ISSN 2096-7071
CN 10-1629/R1

# CHINA CDC WEEKLY

Vol. 3 No. 13 Mar. 26, 2021

CCDC weekly

中国疾病预防控制中心周报

**George F. Gao:**

**If the world does not share the vaccine, the virus will take on the world.**


烏干達通過世界衛生組織主導的“新冠肺炎疫苗實施計劃(COVAX)”收到首批新冠疫苗。（新華社）

若世界不共用疫苗

高福：病毒就共用世界

【本報訊】據鳳凰網九日消息：全國政協委員、中國疾控中心主任高福稱，全世界不共用疫苗，病毒就會共用世界。

呼籲民眾接種疫苗

高福現在最擔心的是變異。他接受採訪時說得最多的，就是呼籲民眾接種疫苗。他說，自己在去年上半年已經接種疫苗，民眾不用對疫苗有太多擔心。他還說，如果全世界不共用疫苗，病毒就會共用世界了。

患者留下心理創傷

預。

去年曾長期在一線救治新冠患者的廣州市八院國家臨床重點專科（感染性疾病科）首席專家蔡衛平表示，感染新冠，可以完全恢復。

蔡衛平說，大部分能夠恢復到正常的狀態，體力稍微差一些，持續的時間不會太長，幾個月內，可能會覺得體力差一些，逐漸逐漸能夠恢復正常。絕大部分人能夠恢復到正常狀態。

蔡衛平表示，對患者最大的影響是心理影響，根據調查感染過新冠的患者不少人都形成心理創傷。從去年一月七日分離出首株新冠病毒，至今人類與新冠病毒打交道已經一年多時間。他說，關於新冠病毒未知的東西還有非常多，尤其是病毒不斷傳播，變異程度會如何。

## Foreword



## Preplanned Studies



## Methods and Applications



ISSN 2096-7071

Cover Image: Adapted from Macao Daily, March 10, 2021 (A4).

Foreword

# "If the world doesn't share the vaccine, the virus will take on the world"

Zundong Yin[1]; Lance Rodewald[1]; Dan Wu[1]

What did George Gao mean by the title quote? The statement certainly feels like a warning, but it is a warning that comes with a prescription that carries optimism and hope.

The warning that the virus will "take on the world" has indeed been the world's experience during the first year of COVID-19. But the warning is more ominous with the continual emergence of variants of the coronavirus that have differing characteristics – transmission speed, pathogenicity, evasion of immunity to prior infection or immunization (*1*).

Viruses do not have wants or desires; viruses do not have goals or objectives; and viruses do not have plans for the future. However, viruses are in the realm of the living, they do replicate (with the host's machinery), and they evolve in directions that favor their continued existence. As long as their continued existence threatens human health, they are taking on the world.

Why should the world's sharing of vaccines be part of the solution? What contribution can COVID-19 vaccines make? How confident should we be in the ability of vaccines to stop these viruses?

Virus evolution is dependent on mutations that arise during replication in a host that are transmitted to others, creating subtly and sometime not-so-subtly different lineages that can have selective advantage. Stopping replication stops evolution. Preventing infection prevents replication. Preventing transmission prevents infection. To the extent that vaccines are able to decrease the amount of viral replication, viral infection, and viral transmission, the pace of evolution should be able to be slowed, slowing generation of variants, and slowing the virus' taking on of the world.

Can vaccines do that? The current COVID-19 vaccines have been authorized for use based on their proven ability to prevent clinical disease, not their ability to prevent transmission and infection. However, animal models in preclinical trials showed evidence of prevention of transmission, and evidence is emerging that COVID-19 vaccines prevent infection and transmission. Seeing the large decreases of COVID-19 with widespread use of COVID-19 vaccine in Israel is a good sign with real world evidence (*2*). We are likely to see more and more evidence that COVID-19 vaccines prevent infection and transmission as the world has more experience with the vaccines.

Based on other routinely-used vaccines, one would expect the COVID-19 vaccines to have some effectiveness against infection and transmission. Look at hepatitis A in China. The number of infections is hundreds of times lower than in the pre-vaccine era after use of hepatitis A vaccines; fewer infections mean fewer replications. Even inactivated poliovirus vaccine (IPV), which is often said to not be effective against infection/transmission, has epidemiologically meaningful effectiveness against infection/transmission (*3*). Several European countries eliminated polioviruses with IPV alone. Last year, China stopped a three-year-old outbreak of circulating vaccine-derived poliovirus type 2 with Sabin-strain IPV alone (*4*). These accomplishments would not have been possible without vaccine effectiveness against infection/transmission.

Will vaccines cause selection of vaccine-escape mutants? One would expect that viruses less neutralized by vaccines to have selective advantage over viruses more susceptible to vaccine-induced immunity. However, this is not a reason to not vaccinate. The contribution of selection pressure leading to meaningful vaccine escape is not known. Every year, influenza vaccine is changed in attempt to match the upcoming circulating strains, but the reason that circulating strains change is not from vaccine selection pressure, but rather from genetic drift that happens with or without vaccination.

Virus replication anywhere is a threat everywhere. Not only is ongoing transmission a risk to health where it is happening, but also a risk to other places to which the virus can travel. This is in part the reason for the World Health Organization's (WHO) call for solidarity in the fight against the COVID-19 pandemic. Along with promoting the development of COVID-19 vaccines, WHO, the Coalition for Epidemic Preparedness, and Gavi created COVAX, a mechanism for sharing vaccines globally. Almost all countries of the world have signed onto

COVAX, and indeed COVAX has already started sharing COVID-19 vaccines (*5*). Strengthening COVAX with financing and vaccine supports sharing the vaccine with the world.

As George Gao says, sharing vaccines with the world is important to prevent the virus from taking on the world. Vaccines alone, of course, are not enough. Constant vigilance and sensitive surveillance of circulating coronavirus is absolutely essential. The first generation of vaccines may need to be updated to keep up with, and ideally get ahead of virus evolution by finding additional vaccine targets. Population immunity will need to be frequently assessed against circulating strains and tested for waning immunity. Vaccination policies will need to be adjusted as the epidemiology changes.

Ensuring availability and large-scale use of COVID-19 vaccines by all countries, in solidarity against the COVID-19 pandemic, is a vital strategy to prevent the virus from taking on the world.

**doi:** 10.46234/ccdcw2021.080

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Submitted: March 25, 2021; Accepted: March 26, 2021

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Preplanned Studies

# Breast Cancer Screening Rates Among Women Aged 20 Years and Above — China, 2015

Mei Zhang[1,&]; Yijing Zhong[2,&]; Heling Bao[1,3]; Zhenping Zhao[1]; Zhengjing Huang[1]; Xiao Zhang[1]; Chun Li[1]; Maigeng Zhou[1,&]; Limin Wang[1]; Jing Wu[1]; Xiaoying Zheng[2,#]; Linhong Wang[1,#]

**Summary**

**What is already known about this topic?**

Breast cancer is the most common cancer in women in China and around the world. By 2019, 121 countries have instituted a national screening program as a secondary prevention measure for breast cancer.

**What is added by this report?**

Breast cancer screening rates in China were 18.9% in women aged 20 years and above, and 25.7% in women aged 35–64 years in 2015. The screening rate for women aged 20 years and above was significantly higher in urban areas than in rural areas (24.6% *vs.* 15.0%), and in the eastern region than in the central and western regions (24.0% *vs.* 15.1% and 15.3%).

**What are the implications for public health practice?**

Continued efforts should be made to strengthen national and local policy initiatives and financial support for population-based, organized screening programs for breast cancer. Health education and accessibility of screening services to women across the country should be strengthened, especially for women aged 50 years and above.

Breast cancer is the most common cancer in women in China and around the world. Age-standardized incidence and mortality by Chinese standard population were 31.54/100,000 population and 6.67/100,000, respectively, in China in 2015 (*1*). The breast cancer screening rate in China reached 21.7% in women aged 18 years and above in 2010 (*2*) and 22.5% in women aged 35–64 years in 2013 (*3*). To understand the latest screening coverage in China, this study estimated screening rates in 2015 based on nationally and provincially-representative survey data, and Rao Scott chi-squared tests and logistic regression models were conducted to analyze key demographic and geographic factors. This study showed improving but still low levels of breast cancer screening coverage of women in China. Continued efforts should be made to strengthen national and local policy initiatives and financial support for population-based, organized screening programs for breast cancer. Health education and accessibility of screening services to women across the country should be strengthened, especially to women aged 50 years and above.

In 2020, breast cancer age-standardized incidence rates by world standard population ranged from 30/100,000 in East Africa to above 95/100,000 in Australia and New Zealand (*4*). Since the 1990s, breast cancer mortality notably declined in the developed world, which according to evidence of randomized controlled trials was largely due to breast cancer screening, though the actual amount of reduction attributable to screening was subject to controversy (*5*). By 2019, 121 countries have instituted a national screening program as a secondary prevention measure for breast cancer (*6*). To reduce the burden of breast cancer, China launched a national breast cancer screening program for rural female residents aged 35–59 years old in 2009 (extended to 35–64 years after 2012), as well as for urban female residents aged 40–69 years old in 2012 (later changed to 45–74 years after 2016) (*7*).

This study estimated the latest breast cancer screening rates in China based on nationally and provincially representative survey data. The survey was conducted in 2015 using a multistage, cluster-randomized sampling method. Female respondents aged 18 years and above were randomly selected from 298 districts/counties that were randomly selected from over 2,400 districts/counties across 31 provincial-level administration divisions (PLADs). Respondents answered a set of questionnaires on chronic diseases and related behaviors, which were recorded by trained professionals from the local CDCs (*8*). With regard to breast cancer screening, all participants were asked whether they have ever had breast cancer screening, the time of the most recent screening, and the method of screening.

In 2015, of 88,250 households sampled, 100,543 female participants completed the survey from August to December, which yielded a 95.4% response rate. Several participants who did not meet criteria were excluded including 612 female participants who were less than 20 years, 7,902 participants who were unclear whether they have been screened, and 3,150 participants with missing data. The study was approved by the Ethical Committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China CDC. All participants provided written informed consent.

Weighting was applied to all statistical analyses for both national and regional-specific estimates and the weighted proportion was reported. Chi-squared tests and logistic regression models were used to examine differences in unordered categorical variables and trends in ordered categorical variables, respectively. Taylor linearization methods with a finite population correction were used to estimate standard errors (SE). Statistical significance was determined as a two-sided $p<0.05$. All statistical analyses used SAS (version 9.4, SAS Institute Inc., Cary, USA).

The final sample of 88,879 female participants aged 20 years and above were 51.4 years of mean age, 59.0% from rural areas, and 41.3% with primary school or less education (Table 1).

The national breast cancer screening rate was 18.9% in women aged 20 years and above, and 25.7% in women aged 35–64 years. For women aged 20 years and above, the urban screening rate was significantly higher than the rural screening rate (24.6% *vs.* 15.0%, $p<0.0001$). The eastern region showed a significantly higher screening rate than the central and western regions (24.0% *vs.* 15.1% and 15.3%, $p<0.0001$). The 40–49 age group had the highest screening rate (29.2%), whereas the 60–69 age group (12.3%) and the 70 years and above age group (5.0%) had much lower screening rates. Overall, 16.7% of women aged 20 years and above were screened within the past 2 years (Table 2). Moreover, 55.1% of women were screened by ultrasound, 14.5% by X-ray, 12.8% by only clinical examination, while 15.0% of women were unaware of their screening method.

