, magnesium, and potassium in Chinese adults remains suboptimal, while sodium intake and the sodium-to-potassium ratio are elevated. The Chinese Nutrition and Health Surveillance (CNHS) in 2015–2017, a nationally representative survey, reported mean intakes of calcium, magnesium, sodium, and potassium of 328.3, 251.8, 5,681.4, and 1,474.1 mg/d for adults aged 18–59 years, and 333.2, 242.5, 5412.1, and 1392.6 mg/d for those aged 60 and above, respectively (*3*). Despite China's implementation of comprehensive policies to enhance nutritional and health status, including the "*National Nutrition Plan 2017–2030*" and the "*Healthy China Initiative 2019–2030: Reasonable Diet Action*", our findings indicate no substantial improvement in macroelement intake among Chinese adults over this seven-year period.

As illustrated in Supplementary Figure S1 (available at https://weekly.chinacdc.cn/), vegetables, cereals, and dried legumes constitute the primary dietary sources of calcium, aligning with findings from the CHNS project in 2015 (*4*). Notably, milk's contribution to total calcium intake has increased to 9.7% from 6.7% in 2015 (*4*). However, given the persistently low consumption of dairy products (*5*), there remains substantial room for improving dairy intake among the population.

Our analysis indicates that 64.4% of Chinese adults exhibit inadequate magnesium intake, consistent with the CHNS project findings from 2015, which reported inadequacy rates between 60.9% and 68.45% (*6*). Whole grains and dark vegetables, recognized as

TABLE 1. Daily intake of calcium, magnesium, sodium, potassium (mg/d) and sodium/potassium ratio.

Characteristics	*n* (%)	Ca		Mg		Na		K		Na/K ratio	
		Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD
Age, years											
18–44	2,032 (22.8)	283.7 (198.8)	313.5±155.8	222.3 (122.3)	243.4±102.4	4,010.8 (3,461.1)	5,039.4±3,906.9	1,422.1 (748.6)	1,512.4±612.8	2.9 (2.5)	3.7±3.5
45–59	3,092 (34.7)	296.3 (192.7)	321.6±153.4	238.8 (126.5)	258.2±102.9	4,399.7 (3,390.4)	5,407.5±4,015.9	1,443 (793.2)	1,551.7±611.5	3.1 (2.6)	3.9±3.3
60–79	3,430 (38.5)	285.3 (204.3)	319.5±158.2	227.5 (125.7)	249.1±104.1	4,119.9 (3,212.6)	5,048±3,689.9	1,354.4 (760)	1,460.1±598.5	3 (2.6)	3.9±3.3
≥80	358 (4.0)	273.7 (223.8)	316.5±174.8	197.3 (117.9)	219.2±99	3,671.3 (3,138.5)	4,814±4,430.6	1,153.4 (717.7)	1,288.9±570.6	3.1 (2.6)	4.3±4.9
P	–	0.019	–	<0.001	–	<0.001	–	<0.001	–	<0.001	–
Gender											
Male	4,104 (46.1)	303.1 (203.0)	330.7±157.1	245.8 (129.1)	265.2±106.2	4,540.1 (3,489.1)	5,497.7±3,914.9	1,478.7 (800.8)	1,576.6±622.5	3.1 (2.6)	3.9±3.2
Female	4,808 (53.9)	276.7 (194.8)	308.5±155.7	216.0 (118)	236.6±99.1	3,878.8 (3,095.7)	4,874.4±3,846.1	1,327.7 (730.2)	1,428.9±586.7	2.9 (2.5)	3.9±3.6
P	–	<0.001	–	<0.001	–	<0.001	–	<0.001	–	0.002	–
Area type											
Urban	2,899 (32.5)	311.4 (216.1)	338.8±163.4	234.3 (125.8)	254.3±104.2	4,094.7 (3,372.6)	5,121.7±4,045.6	1,467.6 (784.6)	1,565±616	2.8 (2.5)	3.7±3.2
Rural	6,013 (67.5)	278 (191.0)	309.1±152.5	226.2 (125.3)	247.6±103.0	4,244.8 (3,350.8)	5,180.5±3,813.1	1,359.9 (748.7)	1,464.1±601.3	3.1 (2.6)	4.0±3.5
P	–	<0.001	–	<0.001	–	0.122	–	<0.001	–	<0.001	–
Total	8,912 (100.0)	288.3 (199.2)	318.7±156.7	228.9 (125.5)	249.8±103.4	4,182.4 (3,355)	5,161.4±3,890.1	1,397.6 (770.7)	1,496.9±607.9	3.0 (2.6)	3.9±3.4

Note: Statistical analyses were performed using Wilcoxon rank sum test for two-group comparisons and Kruskal-Wallis test for multiple group comparisons.
-: Not applicable.
Abbreviation: IQR=interquartile range; SD=standard deviation.

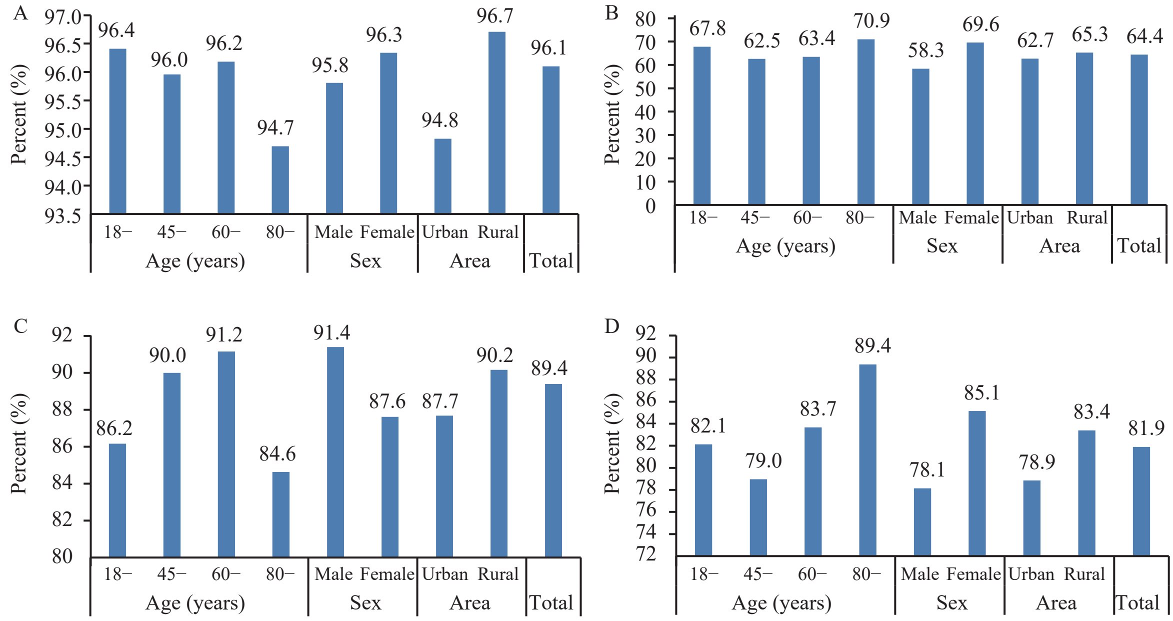

FIGURE 1. Proportions of insufficient intake of calcium, magnesium, and potassium, and excessive intake of sodium. (A) Calcium; (B) Magnesium; (C) Sodium; (D) Potassium.

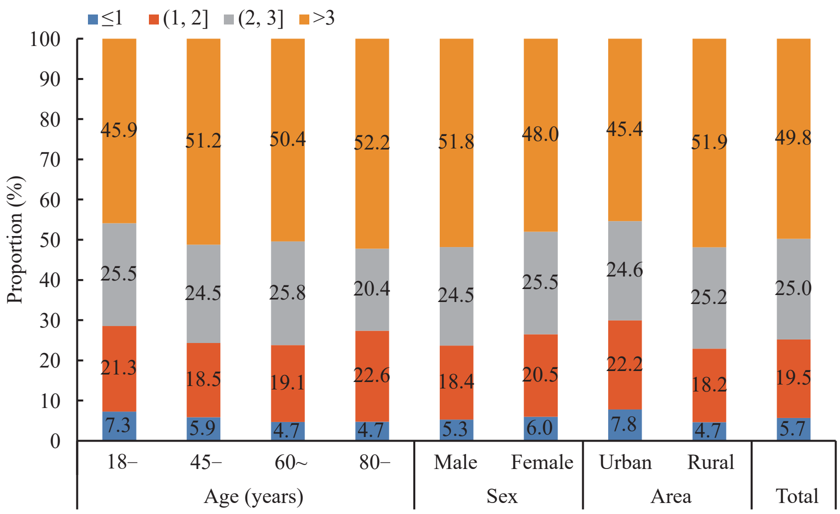

FIGURE 2. Distribution of sodium-to-potassium ratio among Chinese adults in 2022–2023.

superior sources of dietary magnesium, remain the predominant contributors to magnesium intake among Chinese adults in 2022–2023, accounting for 40.4% and 16.2% of total intake, respectively. The observed inadequate magnesium intake may be attributed primarily to the declining consumption patterns of cereals and vegetables (*3*).

The *Chinese Dietary Guidelines* recommend a daily sodium intake not exceeding 2,000 mg. Our findings from 2022–2023 reveal that Chinese adults' median and mean sodium intakes are 4,182.4 and 5,161.4 mg/d respectively, more than double the recommended maximum. The proportion of individuals exceeding the PI-NCD for sodium intake has reached 89.4%, compared to 86.7% and 88.2% exceeding 2,000 mg/d in 2018 and 2015, respectively (*7*–*8*). Notably, 89.1% of dietary sodium intake derives from cooking salt, as shown in Supplementary Figure S1. While the National '*Healthy Lifestyle Action Plan (2017–2025)*' has implemented six specific action plans — targeting reductions in salt, oil, and sugar, alongside promoting healthy oral health, weight, and bones — and despite a modest downward trend in salt consumption, sodium intake remains persistently elevated (*9*). Future interventions must continue prioritizing salt reduction strategies to achieve meaningful decreases in salt and sodium consumption.

Meta-analytic evidence indicates that early dietary modifications targeting a Na/K molar ratio of approximately one unit could significantly contribute to hypertension prevention. Our study reveals a concerning Na/K ratio of 3.0 (mean 3.9). The *Action on Salt China* conducted the largest-scale survey across six PLADs in 2018, employing 24-hour urinary sodium and potassium measurements — the gold standard for intake assessment. Their findings revealed a markedly imbalanced sodium-to-potassium ratio of 5:1 among the Chinese population (*10*). This substantial imbalance primarily stems from excessive salt consumption coupled with insufficient intake of potassium-rich foods.

A notable urban-rural disparity exists in macroelement intake patterns, with urban areas demonstrating higher intake levels of calcium, magnesium, and potassium. While sodium intake shows no significant urban-rural difference, the lower dietary potassium intake in rural areas results in a higher sodium-to-potassium ratio compared to urban areas. These findings collectively indicate that urban populations maintain generally superior macroelement intake patterns compared to their rural counterparts.

A limitation of this study is that the subjects, drawn from 10 PLADs in China, do not constitute a nationally representative sample. In addition, the macroelement intake in this study only considered food sources. The ignorance of additional intake of nutrient supplements may result in a slight underestimate of calcium or magnesium.

In conclusion, our findings reveal that macroelement intake among Chinese adults remains substantially below recommended targets. To address these nutritional disparities, strict adherence to and implementation of national policies and guidelines — including the *National Nutrition Plan 2017–2030* and the *Healthy China Initiative 2019–2030: Reasonable Diet Action* — is essential for improving overall nutrition status and reducing the urban-rural nutritional gap.

Conflicts of interest: No conflicts of interest.

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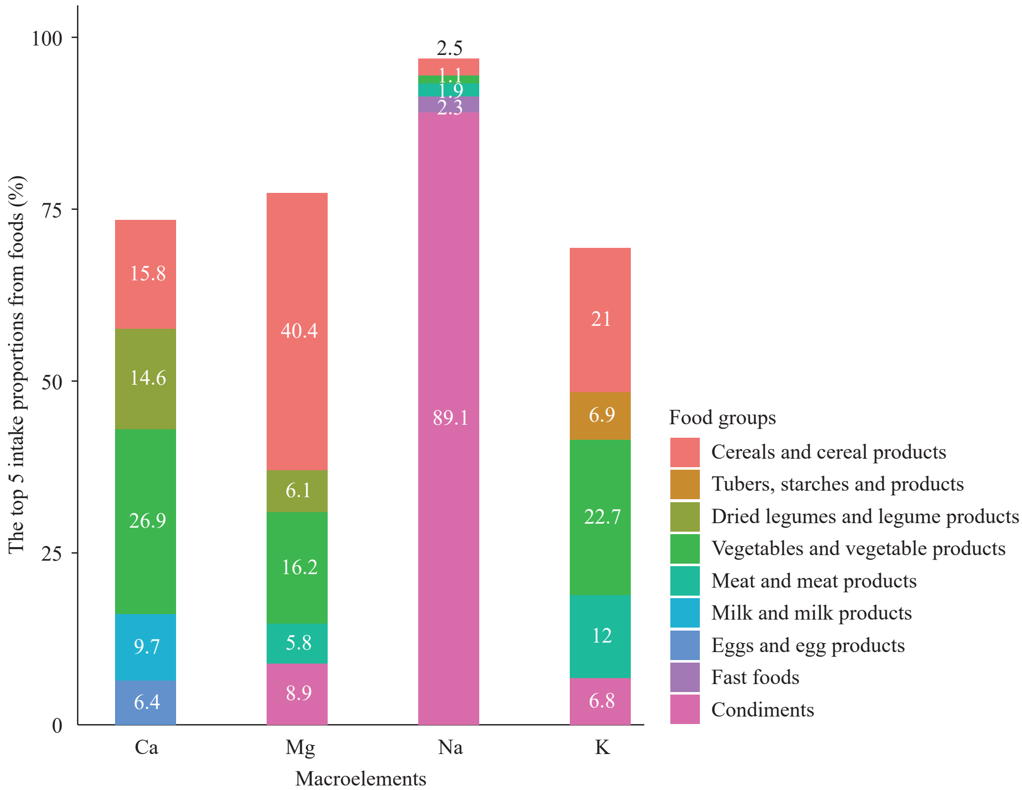
SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Age-specific EAR, RNI, AI, and PI-NCD values.

Age group, years	Ca		Mg		Na		K	
	EAR	RNI	EAR	RNI	AI	PI-NCD	AI	PI-NCD
18–29	650	800	270	330	1,500	≤2,000	2,000	3,600
30–64				320				
65–74			260	310	1,400	≤1,900		
≥75			250	300		≤1,800		

Abbreviation: EAR=estimated average requirement; RNI=recommended nutrient intake; AI=adequate intake; PI-NCD=prevention of non-communicable diseases intake level.



SUPPLEMENTARY FIGURE S1. Food sources contributing to the top 5 intake proportions of four macroelements.

Preplanned Studies

Physical Activity and Sedentary Behavior Among Chinese Adults — 10 PLADs, China, 2022–2023

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Summary

What is already known about this topic?

The prevalence of insufficient physical activity (PA) among Chinese adults has shown an upward trend, reaching 22.3% in 2018. Leisure time PA (LTPA) constitutes a minimal proportion of total physical activity patterns.

What is added by this report?

The adherence rate to Physical activity guidelines (PAGs) was 85.7%. While occupational PA remained the predominant form of physical activity, its proportion has decreased. LTPA has emerged from its historically lowest position among activity types. Screen-based activities now constitute the primary form of sedentary behavior.

What are the implications for public health practice?

Strategic interventions are needed to promote LTPA by addressing urban-rural disparities in sports facility access and increasing public venue availability. Additionally, targeted initiatives are required to reduce sedentary time, particularly among young people and urban residents, while maintaining engagement in LTPA.

Physical inactivity and prolonged sedentary behavior are well-established risk factors for numerous chronic diseases, imposing substantial human and economic costs (*1*). The global prevalence of insufficient physical activity (PA) among adults has shown a concerning upward trend in recent years (*2*). In China, the prevalence of insufficient PA among adults has gradually increased, reaching 22.3% by 2018 (*3*). Sedentary behavior is similarly prevalent throughout China. In response, the Chinese government has implemented various measures to reduce insufficient PA levels and sedentary behavior while improving nationwide fitness. However, current data on PA and sedentary behavior patterns in China are limited despite their critical importance for informing research and public health policy. To address this knowledge gap, we analyzed data from the twelfth wave of the China Health and Nutrition Survey (CHNS), conducted between 2022 and 2023. Our analysis included 10,103 participants aged 18 years and above. Results showed that 85.7% and 70.9% of adults in ten provincial-level administrative divisions (PLADs) adhered to the physical activity guidelines (PAGs) of 150 minutes and 300 minutes, respectively. While occupational PA remained the primary domain, domestic PA and leisure time physical activity (LTPA) followed at 16.9% and 14.2% respectively, with minimal difference between these latter two categories. Screen-based activities emerged as the predominant form of sedentary behavior, with approximately 25% of Chinese adults spending more than 6 hours daily in sedentary activities. Given that social change and rapid urbanization will inevitably continue, increasing LTPA represents the most viable strategy for reducing physical inactivity rates. Further interventions are particularly needed to reduce sedentary time while promoting LTPA participation, especially among young residents and urban populations.

The twelfth round of the CHNS provided an opportunity to investigate the current status of physical activity and sedentary behavior in China. During the 2022–2023 wave, a multistage, stratified sampling design was implemented across ten PLADs: Guangxi, Guizhou, Hunan, Hubei, Shanxi, Shandong, Henan, Jiangsu, Heilongjiang, and Liaoning. Detailed information about the CHNS methodology has been published elsewhere (*4*). Physical activity and sedentary behavior data were collected through face-to-face interviews using a tablet device (ThinkPad Tablet2, Lenovo, Beijing, China), following previously reported calculation methods. The analysis included 10,103 participants aged 18 years and above with complete physical activity and sedentary behavior data. The study protocols were approved by the institutional review committees of the National Institute for Nutrition and Health, Chinese Center for Disease

Control and Prevention (2022–2024), with all participants providing written informed consent. Investigators underwent systematic training and qualification assessment before conducting surveys. Quality control was maintained through a hierarchical supervision system, with designated personnel performing daily spot checks on the electronic survey system and implementing timely corrections.

The metabolic equivalent of task (MET) hours per week was calculated for occupational, domestic, travel, and leisure domains, along with sedentary hours per day. Two adherence proportions were assessed based on the PAGs 2021: first, participation in at least 150 minutes per week of moderate-intensity physical activity or 75 minutes per week of vigorous-intensity physical activity; second, participation in at least 300 minutes per week of moderate-intensity physical activity or 150 minutes per week of vigorous-intensity physical activity. Following established protocols, daily total sedentary time was categorized into two groups (<6 h/d and ≥6 h/d). Categorical variables were expressed as numbers (percentages), with Chi-square tests used for group comparisons. All statistical analyses were performed using SAS (version 9.4, SAS Inc., Cary, NC, USA), with statistical significance set at a two-tailed $P<0.05$.

Analysis revealed that 85.7% and 70.9% of the study population adhered to the PAG recommendations of 150 minutes and 300 minutes, respectively (Table 1). Additionally, 71.2% of the population reported total sedentary time below 6 hours daily. Notably, males, individuals aged 18–44 years, and urban residents demonstrated significantly higher proportions of extended sedentary time (≥6 h/d) compared to their demographic counterparts.

Figure 1 illustrates the distribution of physical activity across four domains. Occupational PA emerged as the predominant contributor to total PA across all demographic subgroups. Domestic PA and LTPA ranked second and third, contributing 16.9% and 14.2% respectively, with a minimal differential between these domains. Figure 2 demonstrates that screen-based sedentary time exceeded 50% across all population subgroups. The 18–44 age group and urban residents exhibited the highest proportions of sedentary time, with screen-based activities accounting for 53.6% and 52.7% of total sedentary time, respectively.

DISCUSSION

Our analysis revealed that 85.7% and 70.9% of adults in ten PLADs of China met the PAG recommendations for 150 minutes and 300 minutes of physical activity, respectively. This improvement in adherence rates can be attributed to recent government initiatives promoting physical fitness. The implementation of the Healthy China strategy and

TABLE 1. Adherence proportion to the PAGs and sedentary behavior among Chinese adults in ten PLADs, 2022–2023.

Characteristics	*N*	Adherence proportion to the PAGs (*N*, %)		Total sedentary time (*N*, %)	
		≥150 mins/w	≥300 mins/w	<6 h/d	≥6 h/d
Total	10,103	8,658 (85.7)	7,163 (70.9)	7,193 (71.2)	2,910 (28.8)
Gender					
Male	4,675	4,193 (89.7)	3,698 (79.1)	3,235 (69.2)	1,440 (30.8)
Female	5,428	4,494 (82.8)	3,517 (64.8)	3,957 (72.9)	1,471 (27.1)
P		<0.001	<0.001	<0.001	<0.001
Age group (years)					
18–44	2,399	1,960 (81.7)	1,487 (62.0)	1,188 (49.5)	1,211 (50.5)
45–59	3,463	3,027 (87.4)	2,576 (74.4)	2,393 (69.1)	1,070 (30.9)
≥60	4,241	3,660 (86.3)	3,066 (72.3)	3,584 (84.5)	657 (15.5)
P		<0.001	<0.001	<0.001	<0.001
Area					
Urban	3,280	2,627 (80.1)	1,955 (59.6)	2,116 (64.5)	1,164 (35.5)
Rural	6,823	5,991 (87.8)	5,165 (75.7)	5,069 (74.3)	1,754 (25.7)
P		<0.001	<0.001	<0.001	<0.001

Abbreviation: PAGs=physical activity guidelines; PLADs=provincial-level administrative divisions.

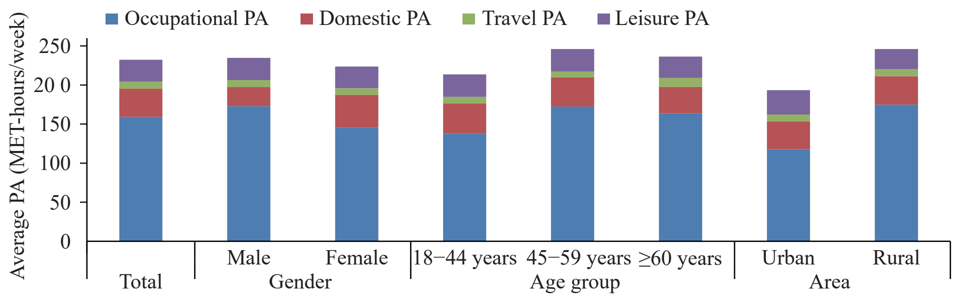

FIGURE 1. Composition of four different domains of physical activity among Chinese adults in ten PLADs, 2022–2023.
Abbreviation: PA=physical activity; MET-hour/week=metabolic equivalent of task hours per week; PLADs=provincial-level administrative divisions.

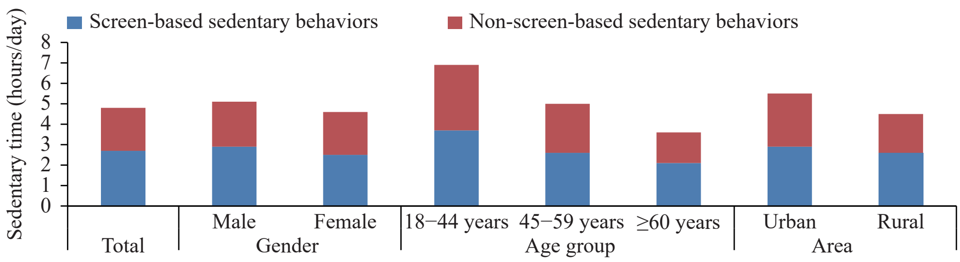

FIGURE 2. Composition of different types of sedentary behaviors among Chinese adults in ten PLADs, 2022–2023.
Abbreviation: PLADs=provincial-level administrative divisions.