Women with college or above education and with high school education (28.0% and 24.7%, respectively) had significantly higher screening rates than women with lower education levels ($p<0.0001$). Women with higher income showed significantly higher screening

TABLE 1. Sociodemographic characteristics of female participants aged 20 years and above — China, 2015.

| Characteristics | No. of participants (N=88,879) | Weighted proportion (%) (95% CI)* |
|---|---|---|
| Age (years) | | |
| 20–29 | 8,121 | 23.5 (22.5–24.5) |
| 30–39 | 11,438 | 21.1 (20.3–21.9) |
| 40–49 | 20,519 | 22.6 (22.0–23.2) |
| 50–59 | 21,888 | 15.5 (15.0–16.1) |
| 60–69 | 18,765 | 9.6 (9.1–10.1) |
| 70 and above | 8,148 | 7.7 (6.9–8.5) |
| Area type | | |
| Urban | 38,829 | 41.0 (35.3–46.6) |
| Rural | 50,050 | 59.0 (53.4–64.7) |
| Region | | |
| East | 33,603 | 42.5 (38.6–46.5) |
| Central | 25,669 | 32.2 (28.5–35.9) |
| West | 29,607 | 25.2 (22.5–28.0) |
| Education | | |
| Primary or less | 49,062 | 41.3 (39.0–43.5) |
| Junior high | 23,615 | 30.0 (28.7–31.3) |
| Senior high | 9,688 | 14.2 (13.0–15.3) |
| College or above | 6,514 | 14.5 (12.7–16.3) |
| Household income per capita (CNY) | | |
| Q1 (<7,200) | 14,572 | 12.5 (11.4–13.7) |
| Q2 (7,200–14,999) | 15,480 | 15.6 (14.5–16.7) |
| Q3 (15,000–24,999) | 19,233 | 21.3 (20.3–22.3) |
| Q4 (25,000 and above) | 24,168 | 32.5 (30.2–34.9) |
| Don't know/refused | 15,426 | 18.0 (16.5–19.6) |
| Employment status | | |
| Employed | 57,792 | 67.1 (65.0–69.2) |
| Housework | 18,927 | 19.8 (18.0–21.7) |
| Retired | 7,961 | 5.7 (4.7–6.6) |
| Unemployed | 4,199 | 7.4 (6.6–8.1) |
| Health insurance coverage | | |
| No | 2,476 | 4.1 (3.7–4.6) |
| Yes | 86,403 | 95.9 (95.4–96.4) |
| Health examination in the past 3 years | | |
| No | 52,565 | 59.6 (57.6–61.5) |
| Yes | 36,314 | 40.4 (38.5–42.4) |
| Self-assessed health status | | |
| Poor or fair | 53,296 | 55.4 (54.0–56.8) |
| Good | 35,583 | 44.6 (43.2–46.0) |

* Proportions are weighted to represent the national total population with poststratification for age gender, and urban/rural residence.

TABLE 2. Breast cancer screening rates among Chinese women aged 20 years and above by sociodemographic factors — China, 2015*.

| Item | Ever screened (%) (95%CI) | | | | Screened in 1 year (%) (95% CI) | Screened in 2 years (%) (95% CI) | Screened in 3 years (%) (95% CI) |
|---|---|---|---|---|---|---|---|
| | Total | Urban | Rural | *p*-value | | | |
| Total | 18.9 (17.5–20.4) | 24.6 (22.3–26.8) | 15.0 (13.2–16.9) | <0.0001 | 14.2 (13.0–15.4) | 16.7 (15.4–18.0) | 17.5 (16.1–18.8) |
| Age (years) | | | | | | | |
| 20–29 | 8.5 (7.3–9.7) | 10.6 (8.8–12.5) | 6.9 (5.4–8.3) | 0.0019 | 7.0 (6.0–8.0) | 8.1 (6.9–9.2) | 8.2 (7.1–9.4) |
| 30–39 | 25.3 (23.0–27.6) | 32.0 (28.3–35.7) | 20.0 (17.4–22.5) | <0.0001 | 20.1 (18.2–21.9) | 22.8 (20.9–24.8) | 23.8 (21.8–25.8) |
| 40–49 | 29.2 (26.9–31.6) | 38.1 (34.6–41.7) | 23.6 (20.6–26.6) | <0.0001 | 22.3 (20.3–24.4) | 26.3 (24.0–28.5) | 27.4 (25.1–29.6) |
| 50–59 | 22.2 (20.4–24.0) | 28.5 (25.9–31.1) | 18.1 (15.4–20.9) | <0.0001 | 14.9 (13.6–16.2) | 18.4 (16.7–20.0) | 19.7 (17.9–21.5) |
| 60–69 | 12.3 (11.0–13.5) | 17.8 (15.5–20.1) | 8.8 (7.4–10.3) | <0.0001 | 7.5 (6.5–8.5) | 9.3 (8.2–10.3) | 10.1 (9.0–11.2) |
| 70 and above | 5.0 (4.1–6.0) | 8.9 (7.1–10.8) | 2.5 (1.6–3.3) | <0.0001 | 3.4 (2.7–4.2) | 3.9 (3.1–4.7) | 4.2 (3.4–5.0) |
| *p*-value for trend | 0.5242 | 0.1591 | 0.0890 | | <0.0001 | 0.0025 | 0.0193 |
| Geographic Region | | | | | | | |
| East | 24.0 (22.0–26.1) | 29.7 (26.8–32.7) | 18.4 (15.3–21.5) | <0.0001 | 18.6 (16.8–20.4) | 21.7 (19.7–23.6) | 22.5 (20.6–24.5) |
| Central | 15.1 (12.6–17.7) | 20.2 (16.9–23.5) | 12.9 (9.6–16.2) | 0.0047 | 11.1 (9.3–12.9) | 13.1 (10.9–15.3) | 13.8 (11.5–16.1) |
| West | 15.3 (13.2–17.3) | 17.9 (14.3–21.5) | 13.5 (10.7–16.3) | 0.0865 | 10.9 (9.1–12.6) | 12.9 (10.9–14.9) | 13.7 (11.7–15.8) |
| *p*-value for difference | <0.0001 | <0.0001 | 0.0295 | | <0.0001 | <0.0001 | <0.0001 |
| Education | | | | | | | |
| Primary or less | 13.2 (11.7–14.7) | 14.7 (12.3–17.1) | 12.7 (10.9–14.6) | 0.2483 | 9.4 (8.3–10.5) | 11.1 (9.8–12.5) | 11.8 (10.5–13.2) |
| Junior high | 19.7 (17.7–21.8) | 25.1 (21.6–28.6) | 16.8 (14.2–19.4) | <0.0001 | 14.3 (12.6–15.9) | 17.2 (15.3–19.1) | 18.0 (16.1–20.0) |
| Senior high | 24.7 (22.6–26.7) | 28.4 (25.5–31.2) | 19.3 (16.3–22.2) | <0.0001 | 18.7 (16.4–20.9) | 21.8 (19.7–24.0) | 22.8 (20.6–24.9) |
| College or above | 28.0 (25.4–30.6) | 30.4 (27.2–33.7) | 19.4 (15.8–22.9) | <0.0001 | 23.4 (21.0–25.8) | 26.5 (23.8–29.1) | 27.3 (24.6–30.0) |
| *p*-value for trend | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |
| Household income per capita (CNY) | | | | | | | |
| Q1 (<7,200) | 10.5 (9.0–12.1) | 13.1 (10.4–15.7) | 9.8 (7.9–11.8) | 0.0922 | 7.4 (6.4–8.5) | 8.9 (7.7–10.0) | 9.5 (8.3–10.7) |
| Q2 (7,200–14,999) | 14.0 (12.6–15.4) | 14.5 (12.1–17.0) | 13.8 (12.0–15.6) | 0.2316 | 11.0 (9.8–12.1) | 13.1 (11.8–14.4) | 13.8 (12.5–15.2) |
| Q3 (15,000–24,999) | 18.5 (16.8–20.2) | 21.9 (18.6–25.1) | 16.4 (14.3–18.4) | 0.0007 | 14.3 (12.9–15.7) | 17.1 (15.6–18.5) | 18.1 (16.5–19.7) |
| Q4 (25,000 and above) | 26.9 (25.2–28.6) | 30.3 (28.1–32.5) | 21.7 (18.6–24.9) | 0.0002 | 22.2 (20.5–23.8) | 25.5 (23.7–27.3) | 26.5 (24.7–28.3) |
| Don't know/refused to answer | 15.3 (13.2–17.3) | 22.1 (18.6–25.5) | 11.7 (9.4–14.0) | <0.001 | 11.4 (9.8–12.9) | 13.5 (11.7–15.3) | 13.9 (12.1–15.7) |
| *p*-value for trend † | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |

TABLE 2. (Continued)

| Item | Ever screened (%) (95%CI) | | | | Screened in 1 year (%) (95% CI) | Screened in 2 years (%) (95% CI) | Screened in 3 years (%) (95% CI) |
|---|---|---|---|---|---|---|---|
| | Total | Urban | Rural | *p*-value | | | |
| Employment status | | | | | | | |
| Employed | 20.7 (19.1–22.3) | 27.0 (24.4–29.6) | 16.6 (14.7–18.5) | <0.0001 | 16.0 (14.7–17.3) | 18.6 (17.1–20.0) | 19.3 (17.9–20.8) |
| Housework | 13.6 (11.5–15.6) | 17.4 (14.4–20.5) | 11.9 (9.2–14.6) | 0.0161 | 9.8 (8.3–11.3) | 11.6 (9.8–13.4) | 12.2 (10.3–14.1) |
| Retired | 26.9 (24.2–29.6) | 27.4 (24.5–30.3) | 22.8 (15.3–30.2) | 0.3039 | 16.7 (14.1–19.2) | 21.0 (18.4–23.5) | 22.7 (20.2–25.3) |
| Unemployed | 11.4 (8.4–14.4) | 14.7 (10.3–19.0) | 8.2 (4.5–11.9) | 0.0350 | 8.4 (5.7–11.1) | 10.2 (7.2–13.2) | 10.7 (7.7–13.6) |
| *p*-value for difference | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |
| With health insurance coverage | | | | | | | |
| No | 8.5 (6.8–10.2) | 9.1 (7.0–11.3) | 7.4 (4.5–10.3) | 0.3808 | 6.8 (5.1–8.4) | 7.7 (6.0–9.4) | 8.1 (6.4–9.8) |
| Yes | 19.4 (17.9–20.9) | 25.6 (23.3–28.0) | 15.2 (13.4–17.1) | <0.0001 | 14.5 (13.3–15.7) | 17.1 (15.7–18.4) | 17.9 (16.5–19.3) |
| *p*-value for difference | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |
| Health examination in past 3 years | | | | | | | |
| No | 10.8 (9.6–12.0) | 12.3 (9.9–14.8) | 10.1 (8.8–11.4) | 0.1153 | 7.4 (6.3–8.5) | 8.9 (7.8–10.1) | 9.4 (8.3–10.6) |
| Yes | 31.0 (29.1–32.9) | 35.3 (32.9–37.7) | 25.9 (22.7–29.0) | <0.0001 | 24.3 (22.7–25.9) | 28.1 (26.3–29.9) | 29.4 (27.5–31.2) |
| *p*-value for difference | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |
| Self–assessed health status | | | | | | | |
| Poor or fair | 19.8 (18.3–21.3) | 25.9 (23.6–28.1) | 15.8 (13.8–17.7) | <0.0001 | 14.4 (13.2–15.7) | 17.1 (15.7–18.4) | 18.0 (16.6–19.4) |
| Good | 17.9 (16.3–19.4) | 23.0 (20.5–25.6) | 14.1 (12.0–16.2) | <0.0001 | 14.0 (12.6–15.3) | 16.2 (14.7–17.8) | 16.9 (15.3–18.4) |
| *p*-value for difference | 0.0018 | <0.0001 | 0.0340 | | 0.3733 | 0.1496 | 0.0633 |

* Screening rates were all weighted proportions.

† Participants answering "don't know/refused to answer" were not included in the trend test.

participation despite the fact that 15% of the participants did not reveal their income level. Retired women (26.9%) had a significantly higher screening rate than employed women, women doing housework, and unemployed women ($p$<0.0001).

Women with health insurance had significantly higher screening participation than women without health insurance (19.4% *vs.* 8.5%, $p$<0.0001). Women with health check-ups in the past 3 years had significantly higher screening rates than women without health check-ups (31.0% *vs.* 10.8%, $p$<0.0001). Women with self-assessed poor or fair health status had statistically significantly higher screening rates than women with self-assessed good health status (19.8% *vs.* 17.9%, $p$=0.0018).