National Fitness Program has catalyzed a significant increase in public engagement with fitness activities. Infrastructure developments have been substantial, with government-built public sports venues and park locations increasing by 8.5 and 3.6 percentage points compared to 2014. Consequently, 80.7% of adults now have access to sports and fitness facilities within a 15-minute walking distance (*5*). Recent studies indicate an upward trend in both LTPA participation and regular LTPA engagement (*6*). While Western populations predominantly engage in LTPA, Asian countries such as China (*7*) and Iran (*8*) have historically emphasized occupational and domestic PA. Our current findings indicate that while occupational PA remains the primary form of physical activity, its proportion has decreased to 68.6% of total PA. This shift reflects the impact of technological advancement, including smart office systems, household automation, and vehicular transportation, which have reduced PA across occupational, domestic, and travel domains. Notably, LTPA now comprises 14.2% of total PA, approaching the 16.9% contribution from domestic PA. Given the inevitable reduction in work-related, household, and transportation-related PA due to technological progress and artificial intelligence, LTPA represents the most viable pathway for maintaining adequate PA levels. While the government has made strides in creating environments conducive to recreational physical activities, significant disparities persist in the distribution and accessibility of sports facilities between urban and rural areas. Rural regions require additional infrastructure development, while urban areas need to improve public access to existing facilities. These challenges must be addressed within the context of ongoing social transformation and urbanization.

Furthermore, the World Health Organization guidelines emphasize limiting sedentary time to mitigate its detrimental health effects. Our findings align with previous research indicating that approximately 25% of individuals engage in sedentary behavior for more than 6 hours daily, comparable to the United States, where nearly half of adults report sitting for more than 6 hours per day, with higher rates among elderly populations (*9*). Screen-based activities emerged as the predominant form of sedentary behavior, accounting for 55.6% of total sedentary time across the population. This prevalence can be attributed to the widespread adoption of television, portable electronic devices, and mobile phones. China's ongoing rapid urbanization inevitably continues to transform lifestyle patterns, leading to decreased physical activity and increased sedentary time. While previous studies have documented a declining trend in daily dietary energy intake among Chinese adults over recent decades, the prevalence of overweight and obesity continues to rise (*7*,*10*). This paradox may be explained by the reduction in energy expenditure — driven by decreased physical activity and increased sedentary time — outpacing the reduction in dietary energy intake. To address these challenges, we recommend continuing the installation of fitness equipment in rural community spaces to increase per capita sports facility access, while simultaneously improving the utilization of existing urban sports facilities through enhanced public accessibility.

This study has several limitations that warrant consideration. First, the reliance on self-reported physical activity and sedentary behavior data may introduce recall bias. However, we attempted to minimize this bias by separately investigating four distinct types of physical activities and differentiating between weekday and weekend patterns. Second, as our findings are based on data from ten PLADs in China, they may not be fully generalizable to the entire nation. In conclusion, this study provides an up-to-date assessment of physical activity and sedentary behavior patterns among residents in ten PLADs of China. Future public health policies should focus on two key areas: first, promoting LTPA by addressing the urban-rural imbalance in sports facility resources and improving venue accessibility; And second, enhancing public awareness about reducing screen-based sedentary time, particularly among young people and urban residents.

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Preplanned Studies

Trends of Overweight and Obesity Among Chinese Rural Children and Adolescents Aged 6 to 15 Years — the Central and Western Regions, China, 2012–2023

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Summary

What is already known about this topic?

Childhood overweight and obesity pose significant risks to physical and mental health. The Nutrition Improvement Programme for Rural Compulsory Education Students (NIPRCES) has demonstrated effectiveness in reducing malnutrition.

What is added by this report?

From 2012 to 2023, obesity prevalence increased more rapidly (AAPC=10.6%) than overweight prevalence (AAPC=2.0%) among children aged 6–15 years in central and western rural China. A quicker increase in the trends of overweight and obesity was observed in rural western China (AAPC for overweight=3.0%, AAPC for obesity=11.8%), among males (AAPC for overweight=2.1%, AAPC for obesity=10.8%). Additionally, while the prevalence of overweight/obesity was lower in older age groups of children, these cohorts showed more rapid increases.

What are the implications for public health practice?

Continuous monitoring of prevalence and implementation of targeted interventions are essential to prevent and control the expansion of overweight and obesity.

Both international and domestic evidence demonstrates that school feeding programs effectively reduce undernutrition. However, the rising prevalence of overweight and obesity has emerged as a global health concern, even in regions implementing school feeding programs (*1*). Childhood overweight and obesity negatively impact health outcomes, increasing the risk of non-communicable diseases in adulthood while hampering human capital development and economic growth (*2*). The Nutrition Improvement Programme for Rural Compulsory Education Students (NIPRCES), initiated in 2012, is a government-funded initiative providing meal subsidies to enhance school meal quality, aimed at improving the nutritional status of primary and secondary students in economically underdeveloped rural areas of China (*3*). Previous NIPRCES surveys have documented increases in children's and adolescents' height (*4*), accompanied by concurrent weight gains. In this study, we analyzed NIPRCES survey data using joinpoint regression to evaluate overweight and obesity trends among children aged 6–15 years in central and western rural regions of China from 2012 to 2023. Our findings reveal regional, age, and gender disparities in the increasing trends of overweight and obesity, providing a scientific foundation for developing targeted dietary guidance, health education, and intervention strategies in rural China.

Data were obtained from the NIPRCES surveillance program conducted from 2012 to 2023. The study employed a multi-stage, stratified, random cluster sampling design encompassing rural areas of 699 counties across 22 provincial-level administrative divisions (PLADs) in central and western China from 2012 to 2019, expanding to 727 counties in 2021–2023. Analysis included children aged 6–15 years from 9 surveys, with participant numbers of 1,629,899 (2012), 1,768,253 (2013), 1,830,167 (2014), 1,910,146 (2015), 1,405,174 (2016), 1,394,620 (2017), 1,437,184 (2019), 1,583,061 (2021), and 2,009,076 (2023). While surveys were typically conducted from October to December, the 2019 survey was conducted between April and June due to scheduling changes. Regional segmentation into central and western regions was based on economic development levels (*5*). Height and weight measurements were performed by trained investigators using standardized equipment according to the *Anthropometric Methods for Population Health Surveillance* (WS/T 424-2013). Height was measured to the nearest 0.1 cm using a height meter, and weight to the nearest 0.1 kg using an electronic scale. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Overweight and obesity classifications were determined using age-gender-specific BMI cut-off values from the *Overweight and Obesity in School-aged Children and Adolescents* (WST 586-2018) criteria. Overweight was defined as BMI greater than or equal to the overweight cut-off point but below the obesity cut-off point for the corresponding gender and age group, while obesity was defined as BMI greater than or equal to the obesity cut-off point.

Data analysis was performed using SAS 9.4 (version 9.4, SAS Institute Inc., Cary, NC, USA) to clean data and calculate annual prevalence of overweight and obesity. Linear interpolation was employed to estimate prevalence for 2018, 2020, and 2022 to maintain consistent yearly intervals. Segmented line regression was conducted using Joinpoint Regression Program (version 5.0.2 Statistical Research and Applications Branch, National Cancer Institute, Bethesda, MD, USA) to identify significant changes in prevalence trends. The annual percentage change (APC) and annual average percentage change (AAPC) were calculated to quantify trend direction and magnitude (*6*). Statistical significance was set at $P<0.05$.

The prevalence of overweight increased from 8.0% in 2012 to 10.2% in 2023, with an AAPC of 2.0% [95% confidence interval (*CI*): 0.6%, 3.5%] (Table 1 and Figure 1). Further analysis of the joinpoint regression model shown in Table 1 revealed an increasing trend from 2012 to 2023, with an APC of 2.0% (95% *CI*: 0.6%, 3.5%). Regional analysis revealed that overweight prevalence increased from 9.5% to 12.2% in the central region and from 6.9% to 9.5% in the western region between 2012 and 2023. The western region demonstrated a significantly faster increase (AAPC=3.0%, 95% *CI*: 1.3%, 4.7%) compared to the central region (AAPC=2.0%, 95% *CI*: 0.5%, 3.6%) (Table 1 and Figure 1). Gender analysis showed that male overweight prevalence increased from 9.0% to 11.5%, while female prevalence rose from 7.0% to 8.8% during the study period. Males exhibited a higher significant increase (AAPC=2.1%, 95% *CI*: 1.0%, 3.3%) compared to females (AAPC=2.0%, 95% *CI*: 0.4%, 3.6%) (Table 1 and Figure 1). Age-specific analysis revealed that overweight prevalence ranged from 15.0% in 6-year-

TABLE 1. The prevalence and trends of overweight among children aged 6 to 15 years in rural areas of central and western China, 2012−2023.

Category	Prevalence (%)		AAPC (95% *CI*)	APC (95% *CI*) in 2012–2023
	2012	2023	2012–2023	
Total	8.0	10.2	2.0* (0.6, 3.5)	2.0† (0.6, 3.5)
Region				
Central	9.5	12.2	2.0* (0.5, 3.6)	2.0† (0.5, 3.6)
Western	6.9	9.5	3.0* (1.3, 4.7)	3.0† (1.3, 4.7)
Gender				
Male	9.0	11.5	2.1* (1.0, 3.3)	2.1† (1.0, 3.3)
Female	7.0	8.8	2.0* (0.4, 3.6)	2.0† (0.4, 3.6)
Age (years)				
6	15.0	12.6	−1.0 (−2.1, 0.1)	−1.0 (−2.1, 0.1)
7	11.1	10.9	−0.2 (−1.7, 1.4)	−0.2 (−1.7, 1.4)
8	8.1	9.3	1.0 (−0.4, 2.5)	1.0 (−0.4, 2.5)
9	6.8	9.2	2.3* (0.9, 3.8)	2.3† (0.9, 3.8)
10	6.9	9.9	3.1* (1.9, 4.3)	3.1† (1.9, 4.3)
11	6.7	10.2	3.9* (2.7, 5.1)	3.9† (2.7, 5.1)
12	6.1	10.5	5.2* (3.9, 6.5)	5.2† (3.9, 6.5)
13	6.0	10.5	5.3* (4.0, 6.7)	5.3† (4.0, 6.7)
14	5.5	9.9	6.0* (4.7, 7.2)	6.0† (4.7, 7.2)
15	4.9	8.5	5.8* (4.7, 6.8)	5.8† (4.7, 6.8)

Abbreviation: AAPC=annual average percentage change; APC=annual percentage change; *CI*=confidence interval.

* Indicates that the AAPC is significantly different from zero at the *P*=0.05 level.

† Indicates that the APC is significantly different from zero at the *P*=0.05 level.

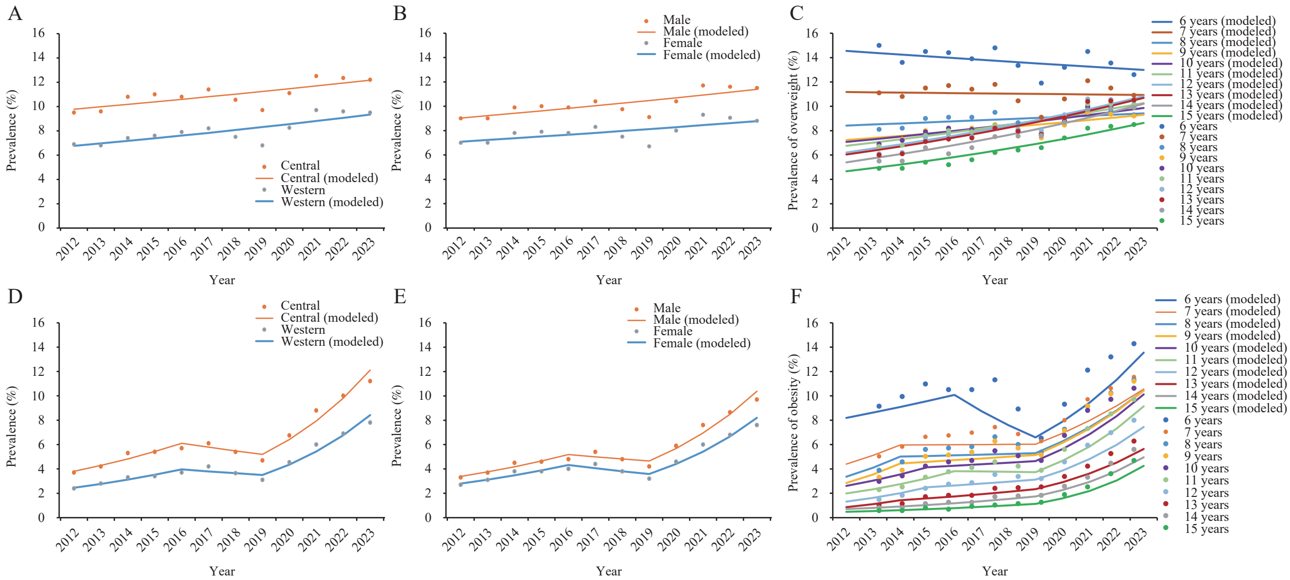

FIGURE 1. Trends in overweight and obesity prevalence among children aged 6 to 15 years in rural areas of central and western China, 2012–2023. (A) Overweight trends by region; (B) Overweight trends by gender; (C) Overweight trends by age; (D) Obesity trends by region; (E) Obesity trends by gender; (F) Obesity trends by age.

olds to 4.9% in 15-year-olds in 2012, and from 12.6% to 8.5%, respectively, in 2023. Significant increases were observed in age groups 9 (AAPC=2.3%, 95% *CI*: 0.9%, 3.8%) through 15 (AAPC=5.8%, 95% *CI*: 4.7%, 6.8%), while no significant changes were found in ages 6 to 8 (Table 1 and Figure 1).

The overall obesity prevalence increased substantially from 3.0% to 8.7%, with an AAPC of 10.6% (95% *CI*: 8.1%, 14.1%). Joinpoint regression analysis identified three distinct trends in obesity prevalence from 2012 to 2023, the corresponding APC values were 11.4% (95% *CI*: 3.6%, 35.9%), −4.7% (95% *CI*: −12.4%, 5.8%) ($P > 0.05$), and 22.8% (95% *CI*: 13.3%, 47.9%), respectively (Table 2 and Figure 1). Regional analysis showed obesity prevalence increased from 3.7% to 11.2% in the central region and from 2.4% to 7.8% in the western region between 2012 and 2023. The western region demonstrated a higher significant increase (AAPC=11.8%, 95% *CI*: 9.9%, 14.5%) compared to the central region (AAPC=11.1%, 95% *CI*: 8.3%, 15.0%) (Table 2 and Figure 1). Gender analysis revealed that male obesity prevalence increased from 3.3% to 9.7%, while female prevalence rose from 2.7% to 7.6% during the study period. Males showed a higher significant increase (AAPC=10.8%, 95% *CI*: 8.3%, 14.2%) compared to females (AAPC=10.3%, 95% *CI*: 7.6%, 14.1%) (Table 2 and Figure 1). Age-specific analysis demonstrated that obesity prevalence ranged from 8.0% in 6-year-olds to 0.5% in 15-year-olds in 2012, and from 12.5% to 4.1%, respectively, in 2023. Significant increases were observed across all age groups, from age 6 (AAPC=4.7%, 95% *CI*: 2.7%, 7.2%) through age 15 (AAPC=21.9%, 95% *CI*: 20.0%, 23.8%) (Table 2 and Figure 1).

DISCUSSION

While national and international studies have demonstrated that school feeding programs effectively reduce childhood undernutrition (*1*,*7*), our analysis reveals a concurrent increase in overweight and obesity prevalence. We observed a significant rise in both conditions, with obesity trends (AAPC=10.6%) accelerating more rapidly than overweight trends (AAPC=2.0%). This pattern suggests that once children become obese, weight reduction becomes particularly challenging. Between 2012 and 2023, the obesity trend exhibited three distinct periods of change magnitude, whereas the overweight trend showed a continuous period of increase.This indicating that obese children are especially susceptible to environmental and dietary influences. Both overweight and obesity trends increased more rapidly in the western region ($AAPC_{overweight}$=3.0%, $AAPC_{obesity}$=11.8%) compared to the central region ($AAPC_{overweight}$=2.0%, $AAPC_{obesity}$=11.1%). Additionally, while the prevalence of overweight/obesity was lower in older age groups, these cohorts showed more rapid increases. These regional and age-

TABLE 2. The prevalence and trends of obesity among children aged 6 to 15 years in rural areas of central and western China, 2012–2023.

Category	Prevalence (%)		AAPC (95% *CI*)	Period 1		Period 2		Period 3	
	2012	2023	2012–2023	Years	APC (95% *CI*)	Years	APC (95% *CI*)	Years	APC (95% *CI*)
Total	3.0	8.7	10.6* (8.1, 14.1)	2012–2016	11.4† (3.6, 35.9)†	2016–2019	−4.7 (−12.4, 5.8)	2019–2023	22.8† (13.3, 47.9)
Region									
Central	3.7	11.2	11.1* (8.3, 15.0)	2012–2016	12.5† (4.1, 40.0)	2016–2019	−5.2 (−13.6, 5.8)	2019–2023	23.6† (13.2, 51.2)
Western	2.4	7.8	11.8* (9.9, 14.5)	2012–2016	12.7† (7.7, 28.3)	2016–2019	−4.1 (−10.2, 4.4)	2019–2023	24.5† (17.2, 44.2)
Gender									
Male	3.3	9.7	10.8* (8.3, 14.2)	2012–2016	11.3† (3.0, 34.8)	2016–2019	−3.5 (−11.3, 7.2)	2019–2023	22.3† (13.0, 46.3)
Female	2.7	7.6	10.3* (7.6, 14.1)	2012–2016	11.6† (3.9, 38.3)	2016–2019	−6.1 (−14.3, 4.7)	2019–2023	23.0† (12.7, 50.5)
Age (years)									
6	8.0	12.5	4.7* (2.7, 7.2)	2012–2016	5.3† (0.3, 20.2)	2016–2019	−13.2† (−19.0, −4.2)	2019–2023	19.7† (12.3, 36.1)
7	4.4	10.1	8.3* (7.1, 9.5)	2012–2014	16.6† (7.9, 24.5)	2014–2019	0.2 (−5.1, 2.5)	2019–2023	15.0† (10.8, 21.8)
8	3.4	9.9	10.9* (9.3, 12.5)	2012–2014	22.1† (10.7, 32.8)	2014–2019	1.1 (−5.8, 4.2)	2019–2023	18.5† (13.1, 28.2)
9	2.9	9.8	12.6* (10.8, 14.5)	2012–2014	25.3† (12.6, 37.9)	2014–2019	2.9 (−4.8, 6.2)	2019–2023	19.3† (13.6, 31.6)
10	2.6	9.3	13.1* (11.2, 15.7)	2012–2015	16.7† (9.6, 34.2)	2015–2019	2.9 (−5.4, 8.4)	2019–2023	21.6† (14.7, 38.8)
11	2.0	8.5	14.9* (13.3, 17.1)	2012–2016	17.9† (13.5, 30.2)	2016–2019	−0.7 (−5.9, 7.2)	2019–2023	25.1† (18.9, 40.7)
12	1.3	7.0	17.1* (15.2, 19.8)	2012–2015	24.0† (16.8, 43.5)	2015–2019	5.7 (−2.6, 10.9)	2019–2023	24.3† (17.4, 42.0)
13	0.9	5.5	18.7* (17.0, 20.7)	2012–2014	29.2† (18.2, 42.2)	2014–2019	10.3† (2.8, 13.5)	2019–2023	24.7† (19.1, 37.7)
14	0.7	4.9	19.5* (16.9, 21.6)	2012–2019	13.9† (4.3, 17.3)	2019–2023	29.8† (21.3, 49.2)	–	–
15	0.5	4.1	21.9* (20.0, 23.8)	2012–2019	13.1† (9.0, 16.1)	2019–2023	39.2† (31.0, 52.6)	–	–

Note: "–" Indicates no APC value for the period.

Abbreviation: AAPC=annual average percentage change; APC=annual percentage change; *CI*=confidence interval.

* Indicates that the AAPC is significantly different from zero at the *P*=0.05 level.

† Indicates that the APC is significantly different from zero at the *P*=0.05 level.

related disparities in both prevalence and growth trends underscore the need for targeted, hierarchical preventive measures to address this rapid expansion of overweight and obesity.

The World Health Organization reports that global overweight and obesity prevalence among children and adolescents aged 5–19 has increased dramatically from 4% in 1975 to over 18% in 2016 (*8*). In China, the overweight and obesity prevalence among children aged 6–17 years reached 19.0% in 2016–2017 (*9*). This study found overweight and obesity prevalence of 11.0% in 2012 and 13.3% in 2016, indicating that the gap between China's central and western regions as well as national and global levels, is narrowing. Socioeconomic status is positively associated with overweight and obesity prevalence (*10*). The western region, characterized by a lower socioeconomic level compared to the central region (*5*), exhibits lower prevalence of overweight and obesity but is experiencing a more rapid increase in these prevalence,warranting particular attention. This study reveals that the prevalence of overweight and obesity is higher in males than in females, and obesity prevalence increases rapidly among males than females. This result is consistent with a paper on the relationship between obesity phenotypes and gender differences, suggesting the necessity of managing obesity from a gender perspective (*11*). We also found higher obesity prevalence among younger children, which is especially concerning given that weight loss before puberty offers greater benefits in reducing obesity-related diseases (*12*). This emphasizes the critical importance of early intervention to prevent overweight and obesity development. Notably, the obesity trend acceleration observed during 2019–2023 exceeded that of 2012–2016 especially among 10-12 and 14-15 years. This may parallel findings from an Italian longitudinal study that documented adverse changes in eating, sleeping, and activity behaviors among children with obesity during COVID-19 lockdowns in 2019, which compromised weight control efforts (*13*). These findings suggest that adverse lifestyle changes may have exacerbated childhood obesity prevention and control challenges.

This study has two notable limitations. First, in 2019, the monitoring protocol changed from annual to biennial frequency, with the survey period shifting from October–December to April–June only in this year, while maintaining consistent geographical coverage. Further research is needed to evaluate the impact of these temporal changes on the results. Second, to satisfy the joinpoint model's requirement for consistent intervals between independent variables, we employed linear interpolation to estimate data for years without direct observations.

While previous research has demonstrated NIPRCES's effectiveness in reducing undernutrition among students (*7*), comprehensive nutritional improvement requires preventing and controlling the rapid increase in overweight and obesity. We recommend a multi-level approach:In forward-looking policy planning, the previously uniform subsidy standard should be adjusted to regional and individual variations based on trends in nutritional status changes; local governments should improve supporting policies to ensure effective NIPRCES implementation and oversight of dietary funding management; health departments should maintain continuous surveillance to track long-term patterns and characteristics of overweight and obesity across regions, genders, and age groups; schools should foster healthy food and exercise environments while strengthening nutrition education for teachers and cafeteria staff. Additionally, enhanced dietary guidance and health education should target both parents and students, improving parental capacity to provide nutritious meals while developing children's ability to make healthy food choices and reduce adverse behaviors such as prolonged sedentary activity and excessive caloric intake.