Provincial data revealed disparities in screening rates across the 31 PLADs. The screening rates in Beijing and Shanghai exceeded 40%, whereas Xizang (Tibet), Anhui, and Hebei had the lowest screening rates of less than 10% (Figure 1).

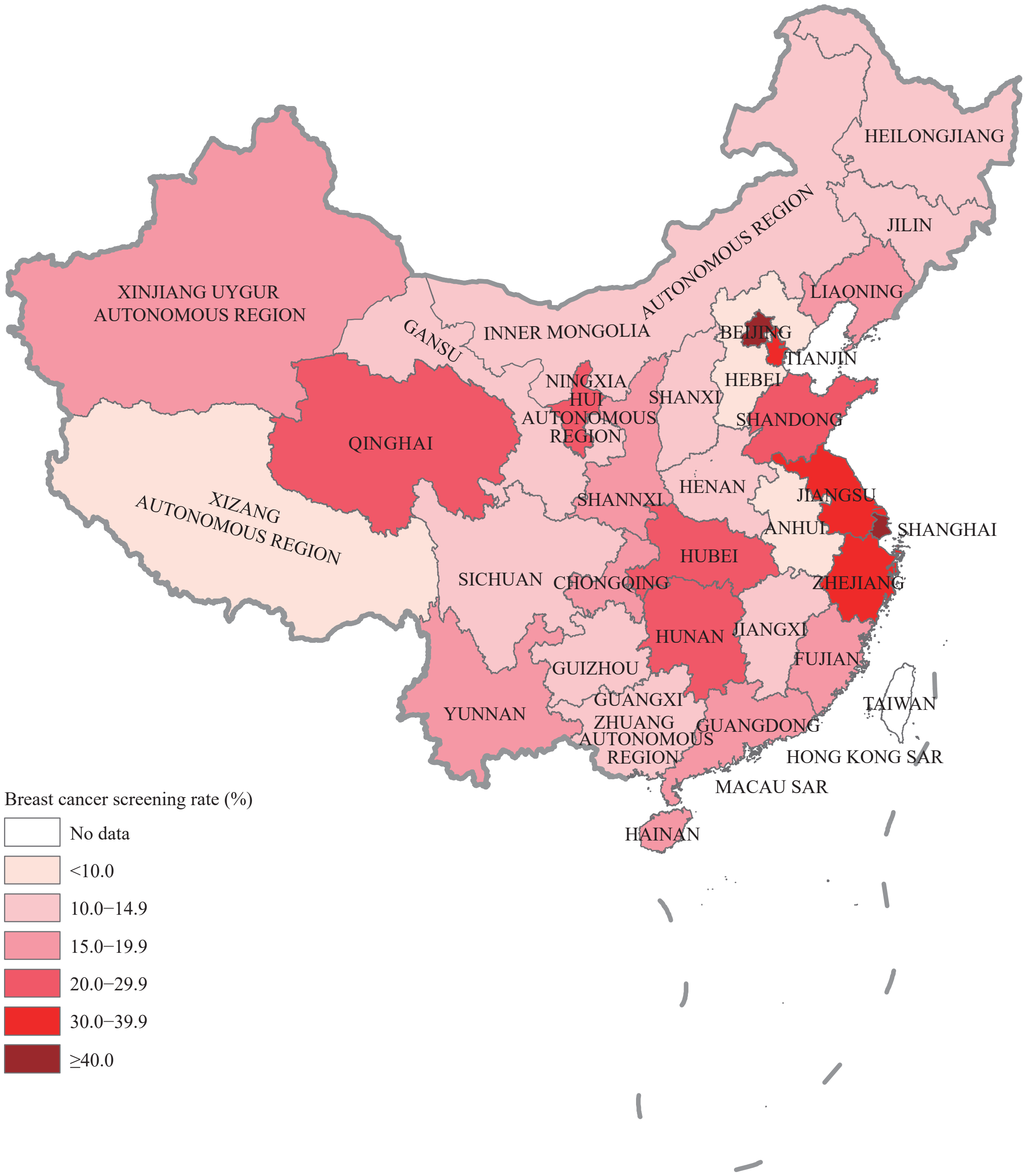


FIGURE 1. Breast cancer screening rates among Chinese women aged 20 years and above at the provincial level in China, 2015.

## DISCUSSION

This study showed that breast cancer screening rates in China in 2015 reached 18.9% and 25.7% for women aged 20 years and above and women aged 35–64 years, respectively. While the screening uptake for all adult women declined about 3% from 2010 to 2015 (*2*), the screening rate for women aged 35–64 years increased about 3% from 2013 to 2015 (*3*), which indicated positive influence of the national breast cancer screening program. Nevertheless, screening uptake remained low compared to screening rates of above 50% in developed countries (*6*). Continued efforts should be made to strengthen breast cancer screening uptake in China.

This study found that the group aged 30–49 years had the highest screening rates, whereas the 60 years and above age groups had ever screening rates of lower than 15% and screening in the past two years lower than 10%. Such age distribution of screening peaked earlier than recommended. While most international breast cancer screening guidelines recommended biennial screening for the 50–74 years age group, the latest guidelines released in 2019 in China based on Chinese women's risk profile recommended biennial screening for the 45–69 years age group of common risk, as well as for women aged 40–44 years and women aged 69 years and above with more than 10 years of life expectancy of common risk upon individual will, whereas women under 40 years old were not recommended for regular screening (*9*).

This study also found that the rural areas and the central and western regions still lagged far behind the urban areas and the eastern region in breast cancer screening uptake, despite national free provision of screening services to women in rural areas. In addition, women with lower education and lower income levels had significantly lower screening participation. These findings were consistent with existing literature that individual and area socioeconomic status (SES) were positively associated with cancer screening participation (*10*). Moreover, the results revealed that participation in breast cancer screening was significantly lower than cervical cancer screening (*8*) upon free screening services. The results highlighted the importance to identify barriers to breast cancer screening, such as embarrassment, as well as the importance of strengthening health education for low SES groups to improve breast cancer screening participation.

This study further found that health insurance was positively associated with screening uptake, which echoes existing literature that health insurance coverage improves access to cancer screening.

This study was subject to some limitations. The absence of some data due to lack of subpar attendance limited the conclusions of the analysis. Moreover, this study was limited by response bias as 7.8% of the initial respondents were excluded from the final analysis, who were unclear of their screening history and were slightly older, more rural, and less educated than the final sample. Assuming that these respondents were all unscreened, it would lower final screening rates by about 1%–2%, which would not change the conclusion. Recall bias may also occur as the respondents might incorrectly recall their screening history.

In conclusion, this study provides the largest nationwide and population-based self-reported history of breast cancer screening in China in 2015. Nearly one-fifth of Chinese women ever had breast cancer screening. Continued efforts should be made to strengthen national and local policy initiatives and financial support for population-based, organized screening programs for breast cancer, and strengthen health education and accessibility of screening services to women across the country, especially women aged 50 years and above.

**Funding**: National Key Research and Development Program of China (2016YFC0901300, 2016YFC 0901301).

**doi:** 10.46234/ccdcw2021.078

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Submitted: March 03, 2021; Accepted: March 24, 2021

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Preplanned Studies

# Health Facilities and Treatment Service Models of the National Tuberculosis Program — China, 2010−2020

Xin Du[1]; Tao Li[1]; Xiaoqiu Liu[1]; Yanlin Zhao[1,#]

**Summary**

**What is already known about this topic?**

A new tuberculosis (TB) treatment service model called "trinity model" has been adopted in China since 2010 but the implementation coverage is still unknown.

**What is added by this report?**

In 2020, more than one-third (36.5%) of health facilities diagnosed less than 100 TB cases, about one-fourth (25.5%) diagnosed 100 to 200 cases, and 94 health facilities diagnosed more than 800 cases. Among 2,960 county-level TB management areas, 157 (5.3%) counties were dominated by CDCs, 364 (12.3%) were dominated by TB/infectious diseases-specific hospitals, 370 (12.5%) independent TB dispensaries (or chronic disease stations), and 2,069 (69.9%) general hospitals.

**What are the implications for public health practice?**

The National TB Program (NTP) needs to explore more suitable treatment reimbursement mechanisms and help treatment facilities build an efficient referral system to provide quality treatment services for TB patients.

A new tuberculosis (TB) treatment service model called the "trinity model" has been established in China since 2010. The majority of TB-designated treatment centers have been adapted from traditional CDCs to designated general hospitals in the past decade. The profiles of TB treatment health facilities from the national TB surveillance system were collected and analyzed for the current situation of TB control network and treatment service models in China. In 2020, more than one-third (38.3%) of health facilities diagnosed less than 100 TB cases, about one-fourth (24.9%) diagnosed less than 200 cases, and 92 health facilities diagnosed more than 800 cases. Among 2,960 county level TB management areas, 157 (5.3%) counties were dominated by CDCs, 364 (12.3%) by TB/infectious disease-specific hospitals, 370 (12.5%) by independent TB dispensaries/chronic disease stations*, and 2,069 (69.9%) by general hospitals. The new "trinity" TB treatment service model has been broadly implemented and proved to be successful in China's National TB Control Program (NTP).

Pulmonary tuberculosis (PTB) was officially categorized as a Class B notifiable infectious diseases in China in 1997 (*1*). TB patient detection and notification have been greatly improved, but there still exists a significant gap between the estimated TB incidence number and cases notified in NTP. The fourth National TB Epidemiological Survey in 2000 (*1*) showed that 91% of TB patients went to general hospitals or clinics rather than TB dispensaries when they first had TB symptoms, and only 13% of them could be referred to NTP treatment center for standard management. Therefore, an integrated collaboration mechanism was started to explore potential opportunities between general health facilities (including general hospitals, clinics, and all other health facilities outside of NTP) and NTP components. Data was collected from the national TB Management Information System (TBMIS) on January 28, 2021. Profiles of TB treatment facilities were extracted and analyzed in an MS Excel® (version 2016; Microsoft Corporation) spreadsheet. Provincial, prefectural, and county level TB management areas were counted as defined in the NTP surveillance system. Treatment service models at the county level were categorized as "CDC dominated," "Independent TB dispensary/chronic diseases station dominated" (both were public health providers rather than hospitals, but independent from CDC), "TB/infectious diseases specific hospital dominated" and "General hospital dominated" according to the type of health facilities providing diagnosis and

* Note: TB dispensaries and chronic diseases stations were categorized as one group since they were all government-funded public health providers based on the CDC system. TB dispensaries usually only focused on treatment and management of TB while chronic diseases stations also addressed other conditions like leprosy and sexually transmitted diseases.

treatment in each county.

There were 40 provincial-level TB treatment facilities in 31 PLADs, none of which were affiliated with the provincial CDC, 3 were independent TB dispensaries, 21 were TB/infectious disease specific hospitals, and the other 16 were general health facilities. There were also 364 prefectural (including 2 CDCs, 45 independent TB dispensaries, 120 TB/infectious disease specific hospitals, and 197 general health facilities), and 2,517 county level treatment facilities (including 180 CDCs, 275 independent TB dispensaries, 39 TB/infectious disease specific hospitals, and 2,023 general health facilities) in 343 prefectural areas and 2,960 county level areas, respectively.

The 2,921 health facilities that were appointed as TB treatment centers diagnosed 633,309 TB cases in 2020. More than one-third (36.5%) of health facilities diagnosed less than 100 TB cases and about one-fourth (25.5%) diagnosed 100 to 200 TB cases. There were 94 health facilities that diagnosed more than 800 TB cases in 2020, among which 11 were provincial, 45 were prefectural, and 38 were county level (Figure 1).

Provincial and prefectural health facilities generally diagnosed more patients than county level health facilities, the median and interquartile range (IQR: Q1, Q3) were 329 (2,176: 75, 2,251), 343 (440: 167, 607), and 125 (191: 53, 243). The number of patients diagnosed by CDCs, general hospitals, independent TB dispensaries/chronic diseases stations, and TB/infectious specific hospitals increased gradually at all levels except that the prefectural-level CDCs diagnosed more patients than general hospitals (Figure 2).