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Preplanned Studies

Accelerometry-Based Physical Activity and Sedentary Behavior Among Chinese Adults — 7 PLADs, China, 2023

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Summary

What is already known on this topic?

Physical activity (PA) and sedentary behavior (SB) are crucial determinants of both physical and mental health outcomes. However, large-scale studies using objective measurements of these behaviors have not been widely implemented across China.

What is added by this report?

Based on World Health Organization guidelines, 56.8% of participants met the recommendation for moderate-to-vigorous physical activity (MVPA) by accumulating more than 150 minutes per week. Additionally, 37.3% adhered to the SB guideline of less than 8 hours per day. However, only 2.7% of adults achieved compliance with both MVPA and SB recommendations simultaneously.

What are the implications for public health practice?

This study provides novel insights into PA levels and SB patterns among Chinese adults using waist-mounted accelerometry. The observed trends of insufficient PA and excessive SB in this multi-provincial sample emphasize the urgent need for targeted interventions to promote physical activity and reduce sedentary time to foster healthier lifestyle behaviors.

Accurate measurement of physical activity (PA) and sedentary behaviors (SB) is fundamental to evidence-based research, policymaking, and clinical practice. While studies frequently employ subjective methods such as self-report questionnaires to assess PA and SB due to their convenience and cost-effectiveness, these self-reported approaches tend to overestimate PA, particularly at moderate or vigorous intensities, while underestimating time spent in SB (*1*). Accelerometry-based measures of PA and SB have emerged as the gold standard for population-level assessment, offering superior accuracy and practical applicability compared to costly and time-intensive laboratory methods. Despite the widespread adoption of accelerometry in individual studies, comprehensive data on PA and SB levels among Chinese adults from large-scale, representative samples remain notably scarce. This study represents one of the first large-scale initiatives in China to employ waist-worn accelerometry for assessing PA levels and SB under free-living conditions. Drawing from a sample of 2,222 Chinese adults aged 20–79 years across 7 administrative regions, our findings revealed that 56.8% of participants achieved the recommended moderate-to-vigorous PA (MVPA) threshold of at least 150 minutes per week, while 37.3% maintained SB within the recommended limit of 8 hours or less per day. Notably, only 2.7% of adults met both the PA and SB recommendations simultaneously. These results underscore the critical need for targeted strategies to enhance PA and reduce SB, with particular emphasis on developing interventions aimed at promoting active lifestyles and reducing prolonged sitting time.

The study "Accelerometry-Based Physical Activity Levels of Chinese Adults" was conducted from September 5 to December 21, 2023, using a stratified sampling approach. Following the sampling framework of the Normalized National Physical Fitness Surveillance, seven provincial-level administrative divisions (PLADs) were selected from distinct administrative regions based on economic development and project feasibility: Shanxi Province (North China), eastern Inner Mongolia Autonomous Region (Northeast China), Zhejiang Province (East China), Guangdong Province (South China), Hubei Province (Central China), Chongqing City (Southwest China), and Ningxia Hui Autonomous Region (Northwest China). Within each PLAD, one urban and one rural county were randomly selected based on economic development and geographical location. Eligible participants were recruited from within a 3-kilometer radius of testing venues, typically located in community sports centers or physical fitness surveillance centers. Adults aged 20–59 years were recruited through their organizations, while adults aged 60 years and older were recruited through their communities. Subject recruitment aimed for balanced gender distribution across age groups: 20–29, 30–39, 40–49, 50–59, and ≥60 years. The study received approval from the Institutional Ethics Committee (No. CISSLA-20240219), and all participants provided written informed consent.

The study successfully recruited 2,500 adults aged 20–79 years across the sampling PLADs, with signed consent forms distributed as follows: Shanxi Province (281), Inner Mongolia Autonomous Region (255), Zhejiang Province (536), Guangdong Province (380), Hubei Province (299), Chongqing City (349), and Ningxia Hui Autonomous Region (400). Participants wore ActiGraph GT3X accelerometers (Actigraph LLC, Pensacola, FL, USA) continuously for seven days, including at least two non-workdays, removing devices only during sleep or water-based activities. Nonwear time was defined as any continuous 90-minute period with zero accelerometer counts. Valid wear-time required a minimum of 480 minutes per day for at least three days within the seven-day assessment period (*2*). Activity intensity categories were classified using Troiano et al.'s three-dimensional cut points (*3*): sedentary (≤100 counts/min), light PA (LPA, 100–2,019 counts/min), moderate PA (MPA, 2,020–5,998 counts/min), and vigorous PA (VPA, ≥ 5,999 counts/min). Data processing was performed using Actilife (Version 6.1.2.1, ActiGraph Corporation) to compute PA and SB durations, with average daily values calculated for analysis. MPA and VPA were combined to measure MVPA. Following World Health Organization (WHO) Guidelines on Physical Activity and Sedentary Behavior (*4*), adults aged 18–64 years should accumulate at least 150 minutes of weekly MVPA and limit daily SB to fewer than eight hours for optimal health benefits. Participants were categorized based on their adherence to these guidelines. Statistical analyses were conducted using SPSS 26.0 (IBM SPSS, IBM Corp, Armonk, NY, USA), with group differences assessed via t-tests and analysis of variance (ANOVA). Multiple comparisons employed Bonferroni correction, with statistical significance set at $P<0.05$.

Of the 2,500 initial participants, 2,222 (88.9%) were included in the final analysis after excluding 278 individuals due to invalid accelerometer data or incomplete sociodemographic information. No significant differences in demographic characteristics were observed between those who provided valid PA data and those who did not. The study cohort comprised 1,031 males (46.4%) and 1,607 urban residents (72.3%). The age distribution across decadal groups was: 23.4% (20–29 years), 18.9% (30–39 years), 20.9% (40–49 years), 18.7% (50–59 years), 13.1% (60–69 years), and 5.0% (70–79 years). Based on the Chinese Guidelines for the Prevention and Control of Overweight and Obesity in Adults (*5*), 36.0% of participants were classified as overweight and 12.7% as obese. Mean daily activity durations were: 465.8 minutes for SB, 128.9 minutes for LPA, 32.7 minutes for MPA, 2.1 minutes for VPA, and 34.8 minutes for MVPA. Rural residents exhibited higher SB compared to urban residents, and adults aged 40–59 years demonstrated greater SB than other age groups. No significant differences in SB were observed across gender or body weight categories. Regarding PA levels, males demonstrated significantly higher engagement in MPA, VPA, and MVPA compared to females. The youngest age group (20–29 years) showed lower MVPA compared to other age groups. Neither residential location nor body weight status was associated with significant differences in MVPA (Table 1).

Based on WHO guidelines for MVPA (*4*), 56.8% of participants achieved the recommended minimum of 150 minutes weekly MVPA, with males (58.4%) showing slightly higher compliance than females (55.4%). Participants aged over 60 years demonstrated marginally higher compliance (58.1%) compared to those aged 20–59 years (56.5%). Rural residents exhibited significantly higher guideline adherence (55.6%) compared to urban residents (47.1%) (χ^2=9.29, $P<0.05$). Compliance rates showed no significant differences across body weight categories, with similar rates observed in participants with normal weight (57.9%), overweight (56.7%), and obesity (52.7%) (Figure 1).

Following WHO guidelines on sedentary behavior, 37.9% of males and 36.8% of females maintained daily sedentary time below 8 hours. Adults aged 60–79 years demonstrated significantly lower compliance (31.7%) compared to those aged 20–59 years (38.6%) (χ^2=6.65, $P<0.05$). Urban residents exhibited higher qualified sedentary behavior rates (44.5%) compared to rural residents (40.9%), though this difference was not statistically significant. Among body weight categories, 41.0% of obese participants maintained sedentary time below 8 hours daily, while normal-weight and overweight participants showed rates of 36.9% and 36.5%, respectively (Figure 1).

Analysis of combined adherence to both MVPA and

TABLE 1. Daily physical activity levels and sedentary behavior in Chinese adults aged 20–79 years (minutes/day).

Groups	*n*	SB	LPA	MPA	VPA	MVPA
Total (mean±SD)	2,222	465.8±376.3	128.9±102.3	32.7±33.7	2.1±4.0	34.8±33.5
Total [median (p25, p75)]	2,222	556.4 (629.6, 772.2)	156.0 (193.9, 231.3)	32.4 (45.5, 61.0)	0.4 (1.5, 4.3)	33.9 (48.6, 65.6)
Sociodemographic data		mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Sex						
Male	1,031	474.2±390.5	127.1±102.0	34.4±33.5	2.5±4.5	36.88±35.98
Female	1,191	458.5±363.9	130.4±102.7	31.2±29.3	1.8±3.6	32.96±31.05
P		>0.05	>0.05	<0.05	<0.01	<0.05
Age, years						
20–29	520	410.7±402.3[†]	104.4±102.8[§]	26.5±28.7[†]	2.1±3.9*	28.6±31.3[¶]
30–39	420	439.6±405.0[†]	110.9±100.3[§]	27.8±27.5[†]	1.9±3.9*	29.7±29.8§[¶]
40–49	464	517.2±393.0*	134.4±100.1[†]	35.3±31.5*	2.3±3.6*	37.6±33.4*[†]
50–59	416	526.6±367.4*	150.4±100.9[†]	41.0±35.5*	2.5±4.7*	43.4±38.0*
60–69	291	450.8±261.1*[†]	157.2±97.0*	35.2±29.6*	1.8±4.3*	37.0±31.1*[†§]
70–79	111	423.0±293.3[†]	134.0±98.7[†§]	31.4±34.6*[†]	1.4±3.3*	32.9±36.3[†§¶]
P		<0.01	<0.01	<0.01	>0.05	<0.01
Area type						
Urban	1,607	354.4±304.1	110.4±100.8	29.4±33.3	1.6±4.2	30.9±35.3
Rural	615	387.0±290.7	125.8±100.0	30.6±30.8	2.0±4.1	32.6±33.0
P		<0.05	<0.05	>0.05	<0.05	>0.05
Body weight status						
Normal weight	1,140	475.5±382.5	129.3±102.6	33.7±32.5	2.12±3.9	35.8±34.6
Overweight	800	462.7±362.6	132.3±101.6	32.6±30.3	2.1±4.1	34.6±32.3
Obesity	282	435.6±388.8	117.8±102.9	29.4±31.0	1.9±4.5	31.3±33.4
P		>0.05	>0.05	>0.05	>0.05	>0.05

Note: For multiple comparisons across age groups, identical superscript letters indicate no statistical difference within subgroups, while different letters denote significant differences between subgroups.

Abbreviation: SB=sedentary behavior; LPA=light physical activity; MPA=moderate physical activity; VPA=vigorous physical activity; MVPA=moderate-to-vigorous physical activity; SD=standard deviation.

sedentary behavior guidelines revealed four distinct categories: participants meeting 1) MVPA recommendations only (54.1%), 2) sedentary behavior recommendations only (34.6%), 3) both recommendations (2.7%), and 4) neither recommendation (8.6%). Figure 2 illustrates the distribution of daily MVPA and sedentary behavior among adults aged 60–79 years through a scatterplot. Only 5.0% of older adults achieved both recommended thresholds (21 minutes per day for MVPA and 480 minutes per day for sedentary behavior), positioning them in the lower right quadrant. Within this age group, 53.1% met only the MVPA guideline, 26.7% met only the sedentary behavior guideline, and 15.2% met neither guideline. Among adults aged 20–59 years, the compliance rates were 2.3% for both guidelines, 54.3% for MVPA only, 36.3% for sedentary behavior only, and 7.1% for neither guideline.

DISCUSSION

This study represents the first large-scale investigation of physical activity and sedentary behavior patterns among Chinese adults using objective measurements from waist-worn accelerometers. Our analysis of 2,222 adults across seven administrative regions revealed that participants averaged 34.8 minutes of MVPA and 465.8 minutes of sedentary behavior daily. While 56.8% of adults met the recommended guidelines for MVPA and 37.3% adhered to sedentary behavior recommendations, only 2.7% achieved compliance with both guidelines simultaneously.