At the end of 2020, among 2,960 county level TB management areas, 157 (5.3%) counties were dominated by CDCs, 364 (12.3%) by TB/infectious disease-specific hospitals, 370 (12.5%) by independent TB dispensaries (or chronic disease stations), and 2,069 (69.9%) by general hospitals. In most western and central areas, general hospitals already dominate as basic management units in treatment. However, independent TB dispensaries or chronic disease stations still played important roles in many northeastern and central southern areas. CDCs were less responsible for treatment and care except in Beijing Municipality, Henan Province, and a few other areas (Table 1).

## DISCUSSION

At the end of 2020, about 70% (2,069/2,960) of county areas had appointed general hospitals as their TB designated treatment center. The “trinity” service model had already become the primary trend in NTP, but many challenges still existed in the new treatment model.

In China, before the TB service system was transformed, most TB healthcare services including diagnosis and treatment were driven by TB dispensaries in CDC or independent TB centers (*2*). This kind of service system has played a great role in improving the detection of TB patients (*3*). However, it also led to many problems. First, patients were more likely to go to general hospitals rather than CDCs when they experienced TB-related symptoms. Second, many CDCs did not possess medical service licenses for clinical services, and the public health physicians in CDC were not qualified to provide clinical services. Meanwhile, the overall level of medical service and rescue capability of CDC were relatively low (*4*). Therefore, shifting TB diagnosis and treatment from CDC to general or TB/infectious disease-specific hospitals was an inevitable choice to provide better

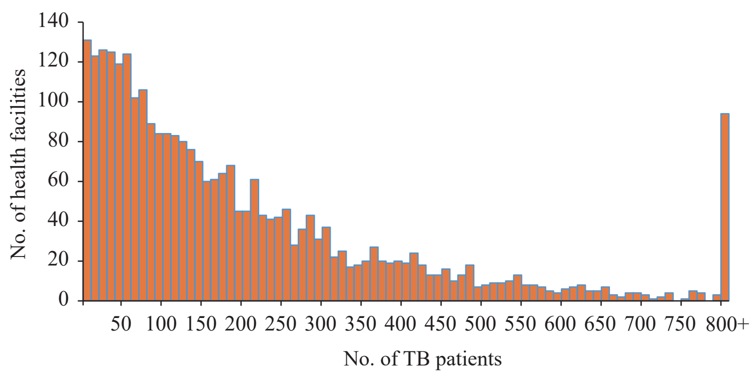


FIGURE 1. Distribution of number of patients diagnosed in tuberculosis treatment health facilities in China, 2020.

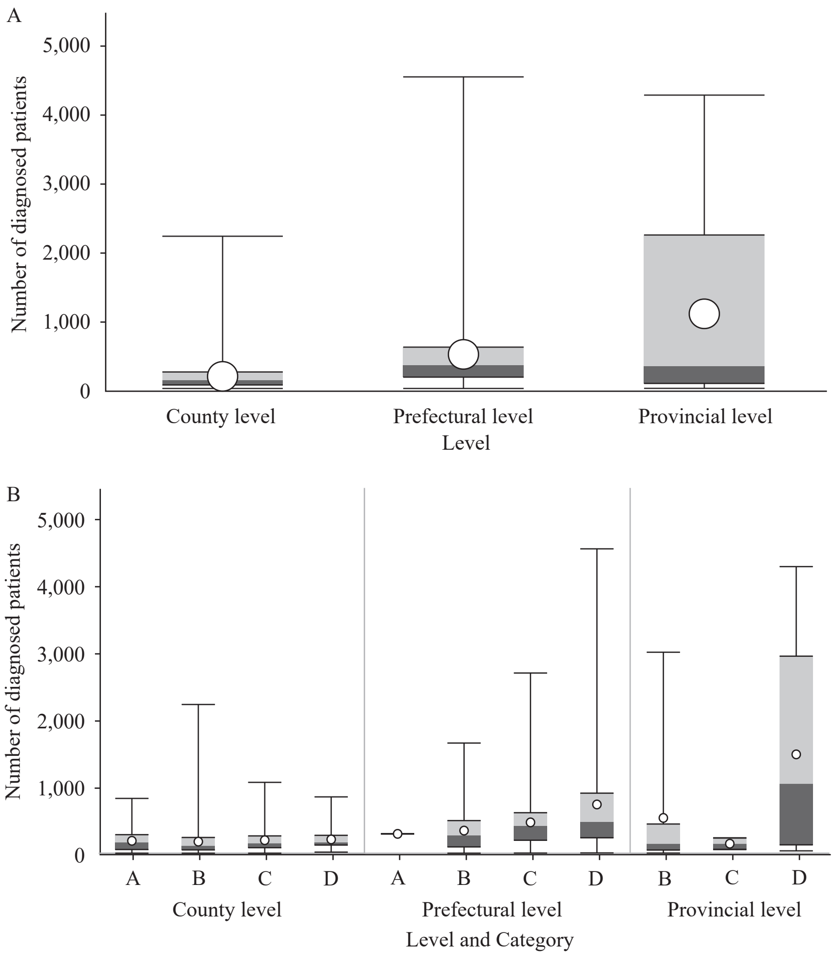


FIGURE 2. Number of patients diagnosed in different types and levels of tuberculosis (TB) treatment health facilities in China, 2020 (median and interquartile range). (A) Patients diagnosed in different level of health facilities. (B) Patients diagnosed in different level and type of health facilities.
Note: A: CDCs; B: General health facilities; C: Independent TB dispensaries/chronic disease stations; D: TB/infectious disease-specific hospitals.

medical services for patients and to ensure the sustainable development of TB control.

The structural reform of China's TB treatment service model has experienced a long but efficient process. After piloting in regional areas, the Ministry of Health (now National Health Commission) revised and established the new *Regulations for TB Control and Prevention* (*5* ) in 2013, which established that designated health facilities should be responsible for diagnosis and treatment for TB patients while CDCs should be responsible for NTP management activities. Some indicators had been influenced at the beginning of the system reform, but they have rebounded and finally exceeded the numbers from before the reform (*6*). In addition, patient detection and treatment success rate were kept at a high level, which resulted in low mortality rates and the annual decreasing of the incidence rate was relatively more significant than global average (*7*).

Many counties and districts shared the same regional designated facilities. Some have been unified as one county-level management area in the NTP, but many areas were still independent. Therefore, at the county level, the total number of facilities were less than management areas. Currently, the majority of county level areas have shifted their TB treatment service models to designated general hospitals. After the "trinity model" was established, diagnosed TB patients could get more prompt notification, standard treatment, and effective management. In addition, a considerable part of designated health facilities remained in independent TB dispensaries or chronic disease stations in northeastern PLADs, Beijing, Tianjin, Shandong, Henan, and Guangdong where historically non-hospital TB treatment centers already have strong clinical capacities and less motivation to

TABLE 1. Proportions of tuberculosis (TB) treatment service model at county level in 31 PLADs of China, 2020.

| PLADs | CDC dominated (%) | TB dispensary or chronic diseases station dominated (%) | TB/infectious diseases specific hospital dominated (%) | General hospital dominated (%) |
|---|---|---|---|---|
| Beijing | 37.5 | 25.0 | 0.0 | 37.5 |
| Tianjin | 0.0 | 62.5 | 0.0 | 37.5 |
| Hebei | 1.2 | 0.0 | 12.9 | 86.0 |
| Shanxi | 0.0 | 0.0 | 2.6 | 97.4 |
| Inner Mongolia | 1.9 | 10.5 | 15.2 | 72.4 |
| Liaoning | 14.0 | 36.0 | 43.0 | 7.0 |
| Jilin | 14.5 | 76.8 | 5.8 | 2.9 |
| Heilongjiang | 2.4 | 35.2 | 31.2 | 31.2 |
| Shanghai | 0.0 | 0.0 | 6.3 | 93.8 |
| Jiangsu | 0.0 | 0.0 | 35.2 | 64.8 |
| Zhejiang | 0.0 | 0.0 | 0.0 | 100.0 |
| Anhui | 0.0 | 0.0 | 13.5 | 86.5 |
| Fujian | 0.0 | 0.0 | 13.6 | 86.4 |
| Jiangxi | 4.0 | 12.0 | 4.0 | 80.0 |
| Shandong | 0.0 | 23.2 | 28.9 | 47.9 |
| Henan | 52.9 | 21.8 | 24.7 | 0.6 |
| Hubei | 7.5 | 14.2 | 10.4 | 67.9 |
| Hunan | 0.0 | 0.8 | 7.7 | 91.5 |
| Guangdong | 4.7 | 76.6 | 4.7 | 14.1 |
| Guangxi | 0.9 | 1.7 | 20.5 | 76.9 |
| Hainan | 0.0 | 19.4 | 0.0 | 80.6 |
| Chongqing | 0.0 | 17.9 | 0.0 | 82.1 |
| Sichuan | 3.7 | 0.0 | 5.8 | 90.5 |
| Guizhou | 1.1 | 0.0 | 1.1 | 97.8 |
| Yunnan | 0.0 | 0.0 | 4.7 | 95.3 |
| Tibet | 1.3 | 0.0 | 0.0 | 98.7 |
| Shaanxi | 0.0 | 0.0 | 5.4 | 94.6 |
| Gansu | 0.0 | 0.0 | 4.5 | 95.5 |
| Qinghai | 0.0 | 0.0 | 0.0 | 100.0 |
| Ningxia | 0.0 | 0.0 | 13.6 | 86.4 |
| Xinjiang* | 0.0 | 0.0 | 1.8 | 98.2 |

Abbreviations: PLADs=provincial-level administrative divisions; CDC=Center for diseases control and prevention.
* Including Xinjiang Production and Construction Corps (XPCC).

reform.

There were still many challenges existing in the new treatment model. Even when all public service providers were managed by the government, hospitals had different funding mechanisms in comparison with CDCs. The compensation investment for designated hospitals needed to be rationalized to reduce the economic burden of patients. Furthermore, TB control activities in designated general hospitals might also be influenced by other public health impacts. For example, during the COVID-19 epidemic in early 2020, many TB-designated hospitals were appointed as COVID-19 treating centers, which affected the diagnosis and treatment of TB patients (*8*). There were also many high-level health facilities that diagnosed more than 800 patients in 2020. These facilities were usually TB or infectious disease-specific hospitals. According to the design of hierarchical diagnosis and treatment, it was more conducive for TB patients to receive medication management and follow-up examinations at county-level designated facilities located in counties where they live in. The large amount of diagnosed patients at high level health facilities might influence the quality of full course patient management.

This study was subject to some limitations. The treatment service models were only evaluated at the county level. The service models at the prefectural and provincial levels should be further investigated and analyzed with patient referral mechanisms and drug resistance control. This study also lacked evaluation of treatment outcomes for each kind of model, which needs to be assessed in the future to better understand the barriers in different settings.

In the light of the requirements of national "Stop TB Action Plan (2019–2022)," the NTP should continue enhancing the collaboration mechanism between TB management institutions and designated health facilities at all levels. NTP also needs to explore more suitable treatment reimbursement mechanism and help them build an efficient referral system to provide quality treatment service for TB patients.

**Acknowledgments:** All participants of the national TB surveillance system. The China National TB Program and the National Special Science and Technology Project for Major Infectious Diseases of China (2017ZX10201302007).

**doi:** 10.46234/ccdcw2021.071

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Submitted: February 24, 2021; Accepted: March 18, 2021

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Preplanned Studies

# Beverage Consumption of Children and Adolescents Aged 6−17 Years — China, 2016−2017

Xiaoli Xu[1]; Wei Piao[1]; Hongyun Fang[1]; Qiya Guo[1]; Lahong Ju[1]; Shuya Cai[1]; Shujuan Li[1]; Xue Cheng[1]; Liyun Zhao[1]; Dongmei Yu[1,#]

**Summary**

## What is already known on this topic?

Beverage consumption has become a problematic dietary behavior in children and adolescents. Excessive drinking of beverages, especially sugary beverages, can increase the risk of chronic diseases such as obesity, dental cavities, and diabetes.