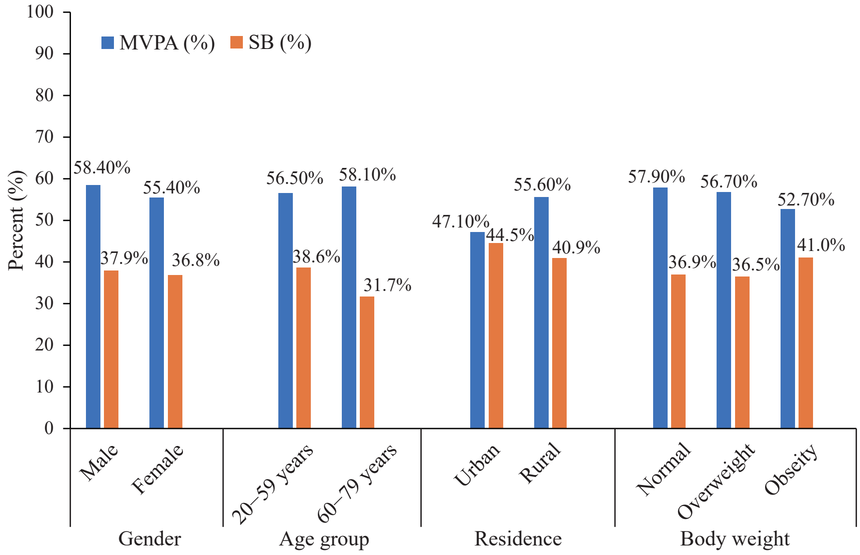

FIGURE 1. Proportion of Chinese adults meeting World Health Organization guidelines for moderate-to-vigorous physical activity and sedentary behavior.
Abbreviation: SB=sedentary behavior; MVPA=moderate-to-vigorous physical activity.

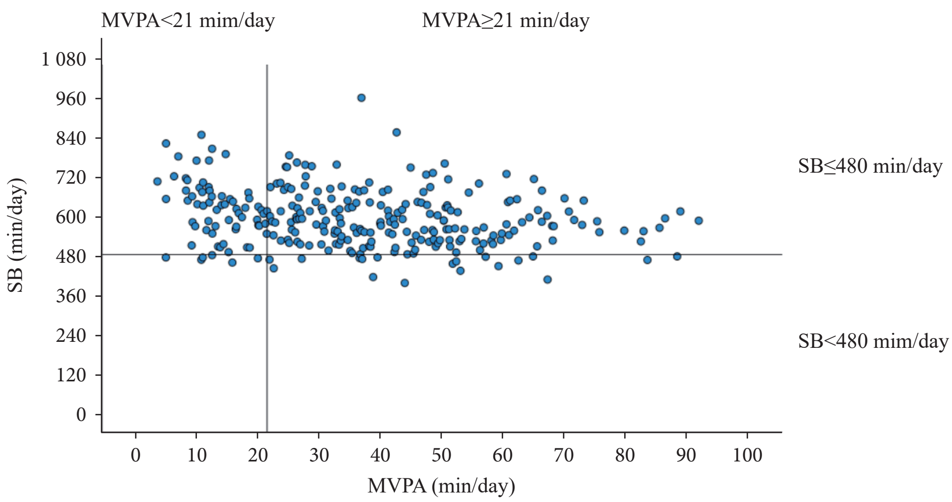

FIGURE 2. Distribution of moderate-to-vigorous physical activity versus sedentary behavior among adults aged 60–79 years, stratified by World Health Organization guideline thresholds (MVPA≥21 minutes/day; SB<480 minutes/day).
Abbreviation: MVPA=moderate-to-vigorous physical activity; SB=sedentary behavior.

Physical activity, characterized by skeletal muscle-induced bodily movement requiring energy expenditure, plays a fundamental role in both physical and mental well-being. Research indicates that physically inactive individuals face a 20% to 30% higher risk of premature mortality compared to their physically active counterparts (*6*). The World Health Organization's "Guidelines on Physical Activity and Sedentary Behavior" indicates that 25% of adults globally fail to meet recommended physical activity levels (*6*). Our findings reveal an even more concerning situation in China, where 43.2% of adults do not achieve sufficient MVPA, with daily averages of just 34.78 minutes. This contrasts markedly with findings from the China Kadoorie Biobank (CKB) study, which reported 104.4 minutes of daily MVPA using device-based measurements (*7*). This substantial disparity likely stems from methodological differences, particularly in device selection and placement. Our study employed waist-mounted ActiGraph triaxial accelerometers, whereas the CKB study utilized wrist-worn Axivity AX3 devices. Previous research has established that device placement significantly influences activity count measurements (*8*). While wrist-mounted accelerometers typically demonstrate higher compliance rates, they tend to record substantially higher activity counts compared to waist-mounted devices. For free-living ambulatory assessments, waist-mounted accelerometers are generally preferred due to their broader applicability and high acceptability.

Sedentary behavior, characterized by sitting or reclining postures with energy expenditure below 1.5 times the basal metabolic rate, represents a distinct health risk factor independent of physical inactivity and is associated with numerous adverse health outcomes (*9*). Current guidelines recommend adults limit SB to no more than 8 hours daily. Our findings reveal that 37.3% of Chinese adults exceeded this recommendation. The observed mean daily SB duration of 465.8 minutes (7.8 hours) closely aligns with findings from the China Kadoorie Biobank study, which reported 8.8 hours per day (*7*). These results suggest that excessive sedentary time, rather than insufficient MVPA, may require more urgent intervention among Chinese adults. Implementation of targeted strategies to reduce and interrupt prolonged periods of SB is therefore crucial.

Perhaps the most striking finding from our investigation was the exceptionally low adherence to combined MVPA and SB recommendations, with only 2.7% of the study population meeting both guidelines. This compliance rate was even lower among adults aged 20–59 years (2.3%), though slightly higher in those aged 60–79 years (5.0%). These rates fall substantially below the 12.6% observed in a cohort of 2,338 participants across eight Latin American countries (*10*). This disparity indicates that while many participants achieved adequate MVPA, they simultaneously accumulated excessive sedentary time. Conversely, others maintained appropriate SB levels but primarily engaged in light-intensity activities. These patterns underscore the critical need for targeted interventions designed to simultaneously reduce sedentary time and increase engagement in more vigorous activities. Furthermore, the observed variations in movement behaviors across gender and urban-rural demographics highlight the necessity for population-specific interventions. Notably, the absence of significant associations between PA, SB, and body weight status warrants further investigation.

This study has several notable limitations. Physical activity and sedentary behavior patterns exhibit significant seasonal variations (*11*), with higher activity levels typically observed during summer compared to winter, particularly among active populations. As our data collection occurred during autumn and early winter, future research across different seasons would strengthen the evidence base. Additionally, while the 7-day measurement period provides valuable insights, it may not fully capture long-term habitual movement behaviors. A longitudinal cohort study with extended measurement periods would offer more comprehensive behavioral patterns. Furthermore, although our multi-provincial study design provides important regional insights, caution should be exercised when extrapolating these findings to represent national patterns.

In conclusion, this study presents the first comprehensive assessment of movement behaviors using waist-mounted accelerometry across seven PLADs in China. Our findings reveal that a substantial proportion of Chinese adults maintain insufficient physical activity levels while engaging in excessive sedentary behavior. These results underscore the urgent need for targeted interventions aimed at both increasing moderate-to-vigorous physical activity and reducing sedentary time to optimize health outcomes associated with physical exercise.

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Preplanned Studies

Assessment of the Public Health Laboratory Capacity — Sierra Leone, 2021

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Summary

What is already known about this topic?

Public health laboratories (PHLs) are critical for effectively identifying, detecting, preventing, and responding to emerging and reemerging infectious diseases. Following the 2014 Ebola outbreak, Sierra Leone implemented a national laboratory strategic plan (2015–2020) aimed at creating, strengthening, and maintaining laboratory capacities for detecting, assessing, notifying, and reporting incidents, with a requirement to review PHL capabilities every five years.

What is added by this report?

This study assessed the comprehensive capacity and personnel status of PHLs in Sierra Leone using a standardized assessment tool following the implementation of the 2015 National Laboratory Strategic Plan. Among 11 indicators evaluated, laboratory infrastructure and equipment, data and information management, experimental technical training, and laboratory performance received low scores. The assessment revealed critical personnel gaps, including limited staff with extensive work experience and advanced education. Additionally, laboratory staff demonstrated limited capabilities in specialized areas such as gene library creation, primer design, sequencing, surveillance, and field epidemiology and laboratory-related training.

What are the implications for public health practice?

Continued investment and capacity building are essential for PHLs to deliver high-quality testing services and effectively support public health functions. The identified gaps across various indicators must be systematically addressed to strengthen PHL capacity in Sierra Leone.

Public health laboratories (PHLs) serve as cornerstones for patient diagnosis, disease management, surveillance, and epidemiological investigations (*1*). The 2014–2016 Ebola outbreak exposed critical weaknesses in Sierra Leone's laboratory system capacity (*2*). In response, the Ministry of Health and Sanitation (MoHS) of Sierra Leone committed to strengthening its laboratory infrastructure in alignment with international frameworks — including the Global Health Security Agenda, International Health Regulations, and Economic Community of West African States guidelines — to establish, enhance, and sustain laboratory capabilities for detecting, assessing, notifying, and reporting infectious disease incidents (*3*). The country's laboratory network comprises eight public health laboratories: one central public health reference laboratory, four national public health laboratories, and three regional public health laboratories (*4*). In 2015, Sierra Leone implemented a national laboratory strategic plan, scheduled for review every five years, focusing on improving diagnostic quality and disease surveillance across all tiers of the laboratory system (*5*). This study evaluated the comprehensive capacity and personnel status of PHLs in Sierra Leone to inform strategic improvements in their capabilities for diagnosing, preventing, and controlling infectious diseases, including tuberculosis (TB), malaria, Acquired Immune Deficiency Syndrome (AIDS), Ebola, Lassa fever, and coronavirus disease 2019 (COVID-19).

This study assessed all PHLs in Sierra Leone in 2021, including the Central Public Health Reference Laboratory (CPHRL), four national-level laboratories, and three regional laboratories. The national-level facilities comprised the Ola During Children's Hospital (ODCH), Connaught Hospital Lab (Connaught), Jui Public Health Laboratory (Jui Lab), and National TB Reference Laboratory Lakka (TB). The regional facilities included Kenema Laboratory, Bo Reference Lab (Bo), and Makeni Laboratory. Assessment was conducted using a standardized tool modified from the World Health Organization

(WHO) laboratory assessment framework and the 2016 Ministry of Health and Sanitation laboratory capacity survey. The tool evaluated both comprehensive laboratory capabilities and personnel status (Supplementary Material, available at https://weekly.chinacdc.cn/). Laboratory directors assessed their facilities' comprehensive capacity using the organizational structure component, while data on staff education and work experience were collected through face-to-face interviews. Of the 79 total staff across all PHLs, 51 (64.6%) were randomly selected based on each facility's human resource distribution and completed the personnel survey. All data were verified and documented using standardized forms and underwent double data entry into Excel spreadsheets. Performance scores were categorized as excellent (100%–85.0%), good (84.0%–70.0%), fairly good (69.0%–60.0%), poor (59.0%–30.0%), or very poor (29.0%–0%).

Statistical analysis employed descriptive methods, with indicator scores calculated as percentages. Inter-facility comparisons were conducted using Student's *t*-test, with statistical significance set at $P<0.05$. All analyses were performed using SPSS (version 20, United States, IBM).

The comprehensive assessment revealed that Sierra Leone's PHLs demonstrated good overall capacity, with a mean score of 71.0% across all indicators. Kenema and CHPRL achieved the highest average scores (83.0% and 81.0%, respectively), followed by Jui Lab (79.0%) and Connaught Lab (70.0%). The remaining facilities — TB, Makeni, ODCH, and Bo — scored 69.0%, 66.0%, 64.0%, and 57.0%, respectively (Table 1). Statistical analysis revealed significant differences in average scores between PHLs ($P<0.05$) (Figure 1).