## What is added by this report?

This report revealed the beverage consumption rate was higher in males, in urban areas, and adolescents aged 12–17 years. The top three beverages by consumption rate were carbonated beverages (33.2%), milk-containing beverages (25.0%), and non-100% fruit and vegetable beverages (23.5%). Children and adolescents in China consumed beverages at a primary frequency rate of 1–3 times/week. Among children and adolescents aged 6–17 years who consumed beverages, the average amount was 193.8 g/d, and was higher in males (210.6 g/d), those in urban areas (204.7 g/d), and adolescents aged 12–17 years (259.0 g/d).

## What are the implications for public health practice?

Children and adolescents are key periods of life to develop healthy dietary behaviors for individuals. The consumption of beverages by Chinese children and adolescents has shown to increase year over year. Parents, schools, and governments need to prioritize promoting health consumption of beverasges.

In recent years, beverage consumption has become more and more popular among children and teenagers in China (*1*). For beverages available in the Chinese market, more than half are sugary beverages (*2*). According to previous studies, excessive consumption of sugary beverages can increase the risk of chronic diseases such as dental cavities and obesity among children and adolescents (*3*). The *Guideline: Sugars Intake for Adults and Children* issued by the World Health Organization (WHO) in 2015 claimed that it was important to reduce the intake of free sugars throughout the life cycle (*4*). The *Ending Childhood Obesity* report also released by the WHO in 2016 emphasized that comprehensive measures should be applied to promote healthy food intake for children and adolescents and to reduce the intake of sugary beverages (*5*). This study analyzed the status and features on beverage consumption of Chinese children and adolescents aged 6–17 years and provided scientific support to policymaking.

The data of this study were obtained from the China Nutrition and Health Surveillance of Children and Lactating Mothers in 2016–2017. This study was a cross-sectional study, covering 31 provincial-level administrative divisions (PLADs) including 275 surveillance points in China (*6*). The survey used multistage stratified random sampling method for nationally and provincially representativeness. Data collection included four parts: interviews to collect demographic information; dietary questionnaires to assess food intake; physical examinations to observe the indicators of growth; and laboratory tests for health conditions. The information on the consumption of beverages was obtained by Food Frequency Questionnaire (FFQ), based on the consumption frequency and consumption of nine types of beverages in the past month. The 9 types of beverages in this study include 100% fruit and vegetable juices, non-100% fruit and vegetable beverages, carbonated beverages, tea beverages, milk-containing beverages, plant protein and cereal beverages, functional beverages, coffee, and other sugary beverages. The samples were grouped by age, sex, and regions. SAS (version 9.4, SAS Institute Inc., Cary, NC, USA) was used to process the quantitative analyses. The protocol of this study was evaluated and approved by the ethical committee China CDC (201614).

A total of 73,427 samples were involved for this report, including 36,701 males (50%) and 36,726 females (50%); and 34,981 (47.6%) in urban areas and 38,446 (52.4%) in rural areas. All subjects were divided into the 6–11 year-old group (44.1%) and

12–17 year-old group (55.9%). The number of children aged 6–11 years was 41,023, including 19,583 (47.7%) in urban areas and 21,440 (52.3%) in rural areas. The number of adolescents aged 12–17 years was 32,404, including 15,398 (47.5%) in urban areas and 17,006 (52.5%) in rural areas.

Table 1 showed that the total beverage consumption rate was 66.2% among children and adolescents aged 6–17 years from 2016 to 2017. The consumption rate was 68.3% for males and 64.1% for females; 71.3% in urban areas and 61.6% in rural areas; and 61.6% for children aged 6–11 years and 72.0% for adolescents aged 12–17 years. The top 3 beverages by consumption rate were carbonated beverages (33.2%), milk-containing beverages (25.0%), and non-100% fruit and vegetable beverages (23.5%). For carbonated beverages, tea beverages, and functional beverages, the consumption rate for males was higher than that for females; for the other six kinds of beverages, the consumption rate for females was higher than that for males.

In Table 2, the frequencies of beverage consumption were divided into: ≥1 time/day, 4–6 times/week, 1–3 times/week, and <1 time/week. The percentages among children and adolescents aged 6–17 years were 23.3%, 16.0%, 44.4%, and 16.4%, respectively. The top beverage consumption frequency was 1–3 times per week. The percentage of ≥1 time/day and 4–6 times/week was at a higher rate in males than in females and higher in urban areas and in adolescents aged 12–17 years. The percentages of 1–3 times/week and <1 times/week were at a higher rate in females than in males and higher in rural areas and in children aged 6–11 years. Children aged 6–11 years who consumed functional beverages, coffee, and other sugary beverages had a higher rate of consumption behavior at frequency of <1 time/week, while other groups were involved in a higher frequency of 1–3 times/week. The top 3 beverages presented by frequency of ≥1 time/day were 100% fruit and vegetable juice (13.3%), milk-containing beverages (13.0%), and vegetable protein and cereal beverages (10.2%).

Table 3 indicated that among the children and adolescents aged 6–17 years who consumed beverages, the average amount of consumption was 193.8 g/d, which was higher in males (210.6 g/d), urban areas (204.7 g/d), and adolescents aged 12–17 years (259.0 g/d). The top 3 beverages for consumers were tea beverages (100.9 g/d), carbonated beverages (91.6 g/d), and 100% fruit and vegetable juice (81.5 g/d). For children aged 6–11 years old, the top 3 beverages were milk beverages (67.4 g/d), 100% fruit and vegetable juice (66.2 g/d), and tea beverages (65.1 g/d). For the 12–17 year-old group, the top 3 beverages were tea beverages (128.7 g/d), carbonated beverages (122.3 g/d), and 100% fruit and vegetable juice (98.7 g/d).

## DISCUSSION

Sugary beverages will often contain added sugar at levels of 8%–10%, and some are even of 13% (*7*). The sugar in the beverages can be quickly digested and

TABLE 1. Consumption rate of different types of beverages among children and teenagers aged 6–17 years — China, 2016–2017 (%).

| Beverage categories | 6–11 years old | | | | | 12–17 years old | | | | | 6–17 years old | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Urban | Rural | Subtotal | Male | Female | Urban | Rural | Subtotal | Male | Female | Urban | Rural | Total |
| 100% fruit and vegetable juice | 12.9 | 13.9 | 21.8 | 5.8 | 13.4 | 12.6 | 13.6 | 19.7 | 7.2 | 13.1 | 12.8 | 13.8 | 20.9 | 6.4 | 13.3 |
| Not 100% fruit and vegetable beverages | 21.8 | 21.6 | 26.9 | 16.9 | 21.7 | 25.6 | 26.0 | 29.6 | 22.4 | 25.8 | 23.5 | 23.5 | 28.1 | 19.3 | 23.5 |
| Carbonate beverages | 31.7 | 24.7 | 29.7 | 26.8 | 28.2 | 46.8 | 32.4 | 41.1 | 38.3 | 39.6 | 38.4 | 28.1 | 34.7 | 31.9 | 33.2 |
| Tea beverages | 16.9 | 14.5 | 18.4 | 13.3 | 15.7 | 33.2 | 27.0 | 34.7 | 26.1 | 30.1 | 24.1 | 20.0 | 25.6 | 18.9 | 22.1 |
| Milk-containing beverages | 24.3 | 26.1 | 28.9 | 21.8 | 25.2 | 21.0 | 28.6 | 25.3 | 24.3 | 24.8 | 22.8 | 27.2 | 27.3 | 22.9 | 25.0 |
| Vegetable protein and cereal beverages | 16.3 | 16.8 | 20.1 | 13.3 | 16.5 | 15.4 | 17.8 | 19.1 | 14.3 | 16.6 | 15.9 | 17.2 | 19.7 | 13.7 | 16.6 |
| Functional beverages | 8.6 | 6.0 | 9.7 | 5.0 | 7.3 | 18.3 | 9.9 | 17.0 | 11.5 | 14.1 | 12.9 | 7.7 | 12.9 | 7.9 | 10.3 |
| Coffee | 1.8 | 1.9 | 2.3 | 1.4 | 1.9 | 10.0 | 11.0 | 14.8 | 6.7 | 10.5 | 5.5 | 5.9 | 7.8 | 3.7 | 5.7 |
| Other sugary beverages | 5.1 | 5.0 | 6.3 | 4.0 | 5.1 | 7.7 | 9.4 | 9.5 | 7.7 | 8.5 | 6.3 | 7.0 | 7.7 | 5.6 | 6.6 |
| Total beverages | 63.4 | 59.8 | 67.5 | 56.2 | 61.6 | 74.5 | 69.6 | 76.1 | 68.4 | 72.0 | 68.3 | 64.1 | 71.3 | 61.6 | 66.2 |

TABLE 2. The distribution of beverage consumption frequency in consumers aged 6–17 years — China, 2016–2017 (%).

| Beverage categories | Drinking frequency | 6–11 years old | | | | | 12–17 years old | | | | | 6–17 years old | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Urban | Rural | Subtotal | Male | Female | Urban | Rural | Subtotal | Male | Female | Urban | Rural | Total |
| 100% fruit and vegetable juice | ≥1 time/day | 11.4 | 11.9 | 11.8 | 11.2 | 11.7 | 15.5 | 15.2 | 16.4 | 12.8 | 15.3 | 13.2 | 13.3 | 13.7 | 12.0 | 13.3 |
| | 4–6 times/week | 3.6 | 3.1 | 3.5 | 2.8 | 3.4 | 4.6 | 3.2 | 3.8 | 4.2 | 3.9 | 4.1 | 3.2 | 3.6 | 3.5 | 3.6 |
| | 1–3 times/week | 53.9 | 52.1 | 52.8 | 53.3 | 52.9 | 54.0 | 53.1 | 52.8 | 55.3 | 53.5 | 53.9 | 52.5 | 52.8 | 54.3 | 53.2 |
| | <1 time/week | 31.1 | 32.9 | 31.9 | 32.6 | 32.0 | 25.9 | 28.5 | 27.0 | 27.7 | 27.2 | 28.8 | 31.0 | 29.9 | 30.2 | 29.9 |
| Not 100% fruit and vegetable beverages | ≥1 time/day | 5.7 | 5.4 | 6.0 | 4.9 | 5.5 | 9.9 | 8.8 | 9.6 | 9.1 | 9.4 | 7.7 | 7.1 | 7.6 | 7.1 | 7.4 |
| | 4–6 times/week | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 4.8 | 3.6 | 4.5 | 3.8 | 4.2 | 3.2 | 2.5 | 2.9 | 2.7 | 2.8 |
| | 1–3 times/week | 52.7 | 51.2 | 51.9 | 52.0 | 52.0 | 59.6 | 58.7 | 58.7 | 59.7 | 59.1 | 56.0 | 54.8 | 55.1 | 55.9 | 55.4 |
| | <1 time/week | 40.0 | 41.8 | 40.6 | 41.4 | 40.9 | 25.7 | 29.0 | 27.2 | 27.5 | 27.3 | 33.1 | 35.6 | 34.4 | 34.3 | 34.3 |
| Carbonate beverages | ≥1 time/day | 5.1 | 4.8 | 4.4 | 5.6 | 5.0 | 10.4 | 8.1 | 9.4 | 9.5 | 9.4 | 8.0 | 6.5 | 7.0 | 7.7 | 7.3 |
| | 4–6 times/week | 2.2 | 1.3 | 1.7 | 2.0 | 1.8 | 5.7 | 3.1 | 4.8 | 4.5 | 4.6 | 4.1 | 2.2 | 3.3 | 3.3 | 3.3 |
| | 1–3 times/week | 53.0 | 51.1 | 51.0 | 53.4 | 52.2 | 62.2 | 58.6 | 60.1 | 61.4 | 60.8 | 58.0 | 54.9 | 55.7 | 57.7 | 56.7 |
| | <1 time/week | 39.6 | 42.7 | 43.0 | 39.0 | 41.0 | 21.8 | 30.2 | 25.7 | 24.7 | 25.2 | 30.0 | 36.4 | 34.0 | 31.4 | 32.7 |
| Tea beverages | ≥1 time/day | 5.5 | 6.0 | 5.8 | 5.6 | 5.7 | 11.2 | 9.7 | 10.5 | 10.5 | 10.5 | 9.0 | 8.2 | 8.6 | 8.6 | 8.6 |
| | 4–6 times/week | 1.8 | 1.3 | 1.4 | 1.7 | 1.5 | 4.7 | 3.3 | 4.5 | 3.7 | 4.1 | 3.6 | 2.5 | 3.2 | 2.9 | 3.1 |
| | 1–3 times/week | 50.5 | 50.3 | 49.0 | 52.2 | 50.4 | 61.6 | 55.9 | 58.0 | 60.4 | 59.1 | 57.3 | 53.6 | 54.4 | 57.2 | 55.6 |
| | <1 time/week | 42.2 | 42.5 | 43.7 | 40.5 | 42.3 | 22.4 | 31.1 | 27.0 | 25.5 | 26.3 | 30.1 | 35.7 | 33.7 | 31.4 | 32.7 |
| Milk-containing beverages | ≥1 time/day | 12.1 | 11.4 | 10.7 | 13.0 | 11.8 | 15.4 | 14.0 | 14.2 | 15.0 | 14.6 | 13.4 | 12.6 | 12.1 | 13.9 | 13.0 |
| | 4–6 times/week | 5.0 | 4.7 | 4.2 | 5.6 | 4.8 | 6.5 | 5.6 | 6.0 | 5.9 | 6.0 | 5.6 | 5.1 | 4.9 | 5.7 | 5.3 |
| | 1–3 times/week | 55.3 | 55.6 | 54.3 | 56.9 | 55.5 | 57.0 | 57.7 | 57.0 | 57.8 | 57.4 | 56.0 | 56.6 | 55.4 | 57.3 | 56.3 |
| | <1 time/week | 27.6 | 28.3 | 30.8 | 24.5 | 28.0 | 21.2 | 22.7 | 22.8 | 21.4 | 22.1 | 25.0 | 25.7 | 27.5 | 23.0 | 25.4 |
| Vegetable protein and cereal beverages | ≥1 time/day | 8.2 | 9.1 | 8.0 | 9.5 | 8.7 | 11.8 | 12.4 | 12.7 | 11.3 | 12.1 | 9.7 | 10.6 | 10.0 | 10.4 | 10.2 |
| | 4–6 times/week | 3.3 | 3.0 | 3.1 | 3.1 | 3.1 | 5.0 | 4.0 | 4.3 | 4.6 | 4.5 | 4.0 | 3.4 | 3.6 | 3.8 | 3.7 |
| | 1–3 times/week | 49.8 | 49.8 | 49.2 | 50.6 | 49.8 | 54.5 | 54.4 | 54.1 | 54.9 | 54.4 | 51.8 | 51.9 | 51.3 | 52.6 | 51.8 |
| | <1 time/week | 38.6 | 38.2 | 39.7 | 36.7 | 38.4 | 28.8 | 29.3 | 28.9 | 29.2 | 29.1 | 34.4 | 34.2 | 35.1 | 33.3 | 34.3 |
| Functional beverages | ≥1 time/day | 4.6 | 5.0 | 4.7 | 4.8 | 4.8 | 7.5 | 7.0 | 7.8 | 6.8 | 7.4 | 6.5 | 6.1 | 6.5 | 6.1 | 6.3 |
| | 4–6 times/week | 1.1 | 1.0 | 0.9 | 1.4 | 1.1 | 3.1 | 1.4 | 2.5 | 2.6 | 2.5 | 2.4 | 1.2 | 1.8 | 2.2 | 2.0 |
| | 1–3 times/week | 42.6 | 38.9 | 41.5 | 40.2 | 41.1 | 56.0 | 50.4 | 53.3 | 55.0 | 54.0 | 51.0 | 45.4 | 48.3 | 49.8 | 48.9 |
| | <1 time/week | 51.7 | 55.1 | 52.8 | 53.6 | 53.1 | 33.4 | 41.2 | 36.5 | 35.5 | 36.1 | 40.2 | 47.2 | 43.4 | 42.0 | 42.8 |
| Coffee | ≥1 time/day | 8.5 | 5.0 | 7.4 | 5.7 | 6.7 | 9.6 | 9.7 | 9.8 | 9.5 | 9.7 | 9.4 | 8.9 | 9.4 | 8.7 | 9.1 |
| | 4–6 times/week | 2.1 | 1.1 | 1.8 | 1.3 | 1.6 | 5.8 | 5.6 | 6.0 | 5.0 | 5.7 | 5.1 | 4.8 | 5.3 | 4.3 | 4.9 |
| | 1–3 times/week | 33.1 | 36.9 | 33.6 | 37.1 | 35.0 | 51.8 | 47.3 | 50.0 | 48.4 | 49.5 | 48.3 | 45.5 | 47.3 | 46.0 | 46.8 |
| | <1 time/week | 56.3 | 57.1 | 57.2 | 55.9 | 56.7 | 32.8 | 37.4 | 34.3 | 37.1 | 35.2 | 37.2 | 40.9 | 38.1 | 41.0 | 39.1 |
| Other sugary beverages | ≥1 time/day | 7.3 | 5.0 | 4.8 | 8.2 | 6.2 | 10.6 | 9.9 | 9.3 | 11.2 | 10.2 | 9.1 | 7.9 | 7.3 | 10.0 | 8.5 |
| | 4–6 times/week | 2.2 | 1.6 | 1.5 | 2.6 | 1.9 | 4.3 | 3.0 | 3.6 | 3.7 | 3.6 | 3.4 | 2.5 | 2.6 | 3.2 | 2.9 |
| | 1–3 times/week | 43.4 | 44.4 | 40.4 | 48.8 | 43.9 | 56.0 | 52.9 | 52.5 | 56.3 | 54.3 | 50.2 | 49.5 | 47.0 | 53.4 | 49.8 |
| | <1 time/week | 47.1 | 48.9 | 53.3 | 40.4 | 48.0 | 29.0 | 34.2 | 34.6 | 28.8 | 31.9 | 37.3 | 40.2 | 43.1 | 33.4 | 38.8 |
| Total beverages | ≥1 time/day | 18.1 | 17.9 | 19.7 | 16.1 | 18.0 | 30.8 | 27.3 | 31.9 | 26.4 | 29.1 | 24.2 | 22.4 | 25.4 | 21.1 | 23.3 |
| | 4–6 times/week | 14.1 | 13.6 | 15.4 | 12.1 | 13.8 | 18.9 | 17.6 | 18.9 | 17.7 | 18.3 | 16.4 | 15.5 | 17.0 | 14.9 | 16.0 |
| | 1–3 times/week | 47.9 | 47.9 | 45.9 | 50.1 | 47.9 | 39.3 | 41.9 | 38.2 | 42.9 | 40.5 | 43.7 | 45.0 | 42.3 | 46.5 | 44.4 |
| | <1 time/week | 20.0 | 20.7 | 19.0 | 21.8 | 20.3 | 11.0 | 13.2 | 11.1 | 13.0 | 12.0 | 15.7 | 17.1 | 15.3 | 17.5 | 16.4 |

TABLE 3. Daily consumption of beverages of consumers aged 6–17 years — China, 2016–2017 (g/d).

| Age groups | Beverage categories | The number of consumer | Male | | Female | | Urban | | Rural | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | $P_{50}$ | Mean | $P_{50}$ | Mean | $P_{50}$ | Mean | $P_{50}$ | Mean | $P_{50}$ |
| 6–11 years old | 100% fruit and vegetable juice | 5,512 | 67.1 | 29.6 | 65.3 | 28.6 | 66.7 | 28.6 | 64.4 | 28.6 | 66.2 | 28.6 |
| | Not 100% fruit and vegetable beverages | 8,897 | 58.5 | 28.6 | 54.1 | 28.6 | 56.4 | 28.6 | 56.3 | 28.6 | 56.3 | 28.6 |
| | Carbonate beverages | 11,561 | 65.2 | 32.9 | 57.4 | 28.6 | 56.0 | 28.6 | 67.6 | 34.3 | 61.8 | 32.9 |
| | Tea beverages | 6,444 | 67.0 | 32.9 | 62.8 | 32.9 | 59.6 | 28.6 | 72.0 | 35.7 | 65.1 | 32.9 |
| | Milk-containing beverages | 10,323 | 68.4 | 35.7 | 66.5 | 35.7 | 62.3 | 29.6 | 73.6 | 41.1 | 67.4 | 35.7 |
| | Vegetable protein and cereal beverages | 6,786 | 57.8 | 28.6 | 58.2 | 28.6 | 56.5 | 28.6 | 60.1 | 31.4 | 58.0 | 28.6 |
| | Functional beverages | 2,981 | 54.0 | 24.6 | 47.2 | 19.7 | 48.1 | 21.4 | 56.6 | 23.7 | 51.2 | 21.4 |
| | Coffee | 757 | 33.3 | 9.9 | 27.9 | 9.2 | 32.0 | 9.9 | 28.4 | 8.2 | 30.6 | 9.9 |
| | Other sugary beverages | 2,085 | 51.5 | 21.4 | 40.4 | 16.4 | 38.9 | 16.4 | 56.1 | 28.6 | 46.0 | 19.7 |
| | Total beverages | 25,280 | 138.3 | 71.4 | 128.6 | 71.4 | 140.5 | 71.4 | 126.0 | 71.4 | 133.6 | 71.4 |
| 12–17 years old | 100% fruit and vegetable juice | 4,251 | 104.1 | 52.6 | 98.7 | 42.9 | 103.5 | 42.9 | 95.8 | 42.9 | 101.3 | 42.9 |
| | Not 100% fruit and vegetable beverages | 8,362 | 109.7 | 65.7 | 89.0 | 42.9 | 99.8 | 57.1 | 98.7 | 57.1 | 99.3 | 57.1 |
| | Carbonate beverages | 12,842 | 130.9 | 71.4 | 100.5 | 57.1 | 114.6 | 71.4 | 122.3 | 71.4 | 118.5 | 71.4 |
| | Tea beverages | 9,767 | 139.4 | 71.4 | 106.0 | 57.1 | 121.0 | 71.4 | 128.7 | 71.4 | 124.5 | 71.4 |
| | Milk-containing beverages | 8,023 | 92.3 | 57.1 | 84.1 | 45.7 | 86.9 | 48.6 | 88.2 | 57.1 | 87.6 | 51.4 |
| | Vegetable protein and cereal beverages | 5,376 | 81.5 | 42.9 | 80.5 | 35.7 | 82.3 | 35.7 | 79.3 | 41.1 | 81.0 | 35.8 |
| | Functional beverages | 4,563 | 99.7 | 50.0 | 76.1 | 35.7 | 93.5 | 42.9 | 88.7 | 49.3 | 91.5 | 43.4 |
| | Coffee | 3,411 | 64.4 | 28.6 | 58.3 | 28.6 | 63.1 | 28.6 | 57.5 | 28.6 | 61.2 | 28.6 |
| | Other sugary beverages | 2,765 | 95.1 | 42.9 | 77.6 | 35.7 | 82.2 | 35.7 | 89.2 | 42.9 | 85.5 | 36.1 |
| | Total beverages | 23,342 | 287.9 | 157.1 | 227.9 | 121.4 | 277.2 | 149.5 | 240.7 | 135.7 | 259.0 | 142.9 |
| 6–17 years old | 100% fruit and vegetable juice | 9,763 | 83.3 | 38.8 | 79.8 | 32.9 | 82.0 | 35.7 | 79.9 | 34.3 | 81.5 | 35.7 |
| | Not 100% fruit and vegetable beverages | 17,259 | 83.2 | 42.9 | 71.1 | 35.7 | 76.5 | 35.7 | 78.1 | 35.7 | 77.2 | 35.7 |
| | Carbonate beverages | 24,403 | 100.7 | 54.2 | 79.2 | 35.7 | 86.5 | 42.9 | 96.7 | 49.3 | 91.6 | 42.9 |
| | Tea beverages | 16,211 | 111.2 | 57.1 | 88.4 | 42.9 | 96.3 | 49.3 | 106.6 | 57.1 | 100.9 | 50.0 |
| | Milk-containing beverages | 18,346 | 78.1 | 42.9 | 74.6 | 35.7 | 72.3 | 35.7 | 80.4 | 42.9 | 76.2 | 40.0 |
| | Vegetable protein and cereal beverages | 12,162 | 68.0 | 34.3 | 68.3 | 32.9 | 67.5 | 31.4 | 69.0 | 35.7 | 68.2 | 34.3 |
| | Functional beverages | 7,544 | 82.7 | 35.9 | 63.6 | 29.1 | 74.4 | 32.9 | 77.3 | 35.7 | 75.6 | 35.7 |
| | Coffee | 4,168 | 58.6 | 28.6 | 52.9 | 21.4 | 57.9 | 28.6 | 51.4 | 21.4 | 55.7 | 26.3 |
| | Other sugary beverages | 4,850 | 75.1 | 32.9 | 62.5 | 28.6 | 62.4 | 28.6 | 76.1 | 35.7 | 68.5 | 28.6 |
| | Total beverages | 48,622 | 210.6 | 107.1 | 175.9 | 85.7 | 204.7 | 101.4 | 182.3 | 88.6 | 193.8 | 98.6 |