Laboratory capacity exhibited considerable variation across indicators. Six of the eleven indicators were assessed as fairly good (60.0%–69.0%), with laboratory infrastructure and equipment, data and information management, and experimental technical training receiving notably low scores. Infrastructure limitations were evident, as only four PHLs maintained 24-hour electricity service. Additionally, half of the facilities lacked sequencing equipment, and while some PHLs had internet-connected personal computers, none possessed servers. Specimen management and biosafety and waste disposal demonstrated moderate performance (70.0% and 81.0%, respectively). Transport and specimen referral and organization and management achieved high scores (88.0% and 94.0%, respectively). Laboratory performance emerged as the sole indicator rated as poor, scoring 59.0% (Table 1). Capacity disparities were also observed among PHLs.

TABLE 1. Scores for 11 indicators and comprehensive capacity of public health laboratories in Sierra Leone, 2021.

Indicators	Public health laboratories' scores (%)								
	CPHRL*	Connaught†	TB†	ODCH†	Jui Lab†	Makeni§	Bo§	Kenema§	Average
Organization and Management	100	100	100	50	100	100	100	100	94
Transport & Specimen Referral	100	100	100	67	100	67	67	100	88
Biosafety & waste disposal	65	75	100	60	95	90	80	85	81
Specimen Management	67	100	56	89	33	44	94	78	70
Stock management for reagents & consumables	89	63	50	63	75	63	63	89	69
Public health functions	92	52	60	73	68	71	61	68	68
Human Resource	90	79	76	39	70	70	31	79	67
Laboratory infrastructure & equipment	80	60	50	50	100	51	30	80	63
Data and information Management	80	55	90	30	60	50	30	100	62
Experimental technical training received	78	33	56	78	89	67	22	56	60
Laboratory Performance	50	50	25	100	75	50	50	75	59
Comprehensive capacity score¶	81	70	69	64	79	66	57	83	71

Abbreviation: CPHRL=Central Public Health Reference Laboratory; Connaught=Connaught Hospital Lab; TB=National TB Reference Laboratory Lakka; ODCH=Ola During Children's Hospital; Jui Lab=Jui Public Health Laboratory; Bo=Bo Reference Lab; PHLs=Public Health Laboratories.

* National reference laboratory.

† National PHLs.

§ Regional PHLs.

¶ Comprehensive capacity score was calculated as the mean of 11 indicators for each PHL.

CPHRL	Makeni	Bo	Kenema	TB	ODCH	Jui Lab	PHLs
t=−2.042 P=0.066	t=0.112 P=0.913	t=2.453 P=0.032	t=−2.755 P=0.019	t=−0.192 P=0.815	t=0.192 P=0.852	t=−1.351 P=0.204	Connaught
	t=3.092 P=0.010	t=3.061 P=0.011	t=0.051 P=0.960	t=2.072 P=0.063	t=1.789 P=0.101	t=0.206 P=0.841	CPHRL
		t=1.550 P=0.149	t=−2.468 P=0.031	t=−0.436 P=0.671	t=−0.128 P=0.901	t=−2.758 P=0.019	Makeni
			t=−3.778 P=0.003	t=−1.644 P=0.128	t=−1.161 P=0.270	t=−2.421 P=0.034	Bo
				t=2.225 P =0.048	t=1.721 P=0.113	t=0.142 P=0.890	Kenema
					t=0.299 P=0.770	t=−1.460 P=0.172	TB
						t=−1.636 P=0.130	ODCH

FIGURE 1. Statistical differences in the scores of different public health laboratories in Sierra Leone, 2021.

Abbreviation: CPHRL=Central Public Health Reference Laboratory; Connaught=Connaught Hospital Lab; TB=National TB Reference Laboratory Lakka; ODCH=Ola During Children's Hospital; Jui Lab=Jui Public Health Laboratory; Bo=Bo Reference Lab; PHLs= Public Health Laboratories.

Note: Statistic values of comparisons between PHLs from Student's t test. Color in yellow presents P<0.05, grey presents P≥0.05.

For instance, the human resources indicator ranged from excellent at CPHRL (90.0%), followed by Connaught and Kenema (both 79.0%), and TB (76.0%), to poor at Bo and ODCH (31.0% and 39.0%, respectively). Laboratory performance scores varied substantially, with TB, Kenema, and Jui laboratories achieving excellent to good ratings, while the remaining facilities scored poor. Notably, each PHL exhibited at least one indicator assessed as poor, scoring below 60.0%.

Regarding educational qualifications and continuing professional development, the laboratory system faces significant limitations in advanced degree holders and specialized public health training. The majority of laboratory staff held bachelor's degrees (52.9%) or national diplomas (27.5%), with only 13.6% possessing master's degrees. Advanced qualifications including PhDs, doctoral degrees, or postgraduate diplomas represented just 6.0% of the workforce. Analysis of educational backgrounds revealed that 41.2% specialized in medical laboratory science, 31.3% in biological sciences, while public health laboratory specialization (2.0%) and public health (5.8%) were notably underrepresented (Table 2). Training assessment indicated high participation rates (74.5%–98.0%) in core competencies including data management, laboratory management, bio-risk and biosafety management, quality assurance systems, specimen handling, and diagnostic techniques. However, critical specialized skills showed concerning deficits, with only 27.5% to 41.2% of staff trained in bioinformatics, epidemiological surveillance, and field epidemiology and laboratory methods (Table 2).

The workforce analysis revealed significant experience gaps, with most staff having less than five years of professional experience and few personnel possessing more than a decade of laboratory practice. While staff demonstrated high competency rates in fundamental laboratory procedures, including diagnostic techniques (100%) and specimen management (92.2%), advanced capabilities were markedly limited. Specifically, proficiency in epidemiological surveillance (39.2%), field epidemiology and laboratory training (37.3%), and bioinformatics (39.2%) was notably deficient. Bioinformatics expertise was particularly constrained in command-line operations and high-throughput sequencing data analysis. Regarding technical competencies, while a substantial proportion of staff (68.6%–100%) demonstrated proficiency in standard procedures such as bacterial culture and identification, rapid diagnostic testing, blood film analysis, malaria parasite microscopy, PCR, and nucleic acid extraction, advanced molecular techniques showed significant gaps. Only a small fraction of personnel demonstrated competency in gene library preparation (15.7%), primer design (19.6%), sequencing (21.6%), and tissue anatomy (23.5%) (Table 3).

DISCUSSION

Our assessment identified critical gaps in Sierra Leone's public health laboratory system that necessitate nationwide commitment to capacity building and

TABLE 2. Educational attainment and continuous medical education in public health laboratories in Sierra Leone, 2021.

Indicators	No. of staff	Percentage
Education		
Bachelor of science degree	27	52.9
National diploma	14	27.5
Master of science	7	13.6
Doctor of Philosophy	1	2.0
Doctoral degree	1	2.0
Postgraduate diploma	1	2.0
Major		
Medical laboratory	21	41.2
Biological science	16	31.3
Chemistry	4	7.7
Public health	3	5.8
Environmental management & quality control	1	2.0
Epidemiology and medical statisitcs	1	2.0
General medicine	1	2.0
Graduate diploma/B.SC chemistry	1	2.0
Immuno-virology	1	2.0
Advance nursing & medical technology	1	2.0
Public health laboratory	1	2.0
Professional training ever received		
Laboratory diagnostic techniques	50	98.0
Specimen collection, packaging and transportation	47	92.2
Laboratory quality assurance	47	92.2
Bio-risk and biosafety management	46	90.2
Laboratory management	41	80.4
Data management	38	74.5
Epidemiological surveillance	21	41.2
Field Epidemiology and Laboratory Training Programme	21	41.2
Bioinformatics	14	27.5
Competency assessment		
Yes	43	84.3
No	8	15.7

enhancement across multiple indicators. The results revealed that laboratory infrastructure and equipment, data and information management, experimental technical training, and laboratory performance represent the most significant weaknesses compared to other indicators. Furthermore, substantial capacity disparities exist among different PHLs, with some facilities demonstrating relatively balanced development, such as the CPHRL, Kenema, and Jui laboratories, while others exhibited poor performance in at least three indicators requiring immediate improvement.

The National Health Sector Strategic Plan 2015–2020 in Sierra Leone established standards and priorities for PHLs, emphasizing laboratory administration (infrastructure, utilities, equipment), human resources (service levels, training), and health and safety (safety officials, biosafety and biosecurity) as top priorities for laboratory development (*1*). Our 2021 assessment revealed that inadequate infrastructure remains prevalent across PHLs. The most critical concern is insufficient electrical supply,

TABLE 3. Work experience of staff in public health laboratories in Sierra Leone, 2021.

Indicators	No. of staff	Percentage
Work in HCS		
≤5 years	25	49.0
>5 years and <10 years	13	25.5
≥10 years	13	25.5
Work in Lab		
≤5 years	33	64.7
>5 years and <10 years	12	23.5
≥10 years	6	11.8
Work experience in the following areas		
Laboratory diagnostic techniques	51	100.0
Specimen collection, packaging and transportation	47	92.2
Laboratory quality assurance	47	92.2
Bio-risk and biosafety management	43	84.3
Laboratory management	42	82.4
Data management	35	68.6
Epidemiological surveillance	20	39.2
Bioinformatics	20	39.2
Field Epidemiology and Laboratory Training Programme	19	37.3
Understanding of molecular genetics	49	96.1
Bioinformatics background		
Basic evolutionary	43	84.3
Heard about bioinformatics genomics	41	80.4
Heard about comparative genomics	23	45.1
Experience on command lines	10	19.6
High-throughput sequencing data	9	17.6
Biological experiments and tests		
Malaria rapid diagnostic tests	51	100.0
Polymerase chain reaction	45	88.2
Blood film and microscopic examination	43	84.3
Nucleic acid extraction	41	80.4
Bacterium culture and identification	35	68.6
Mosquito identification	24	47.1
Microbial strain isolation	22	43.1
Tissue anatomy	12	23.5
Sequencing	11	21.6
Primer design	10	19.6
Gene library creation	8	15.7

Abbreviation: HCS=healthcare system.

with half of PHLs lacking 24-hour electricity service, which compromises normal laboratory operations. Regarding human resources, our findings indicate that the number of skilled professionals is insufficient to meet diagnostic testing needs in several PHLs. This challenge was also highlighted in the Public Health Surveillance Strategy Plan 2019–2023 in Sierra Leone (*4*), which noted that one-third of skilled specialists are approaching retirement age. Despite the inclusion of training initiatives in the National Health Sector

Strategy Plan 2015–2020 (*4*), the high-quality training in specialized fields such as bioinformatics, epidemiological surveillance, and field epidemiology and laboratory programs requires further enhancement to meet minimum qualified personnel requirements for supporting testing services in disease surveillance and outbreak response.

Laboratory information management system development was designated as the second priority for PHLs capacity building in Sierra Leone, with the goal of establishing an integrated laboratory information and management system within the national health management information system by 2020 (*1*,*6*). While paper-based laboratory management information systems were established and electronic systems initiated in some facilities by 2019 (*6*). The shortage of competent staff and inadequate computer infrastructure (*6*) necessitates improvements in basic data management processes, such as standardization of data collection, storage, analysis, and utilization. In addition, laboratory performance remains a critical concern in several facilities, representing the only indicator rated as poor in the assessment. Public health laboratories serve as the cornerstone of emergency response capabilities and are responsible for testing key epidemic-prone diseases in Sierra Leone, including monkeypox, zika, cholera, meningitis, influenza, measles, and rubella (*4*). However, inconsistent funding streams, delays in equipment and reagent procurement. The shortages of qualified personnel have compromised the efficiency and availability of testing services for severe infectious diseases like COVID-19 and Ebola in certain regions (*4*).

This study has several limitations that warrant consideration. First, the high scores achieved by some PHLs may not accurately reflect their actual testing capabilities, potentially leading to an overestimation of their performance. Second, while our investigation focused on PHL capabilities, we did not explore the underlying factors contributing to low-scoring indicators, which should be addressed in future studies.

In conclusion, while PHLs have established foundational capabilities and demonstrate strengths in certain areas, significant capacity disparities and weaknesses persist across different facilities. Continued investment and systematic improvement of PHL capacity are essential to ensure the delivery of high-quality testing services and effective public health functions.

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SUPPLEMENTARY MATERIAL

INSTRUCTIONS

This assessment tool comprises the following components:

PART I: Organizational structure

1. Human resources
2. Laboratory infrastructure and equipment
3. Transport and specimen referral
4. Stock management for reagents and consumables
5. Laboratory performance
6. Specimen management
7. Biosafety and waste disposal
8. Public health functions
9. Organization and management
10. Data and information management
11. The need of experimental technical training

PART II: Personal status

1. Educational attainment and continuous medical education
2. Work experience
3. Biology and bioinformatics background
4. Biological experiments and tests experience

Recollection

China-UK Global Health Collaboration Project on Strengthening Public Health Capacity in Sierra Leone

Xiuli Xue[1]; Jiewen Wu[1]; Lili Wang[1]; Idrissa Laybohr Kamara[2]; Mingfan Pang[1]; Xiaopeng Qi[1,#]

ABSTRACT

Since 2016, the Chinese Center for Disease Control and Prevention has continued to conduct project to assist Sierra Leone in improving its public health capacity and building a laboratory for bacteriological and parasitic diseases. Firstly, we can understand the epidemiological characteristics, etiological characteristics and drug resistance of important infectious diseases in Africa through this project, and provide services and guarantees for the construction of the Belt and Road Initiative. Secondly, the project is to carry out scientific research cooperation on the monitoring and detection capacity of major infectious diseases, biosecurity, and prevention and control technologies for important infectious diseases. Thirdly, in order to implement the concept of "building a community with a shared future for mankind", it is important to improve the capacity of Sierra Leone and West Africa to prevent and control infectious diseases, maintain global health security, and participate in global health governance. This article reviews the implementation of the project, and summarizes the experience and shortcomings, in order to help readers achieve better results in future project practice.

RATIONALE

The Ebola epidemic across West African countries severely compromised Sierra Leone's health system (*1*), exposing critical vulnerabilities in its public health infrastructure, particularly in surveillance capabilities, laboratory testing capacity, and the availability of skilled public health professionals (*2*). The Sierra Leone-China Friendship Bio-safety Level 3 Laboratory (hereinafter referred to as "the BSL-3 Laboratory"), constructed with Chinese government assistance, commenced operations in March 2015. This facility was designed to conduct surveillance and detection of Ebola, malaria, and other infectious disease pathogens, while simultaneously serving as a training center for developing highly qualified laboratory personnel in Sierra Leone (*3*). Given the prevalence of emerging infectious diseases and the insufficient viral and bacterial testing capabilities of existing facilities, there was an urgent need for enhanced professional training of local technical staff. Building upon the existing laboratory infrastructure, our objective was to assist Sierra Leone by establishing comprehensive viral, bacterial, and parasitic testing facilities, strengthening the existing laboratory surveillance system and data management network, and fostering new partnerships for cooperation and resource exchange to improve the country's epidemic and pandemic preparedness (*3*).

Building on successful exchange programs with Public Health England (PHE) and the robust foundation of China-Sierra Leone cooperation (*4*), China CDC initiated an exploratory project in 2016 under the China-UK Global Health Support Programme to enhance Sierra Leone's public health capacity (*5*). Through this initiative, PHE provided ongoing support to China CDC for laboratory testing and capacity building at the BSL-3 Laboratory, leveraging UK expertise and resources. The project's management office (PMO), housed within the Centre for Project Supervision and Management, National Health Commission of the People's Republic of China, oversees daily operations and project management.

PROJECT CONTENT AND ACTIVITIES

China provided comprehensive support to Sierra Leone in developing surveillance and detection capabilities for emerging and re-emerging infectious diseases, training essential health management and technical experts, and establishing technical communication mechanisms with key international partners, including the Ministry of Health of Sierra Leone and the UK.

Conducting A Systematic Survey in Sierra Leone

Expert teams conducted comprehensive field research visits to Sierra Leone to assess the country's infectious disease epidemiological profile, evaluate existing public health infrastructure, and examine the BSL-3 laboratory's operational status. This systematic assessment aimed to identify priority diseases for laboratory testing, evaluate technical and staffing gaps, and determine optimal strategies for integrating the new laboratory within the local public health system.

Sierra Leone's Major Diseases Malaria remains Sierra Leone's predominant vector-borne disease. According to the *World Malaria Report 2023*, the country documented 2,651,760 malaria cases and 8,212 malaria-related deaths in 2022, yielding a case fatality rate of 0.3% (*6*). Additionally, cholera, typhoid, and other enteric diseases constitute significant infectious disease burdens in the nation.

Sierra Leone's Public Health System Chinese experts participated in weekly emergency response meetings coordinated by the Ministry of Health and Sanitation (MoHS), Sierra Leone and conducted field assessments in Makeni. Through these investigations, the experts gained comprehensive insights into Sierra Leone's public health system infrastructure and healthcare operational frameworks. Several critical challenges were identified within the health system, including inadequate epidemic preparedness and response capabilities, insufficient national epidemic surveillance data systems, and unsustainable parasitic disease control programs (*7*).

Operation and Management of the Current Laboratory

The BSL-3 Laboratory, established by the Ministry of Commerce, People's Republic of China, operated under Chinese expert management with local Sierra Leonean staff participating in daily operations. While the facility conducted passive surveillance for Ebola pathogens, it lacked comprehensive bacterial and parasitological testing capabilities. Additionally, a limited number of Sierra Leonean personnel possessed only basic testing skills and were unable to work independently or participate in project management activities.

Carry Out Laboratory Cooperation and Collaboration

Chinese experts facilitated collaborative site visits with PHE representatives Dr. Marcus and Dr. Bausch to the BSL-3 Laboratory and Makeni Regional Hospital Molecular Laboratory. These visits enabled comprehensive knowledge exchange regarding laboratory scale, operational scope, biosafety protocols, staffing structures, and training programs.

Establishment of Bacteriology and Parasitology Testing Laboratories

The Sierra Leone-China Friendship Hospital provided space for establishing bacteriology and parasitology testing laboratories. Chinese experts led the comprehensive laboratory development, implementing a design that incorporated distinct zones with clear signage and separated pathways for personnel, specimens, and laboratory waste to ensure compliance with infection control and prevention protocols. The experts assessed existing bacterial testing reagent inventory, equipped the laboratory with testing apparatus scaled to anticipated specimen volumes, and established robust systems for laboratory storage and waste management. These systems supported the cultivation, storage, and safe disposal of bacterial strains, enabling comprehensive bacterial and parasitic testing capabilities.

Establishing Laboratory Standard Operating Procedures (SOPs)

Chinese experts developed standardized testing procedures for *Vibrio cholerae* and *Salmonella typhi* pathogens, focusing on stool sample analysis from diarrheal patients. They completed procedural documentation and laboratory operation manuals for parasitic disease testing, with particular emphasis on the *Plasmodium* parasite responsible for malaria, incorporating the World Health Organization (WHO) SOPs for *Plasmodium* microscopy detection. These measures ensured consistent laboratory operations and project continuity.

Training and Practice for Laboratory Personnel

Laboratory personnel training was strategically organized by work specialization, with customized theoretical and practical training programs developed for each area. The curriculum encompassed pathogen monitoring and detection in bacteriological laboratories, standardized laboratory operations, sentinel hospital sample collection methodologies, and data collection and statistical analysis. In response to public health emergencies in Sierra Leone, additional practical training sessions focused on environmental sample collection in affected areas, disease surveillance protocols, and environmental decontamination procedures.

PROJECT IMPACTS AND DELIVERABLES

Through rigorous quantification of project outcomes and comprehensive feedback from both UK and Sierra Leone stakeholders, this initiative has achieved its intended impacts. The project successfully trained laboratory professionals to operate BSL-3 facilities, establishing sustainable and efficient operations that exemplify the mutual benefits of China and UK's collaborative health assistance to Sierra Leone.

Chinese Perspective

From China's perspective, the multi-stakeholder collaboration enhanced the nation's capacity to coordinate international health cooperation resources. The China-UK partnership optimized resource sharing and joint laboratory capacity building, maximizing the advantages of their collaborative program. Additionally, the diversification of China's foreign aid activities in Sierra Leone accelerated the development of China's global health workforce, strengthening the country's capacity for international engagement.

Sierra Leone's Perspective

From Sierra Leone's perspective, the establishment of bacteriological and parasitological testing laboratories markedly enhanced the nation's diagnostic capabilities. The successful training of 19 local laboratory technicians has been instrumental in building sustainable operations (*8*). This comprehensive capacity-building initiative improved Sierra Leone's ability to design testing protocols, manage biosafety programs, and maintain a skilled surveillance and testing workforce. The trained laboratory personnel are now central to strengthening the country's emerging infectious disease surveillance systems.

UK's Perspective

The United Kingdom's involvement optimized resource allocation by preventing redundant laboratory investments, thereby enhancing funding efficiency. This tripartite cooperation model improved the effectiveness of UK aid programs while strengthening their capacity to deliver health assistance. Furthermore, the project enabled the UK to leverage its healthcare expertise by transforming technical knowledge, resources, and governmental influence into tangible improvements in socioeconomic outcomes and health security, ultimately advancing their strategic objectives.

The laboratory has achieved significant recognition, being designated as Sierra Leone's "National Reference Laboratory for Viral Hemorrhagic Fever" and "National Training Centre for Virus Detection and Biosafety." During the COVID-19 pandemic, it served as the primary testing facility not only for Sierra Leone but also for the entire West African region.

SUCCESS FACTORS

The United Kingdom's financial support served as the primary catalyst for the project's success. Their comprehensive involvement extended beyond funding to include laboratory capacity-building initiatives and collaborative exchanges. The UK's extensive experience in international project management significantly enhanced the implementation strategy. Their established global health network provided crucial support in developing technical communication mechanisms between China CDC and key stakeholders, including Sierra Leone MoHS, PHE, and other international partners (*9*).

The laboratory capacity training led by Chinese experts constituted another critical success factor. This foundation enabled China and the UK to jointly develop and share laboratory capacity-building resources, leading to optimized resource utilization through mutual exchange of outcomes and experiences.

Sierra Leone's receptive approach toward public health cooperation with China and the UK proved instrumental to the project's success.

LESSONS AND EXPERIENCES

The establishment of an effective communication and coordination mechanism provided a robust foundation for project implementation. Throughout both the application and execution phases, the Center for Global Public Health, China CDC, maintained consistent communication with the Project Management Office through regular progress reports, prompt problem identification, and collaborative solution development guided by the PMO-designated project manual, ensuring smooth project progression.

A strategic focus on innovation and collaboration enabled project expansion beyond its initial scope. Building upon previously established international partnerships, China CDC effectively engaged with PHE, CDC, WHO, UN, and other international organizations to develop new collaborative opportunities (*10*).

Complex logistical challenges and force majeure events, including a devastating mudslide in Freetown in August 2017, impacted expert secondments to international organization offices in third countries. Based on these experiences, researchers recommend earlier planning for secondments to accommodate administrative procedures and enhanced communication with international organization offices in host countries to secure necessary approvals and support.

NEXT STEPS

The China-UK Global Health Programme should expand its multilateral health technical cooperation initiatives in global health, with particular emphasis on tailoring interventions for African nations and other developing countries. By combining China's extensive expertise in infectious disease prevention with the UK's established global health network, this collaboration has the potential to achieve significant innovations and breakthroughs in international public health capacity building.

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