absorbed and increases the risk of overweight and obesity, dental cavities, and type 2 diabetes by promoting fat storage. This study showed the data of the consumption rate and characteristics of beverages for children and adolescents in China. The results revealed the consumption rate was relatively high, especially in males, in urban areas, and in adolescents aged 12–17 years. These results were basically consistent with relevant domestic studies (*8*–*9*), which could be concerned by public health administrators. Carbonated beverages were the beverage with the highest consumption rate for children and adolescents. Carbonated beverages were primarily soft beverages in China and were the primary representative of sugary beverages (*10*). The results of dietary surveys in many countries showed that the high intake of added sugar in children and adolescents was mainly due to the intake of sugary beverages (*11*–*12*), especially carbonated beverages (*10*). As for the choice of beverage types, males prefer carbonated beverages, tea beverages, and functional beverages, while females prefer milk-containing beverages, vegetable protein and cereal beverages, and 100% fruit and vegetable juice. A possible explanation can be that males might prefer beverages based on taste and feelings of being refreshed, while females may be more focused on the nutrition of beverages (*13*).

This study showed that children and adolescents consumed beverages at a primary frequency rate of 1–3 times/week. The top beverages in daily consumption were 100% fruit and vegetable juices, milk-containing beverages, and vegetable protein and cereal beverages. Beverages can hardly function as essential foods for life, and it is difficult to replace vegetables, fruits, milk, soy products, and cereals in supplying demanded nutrition for human beings (*7*).

The WHO comments that the intake of free sugar should be controlled to a rate lower than 10% of the total energy intake and that rates lower than 5% are even more beneficial for health (*5*). The *Dietary Guidelines for Chinese Residents (2016)* suggested that the daily adding of sugar should not exceed 50 g, preferably lower than 25 g (*7*). According to the database of added sugar food ingredient at US Department of Agriculture, on average, each 100 g of sugary beverages contains about 9 g of added sugar (*14*). By drinking an average of 193.8 g of sugary beverages per day, the free sugar intake reaches 17.4 g, which is close to the suggested value in the dietary guidelines with added sugars from other foods excluded. Although the current daily average consumption of sugary beverages by children and adolescents in China was lower than many other countries (*15–16*), more attention still should be paid to the consumption among the target populations.

The *Dietary Guidelines for Chinese Residents (2016)* suggested that children and adolescents should minimize consumption of sugary beverages (*7*). In 2019, the *Healthy Oral Action Plan (2019–2025)* issued by the National Health Commission emphasizes the combination of healthy campus program to support sugar control by joint work of regulating high-sugar beverage sales at junior high schools and elementary schools and management programs of sugar beverages controlling supply at cafeterias. Further involvement in education and managerial work of sugary beverage consumption can play an important role in administrating public health for children and adolescents in China.

The research was subjected to some limitations. First, the detailed sugar rate of beverages is difficult to isolate due to a combination of factors. Second, the samples did not cover the highest grades of children and adolescents in elementary schools, junior high schools, and senior high schools due to sampling design in this research, which could influence the randomness of the sampling to be not as ideal.

**Acknowledgment:** Research staff from local CDCs and respondents in the Surveillance.

**Conflicts of interest:** No conflicts of interest.

**Funding:** National Health Commission of the People's Republic of China Medical Reform Major Program: China Nutrition and Health Surveillance of Children and Lactating Mothers (2016–2017).

**doi:** 10.46234/ccdcw2021.064

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Submitted: March 03, 2021; Accepted: March 11, 2021

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Methods and Applications

# Development of Cryogenic Disinfectants Using in –18 °C and –40 °C Environments — Worldwide, 2021

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## ABSTRACT

**Introduction:** Since the outbreak of coronavirus disease 2019 (COVID-19) in Beijing Xinfadi Wholesale Market, a series of COVID-19 outbreaks has indicated the threat of transmission due to outer surfaces of objects under low temperatures. Therefore, 2 kinds of chlorine-containing disinfectants for −18 °C and −40 °C were developed in order to solve the problem of low temperature disinfection.

**Methods:** The properties of two cryogenic disinfectants were evaluated by low-temperature test. *Staphylococcus aureus* and *Escherichia coli* were used as two indicator microorganisms to evaluate the effects of the two cryogenic disinfectants in the laboratory and field tests according to *Technical Specifications for Disinfection (2002 version)* and *Test method for bactericidal effect of disinfectants in laboratory (GB/T 38502-2020)*.

**Results:** Two disinfectants could remain in the liquid state at −18 °C or −40 °C in 72 hours without crystallization and precipitation, and the average log values of microbial reduction before and after disinfection (the average killing log value) both on *Staphylococcus aureus* and *Escherichia coli* were >3 in the laboratory and field tests.

**Discussion:** The results showed that these two disinfectants remained functional at low temperature to disinfect the packaging of imported cold chain food and surrounding packaging to prevent transmission of COVID-19 from material to people.

## INTRODUCTION

Since the onset of the coronavirus disease 2019 (COVID-19) pandemic, there have been more than 10 million confirmed cases and 2,320,497 deaths (*1*). According to the current understanding of COVID-19 virus, the virus can be transmitted by air droplets and aerosols or through deposit on the surfaces of inanimate objects and subsequent contact with those objects (*2*). A previous study showed that COVID-19 virus survived for 21 days on refrigerated (4 °C) and frozen (–20 °C and −80 °C) salmon and chicken (*3*) but was inactivated after 5 min at 70 °C (*4*), indicating that cold temperature extended the survival time of the virus on surfaces.

COVID-19 virus was detected on a cutting board used for processing imported salmon in a food contamination incident that occurred on June 12, 2020 in Xinfadi Agricultural Produce Wholesale Market in Beijing (*5*), and subsequent outbreaks occurred in Xinjiang and Shanghai (*6*). These incidents demonstrated that COVID-19 virus could survive on the surface of objects in cold environments for long times and could cause cluster outbreaks.

The temperature of Xinjiang, Inner Mongolia, and other places in China has dropped below −20 °C in 2020 winter, as it has in Russia, Canada, and some northern regions of the United States. Temperature is an important factor affecting the effectiveness of disinfection as low temperature will make microbicidal efficiency decrease and there are no appropriate disinfection measures available for use at such cold temperatures. Therefore, the prevention and control of COVID-19 virus in these regions has become more difficult.

In this study, 2 chlorine-containing cryogenic disinfectant were developed to kill *Staphylococcus aureus* and *Escherichia coli* at −18 °C and −40 °C, and these effects were verified.

## METHODS

### Bacterial Strains, Bacterial Carriers, and media

*Staphylococcus aureus* and *Escherichia coli* bacteria were cultured on Tryptone soy agar (TSA) medium; Tryptone soy broth (TSB) medium was used to dilute the bacteria cultured overnight to the required concentration; 10 μL of fresh *Staphylococcus aureus* and *Escherichia coli* were applied to cloth carriers, which were left at room temperature to dry and dropped to –18 °C or –40 °C before disinfection.

### Formula Determination

Calcium chloride, ethanol, and ethylene glycol were chosen as antifreeze agents. Sodium dichloroisocyanurate was selected as the main active ingredient, combined with the optimum proportion of antifreeze to assess the killing effect of microorganisms under low temperatures.

### Icing Test

For this test, 5 mL disinfectant was added to 90 mm glass petri dishes, and 20 mL disinfectant was added to 50 mL centrifuge tubes; the objects were then placed in the – 18 °C or – 40 °C environment and observed at different timepoints.

### Laboratory Bactericidal Experiment

Before each bactericidal experiment, the available chlorine concentration of the disinfectant was measured using the iodometric method described in the *Technical Specifications for Disinfection (2002 version)*(*7*).

For neutralizer identification test, it was divided into 4 groups according to the *Test method for bactericidal effect of disinfectant in laboratory* (GB/T 38502-2020) (*8*) to evaluate whether the neutralizing agent, neutralizing product, and diluent affected the bacterial tablet.

For carrier quantitative germicidal test, the effect of the disinfectant on *Staphylococcus aureus* and *Escherichia coli* was evaluated according to the *Technical Specifications for Disinfection (2002 edition)*. The infected bacterial carriers were immersed into the disinfectant (5.0 mL per carrier tablet) and positive control bacterial carriers into the diluent. The experiment was repeated three times.

### Field Test

Cartons (58 cm × 38 cm × 34 cm) were selected as simulating container to evaluate the disinfection to the outer packaging of refrigerated articles. One piece of *Staphylococcus aureus* carrier and one piece of *Escherichia coli* carrier were fixed on each of the six sides of the carton. Then, the cartons were immediately placed in a high-speed micron spray sterilizer for six-sided disinfection until each carrier was soaked after the bacteria carriers reached – 18 °C or –40 °C.

To test cold storage disinfection, a total of 10 *Staphylococcus aureus* carriers and 10 *Escherichia coli* carriers placed on each plate were evenly placed in the front, back, left, right, and middle of the – 18 °C or –40 °C cold storages. A disinfectant sprayer equipped with the low-temperature disinfectant was used to spray and disinfect the cold storage, and the spraying volume is about 200–300 mL/$m^2$.

In field tests, the temperatures of the carriers were verified to reach – 18 °C or – 40 °C before disinfection and 3 samples for each bacterium were put into cold storage together with the experimental group but not sterilized as the positive control group.

Another 10 minutes after the carriers were completely soaked were allowed, and the bacterial carriers were placed in 10 mL neutralizer solutions while the positive control bacteria carriers were placed in 10 mL diluent. The colonies were then counted. The test was repeated three times.

## RESULTS

### Physical Property Tests

In this study, the disinfectant remained liquid without crystallization or precipitation in cold storage times of 72 h.

When evaluating the bactericidal effect of – 18 °C disinfectant, the mean available chlorine concentration prepared in the laboratory tests was 2,919 mg/L (2,872–2,943 mg/L) while in field tests was 2,795 mg/L (2,765–2,819 mg/L). The available chlorine concentrations of – 40 °C disinfectant before the 3 sets of laboratory experiments were 4,892 mg/L, 4,875 mg/L, and 4,839 mg/L, while those for field tests were 5,283 mg/L, 5,141 mg/L, and 5,247 mg/L.

### Laboratory Bactericidal Experiment

For the two cryogenic disinfectants, two types of neutralizers could effectively neutralize the effect of the disinfectant remaining on the surface of bacteria in diluent on *Staphylococcus aureus,* and neither the neutralizer nor the neutralizing product had any adverse effect on *Staphylococcus aureus* or the medium (Table 1).

Based on neutralizer identification test, we carried out bactericidal experiments with the disinfectants. The average killing log values of the 2 disinfectants against *Staphylococcus aureus* and *Escherichia coli* were >3.00 at –18 °C and –40 °C, demonstrating the qualified effects of the disinfectants (Table 2).

### Field Test

There were 1 sample of *Staphylococcus aureus* and 1 sample of *Escherichia coli* on each side of each carton, and a total of 60 samples were collected at –18 °C or –40 °C. After the carton was sterilized by a high-speed micron spray sterilizer, the killing log values of *Staphylococcus aureus* and *Escherichia coli* on the carrier were all >3.00, demonstrating a qualified disinfection effect.

The killing log values of 30 *Staphylococcus aureus* tablets and 30 *Escherichia coli* tablets were all >3.00 after sterilizing the –18 °C or –40 °C storages with a sprayer (the dosage of disinfectant was 200–300 mL/$m^2$), also meeting the requirements for qualified disinfectants (Tables 3–4).

### Formulation of Disinfectant

With a combination of freezing tests, laboratory experiments and field tests, we obtained two disinfectants, the disinfectant for –18 °C contained 25% calcium chloride, 9.5% ethanol, and 3,000 mg/L sodium dichloroisocyanurate, while 30% calcium chloride, 9.5% ethanol, 9.9% ethylene glycol, 5,000 mg/L sodium dichloroisocyanurate, and 0.09% benzalkonium chloride were used in the –40 °C disinfectant.

## DISCUSSION

In this study, chemical disinfectants were applied to determine effectiveness at low temperatures. Disinfectants with chlorine were considered suitable for disinfecting general object surfaces, food and drinking utensils, fabrics, fruits, vegetables, and water, etc., in public places and families (*9*). COVID-19 virus can be inactivated in 0.5 min at room temperature at an available chlorine level of 250 mg/L (*10*). Considering economic costs and convenience of application, sodium dichloroisocyanurate (available chlorine) was selected as the representative chlorine-containing disinfectant, and a small amount of benzalkonium chloride was added to synergize the disinfection effect in the –40 °C cryogenic disinfectant.

The formulation contained antifreeze agents including calcium chloride, ethanol, and glycol. Industrial calcium chloride aqueous solution was widely used in all kinds of equipment and environments that require a reduced freezing point. However, the saturation point of calcium chloride decreases with decreasing temperature, and calcium chloride is corrosive (*8*). Therefore, ethanol and ethylene glycol were also added as antifreeze agents. Ethanol has a antifreeze effect in chlorine dioxide compounds at –20 °C (*11*). Methanol and ethylene glycol have also been reported as antifreeze compounds facilitating the disinfection effect of chlorine-containing disinfectants at 0°C and –20 °C (*12*). Considering its toxicity and price, methanol was not

TABLE 1. Neutralizer identification test on *Staphylococcus aureus.*

| Group | –18 °C Cryogenic disinfectant | | –40 °C Cryogenic disinfectant | |
|---|---|---|---|---|
| | Average colony forming units of each group (CFU/tablet) | Error rate between groups (%) | Average colony forming units of each group (CFU/tablet) | Error rate between groups (%) |
| 1 | 407 | 4.2 | 542 | 4.23 |
| 2 | 413 | | 592 | |
| 3 | 450 | | 602 | |
| 4 | 0 | | 0 | |

Note: Group 1: soak the carrier tablet in 5.0 mL neutralizing agent for 10 minutes; Group 2: soak the carrier tablet in 5.0 mL of neutralization products for 10 minutes; Group 3: soak the carrier tablet in 5.0 mL tryptone saline solution (TPS) dilution for 10 minutes; Group 4: 1 mL of TPS diluent, 1 mL of neutralizing agent and the same culture medium as that of the first three groups was added and placed into sterile plates.The neutralizer of –18 °C Cryogenic disinfectant was 0.03 mol/L PBS containing 0.3% sodium thiosulfate, 0.1% lecithin and 1% tween-80 while 0.03 mol/L PBS containing 0.5% sodium thiosulfate, 0.5% lecithin and 2% tween-80 was for –40 °C Cryogenic disinfectant.

TABLE 2. Killing effect of disinfectant of –18 °C/–40 °C disinfectant on *Staphylococcus aureus* and *Escherichia coli.*

| Bacteria | Available chlorine (mg/L) | Logarithm of the mean colony number of the positive control group | Average killing log of bacteria at different times of disinfection | | |
|---|---|---|---|---|---|
| | | | 2.5/5 min | 5/10 min | 7.5/15 min |
| *Staphylococcus aureus* | 2,919/4,869 | 6.18/6.07 | 5.81/3.91 | 5.88/4.12 | 6.18/4.10 |
| *Escherichia coli* | 2,919/4,869 | 6.36/6.36 | 5.23/4.78 | 5.23/5.14 | 6.18/5.39 |

TABLE 3. The disinfection effect of – 18 °C/–40 °C cryogenic disinfectant on *Staphylococcus aureus/Escherichia coli* on outer surface of the cartons.

| Sample number | Carrier position | Colony forming units of test group (CFU/tablet) | Killing log value | Sample number | Carrier position | Colony forming units of test group (CFU/tablet) | Killing log value |
|---|---|---|---|---|---|---|---|
| 1 | Top side of carton 1 | (265, 0)/(10, 25) | >3.00 | 16 | Right side of carton 3 | (10, 0)/(20, 5) | >3.00 |
| 2 | Bottom side of carton 1 | (235, 15)/(615, 0) | >3.00 | 17 | Front side of carton 3 | (5, 10)/(30, 0) | >3.00 |
| 3 | Left side of carton 1 | (15, 0)/(10, 15) | >3.00 | 18 | Back side of carton 3 | (0, 0)/(5, 0) | >3.00 |
| 4 | Right side of carton 1 | (15, 0)/(10, 0) | >3.00 | 19 | Top side of carton 4 | (0, 15)/(65, 0) | >3.00 |
| 5 | Front side of carton 1 | (5, 10)/(50, 30) | >3.00 | 20 | Bottom side of carton 4 | (425, 65)/(60, 950) | >3.00 |
| 6 | Back side of carton 1 | (0, 5)/(0, 0) | >3.00 | 21 | Left side of carton 4 | (0, 0)/(5, 0) | >3.00 |
| 7 | Top side of carton 2 | (0, 15)/(480, 45) | >3.00 | 22 | Right side of carton 4 | (10, 0)/(0, 0) | >3.00 |
| 8 | Bottom side of carton 2 | (10, 50)/(515, 20) | >3.00 | 23 | Front side of carton 4 | (5, 0)/(10, 0) | >3.00 |
| 9 | Left side of carton 2 | (145, 0)/(5, 0) | >3.00 | 24 | Back side of carton 4 | (10, 0)/(0, 0) | >3.00 |
| 10 | Right side of carton 2 | (5, 0)/(5, 25) | >3.00 | 25 | Top side of carton 5 | (0, 0)/(5, 5) | >3.00 |
| 11 | Front side of carton 2 | (0, 10)/(5, 55) | >3.00 | 26 | Bottom side of carton 5 | (15, 40)/(210, 5) | >3.00 |
| 12 | Back side of carton 2 | (0, 20)/(5, 0) | >3.00 | 27 | Left side of carton 5 | (50, 0)/(0, 5) | >3.00 |
| 13 | Top side of carton 3 | (5, 0)/(10, 10) | >3.00 | 28 | Right side of carton 5 | (5, 0)/(0, 15) | >3.00 |
| 14 | Bottom side of carton 3 | (100, 5)/(0, 10) | >3.00 | 29 | Front side of carton 5 | (0, 0)/(10, 0) | >3.00 |
| 15 | Left side of carton 3 | (0, 0)/(10, 0) | >3.00 | 30 | Back side of carton 5 | (230, 0)/(0, 0) | >3.00 |

Note: Positive control bacteria count of *Staphylococcus aureus* and *Escherichia coli*: $4.26\times10^6$ CFU/tablet ($9.0\times10^5$–$6.6\times10^6$ CFU/tablet), $1.91\times10^6$ CFU/tablet ($3.15\times10^5$–$9.15\times10^6$ CFU/tablet).

TABLE 4. The disinfection effect of – 18 °C/–40 °C cryogenic disinfectant on *Staphylococcus aureus/Escherichia coli* in –18 °C/–40 °C storage.

| Sample number | Colony forming units of test group (CFU/tablet) | Killing log value | Sample number | Colony forming units of test group (CFU/tablet) | Killing log value |
|---|---|---|---|---|---|
| 1 | (0, 0)/(30, 5) | >3.00 | 16 | (5, 0)/(0, 5) | >3.00 |
| 2 | (0, 0)/(0, 0) | >3.00 | 17 | (0, 0)/(20, 10) | >3.00 |
| 3 | (0, 0)/(5, 0) | >3.00 | 18 | (0, 0)/(0, 0) | >3.00 |
| 4 | (0, 0)/(0, 65) | >3.00 | 19 | (0, 0)/(0, 0) | >3.00 |
| 5 | (0, 0)/(10, 5) | >3.00 | 20 | (0, 0)/(0, 70) | >3.00 |
| 6 | (0, 0)/(10, 0) | >3.00 | 21 | (0, 0)/(0, 65) | >3.00 |
| 7 | (0, 0)/(0, 0) | >3.00 | 22 | (0, 0)/(0, 0) | >3.00 |
| 8 | (0, 0)/(0, 0) | >3.00 | 23 | (0, 0)/(15, 135) | >3.00 |
| 9 | (0, 0)/(0, 0) | >3.00 | 24 | (0, 0)/(5, 115) | >3.00 |
| 10 | (0, 0)/(0, 0) | >3.00 | 25 | (0, 0)/(20, 10) | >3.00 |
| 11 | (0, 0)/(0, 15) | >3.00 | 26 | (0, 0)/(10, 100) | >3.00 |
| 12 | (0, 0)/(5, 0) | >3.00 | 27 | (0, 0)/(20, 0) | >3.00 |
| 13 | (0, 0)/(0, 0) | >3.00 | 28 | (0, 0)/(30, 0) | >3.00 |
| 14 | (0, 0)/(5, 0) | >3.00 | 29 | (0, 0)/(20, 340) | >3.00 |
| 15 | (0, 0)/(0, 0) | >3.00 | 30 | (0, 0)/(0, 170) | >3.00 |

Note; Positive control bacteria count of *Staphylococcus aureus* and *Escherichia coli*: $4.26\times10^6$ CFU/tablet ($9.0\times10^5$–$6.6\times10^6$ CFU/tablet), $1.91\times10^6$ CFU/tablet ($3.15\times10^5$–$9.15\times10^6$ CFU/tablet).

selected for this formula.

The COVID-19 virus is lipophilic and an enveloped virus (*13*), and it is generally believed to be more sensitive to chemical disinfection factors than *Staphylococcus aureus* and other bacteria (*14*). So, *staphylococcus aureus* and *Escherichia coli* were considered indicators to evaluate the disinfection effect. The cryogenic disinfectant developed in this study solved the problem of freezing and effectiveness of chemical disinfectants at low temperatures, which meant that the cryogenic disinfectants could be used for disinfection of COVID-19 virus. This study provided a new method for solving the technical problems of the disinfection of cold chain food packaging or environments, outdoor environments, and cold winter items.

This study was subject to some limitations. First, since the stability of this disinfectant has not been studied, it should be created for use immediately. Second, because there was no evaluation method for the metal corrosion of disinfectants at low temperatures, the metal corrosion test at low temperature has not been conducted for these two disinfectants.

Further studies are needed to adjust the formulation without affecting the effectiveness of disinfection to enhance stability for better application. This disinfectant should be used only when the effectiveness of disinfection reaches qualifying levels. Strict personal protection measures should be carried out in the process of disinfectant configuration and onsite disinfection because of the bleachability, corrosiveness, and skin irritation of the disinfectant as it is a chlorine-based disinfectant.

**Acknowledgment:** HaiYunYiJianPan-Health Techno logy Co., Ltd and Beijing Capital Agribusiness Group.

**doi:** 10.46234/ccdcw2021.079

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Submitted: February 12, 2021; Accepted: March 24, 2021

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The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).

CCDC weekly

Vol. 3 No. 13 Mar. 26, 2021

**Responsible Authority**

National Health Commission of the People's Republic of China

**Sponsor**

Chinese Center for Disease Control and Prevention

**Editing and Publishing**

China CDC Weekly Editorial Office

No.155 Changbai Road, Changping District, Beijing, China

Tel: 86-10-63150501, 63150701

Email: weekly@chinacdc.cn

**CSSN**

ISSN 2096-7071

CN 10-1629/R1