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The performance of a community-based colorectal cancer screening program: Evidence from Shanghai Pudong New Area, China

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ABSTRACT

Despite the rising disease burden of colorectal cancer (CRC), CRC screening has not yet been widely introduced as a large organized program in developing countries. To facilitate better delivery of screening in these areas, we investigated the performance of a large community-based CRC screening program implemented in Shanghai Pudong New Area during the period 2013–2016.

We conducted a prospective cohort study by following up the screening behavior and results of tested participants in the program. Data from the program reporting system and monthly progress reports were collected. We used standard measures and indicators with modifications to evaluate the performance of the program. Disparities in CRC screening by age categories, primary screening results, and geographic areas were examined.

A total of 403,098 individuals participated in the program, 25,764 of them were further screened by diagnostic colonoscopy (COL), and 505 people were eventually diagnosed with CRC as a result of the program. The program produced the following rates: participation (35.18%), primary screening positivity (24.89%), positive primary screening follow-up (26.26%), diagnostic COL (6.37%), and cancer detection (1.25‰). Vast variations in the quality of the program were observed across areas with different socioeconomic environments.

The experience and lessons from the program suggest that incorporating the screening with other public health campaigns, using better-developed risk assessment tools, and allowing individual screening decisions for those aged above the target are possible practical ways to promote a better delivery of organized CRC screening programs.

1. Introduction

The disease burden of colorectal cancer (CRC) is severe and has been increasing in China in recent years. CRC is among the top five most common cancers and leading causes of cancer death in both Chinese men and women (Chen et al., 2016). Medical costs of diagnosis and treatment of CRC are catastrophic in China. The 1-year out-of-pocket expenditure of a newly diagnosed patient accounts for 59.9% of his household income in the previous year (Huang et al., 2017).

Studies from high-income countries have suggested that screening can reduce CRC incidence and mortality (Siegel et al., 2018; Center et al., 2009). However, in developing regions, CRC screening has not yet been adequately provided, probably because of challenges in continuing and promoting a population-based screening program (Gupta et al., 2014; Rohan et al., 2013). Therefore, experience and lessons from areas with similar socioeconomic backgrounds have been called for to support the development and implementation of local screening programs in these areas (Chiu et al., 2017, 2015; Hirai et al., 2016).

A CRC screening program involves the combination of tests, clinical practices and organizational factors. Several screening tests for the detection of CRC and precancerous lesions are commonly used, including diagnostic colonoscopy (COL), sigmoidoscopy, CT colonography, fecal occult blood test (FOBt), fecal immunochemical tests (FIT), and multitarget stool DNA (mt-sDNA) test. Each test has its own advantages and limitations (Simon, 2016). Moreover, appropriate risk

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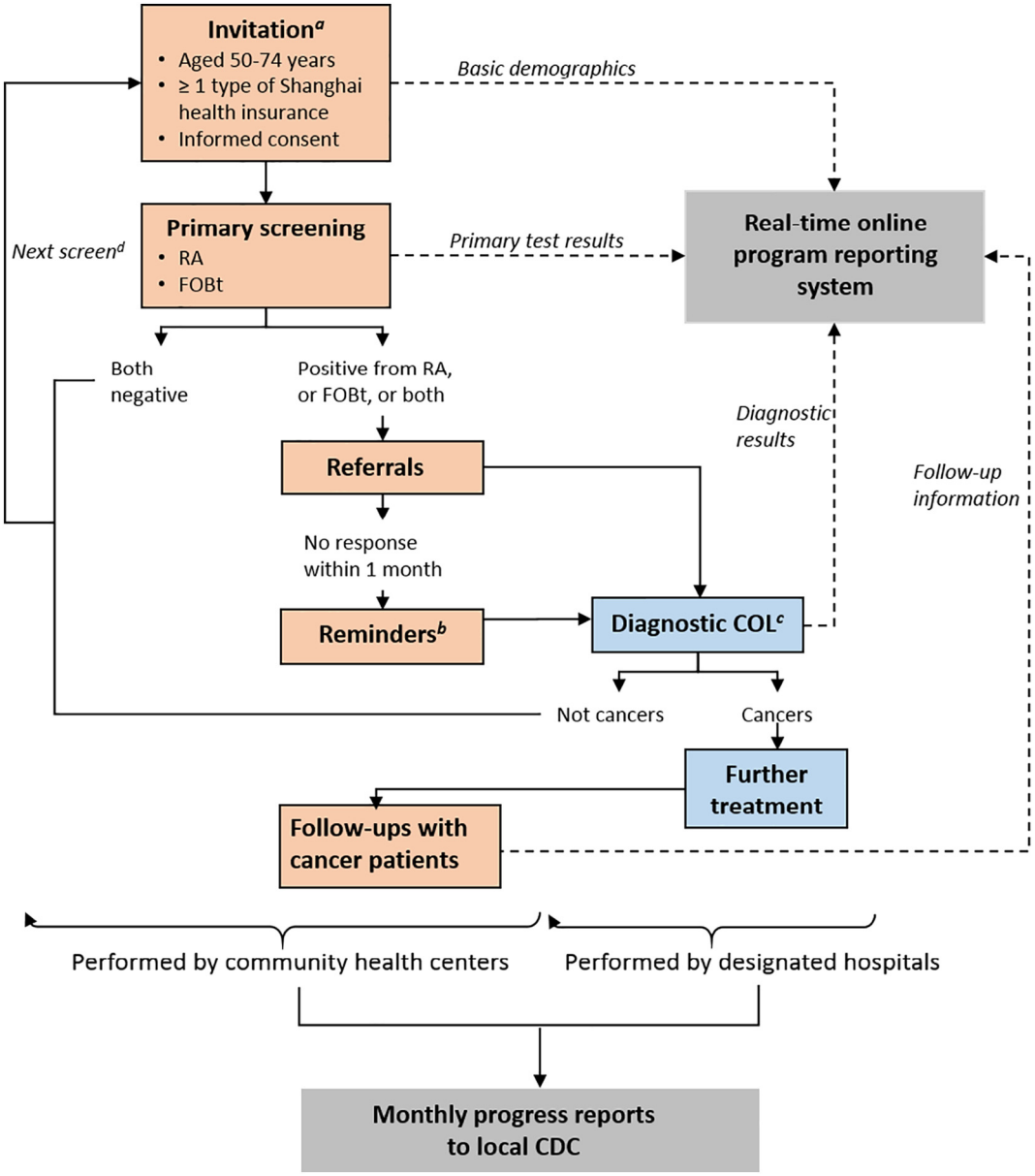

Fig. 1. The workflow of the community-based colorectal cancer screening program in Shanghai Pudong New Area, 2013–2016.
[a]The providers sent out CRC screening invitations only to the target population. But the program was also opened to insured individuals not invited or those not aged 50–74 years if they requested for the screening, because the program was provided as part of essential public health services.
[b]Providers would remind participants with positive primary screening result to have a diagnostic COL every month for the first three months after their test results were received. If no follow-up tests were observed after that, the participants were considered dropouts.
[c]Precancerous lesions were removed once diagnosed during diagnostic COL.
[d]According to the clinical practice guidelines (Zheng and Gong, 2013), those with both negative results from RA and FOBt would be invited every 3 years, those with adenomas diagnosed and removed during COL would be invited every 5 years, and those with low-risk precancerous lesions diagnosed and removed would be invited every 10 years.
Abbreviations: RA (risk assessment), FOBt (fecal occult blood test (colloidal gold)), COL (colonoscopy), CDC (Center for Disease Control and Prevention).

assessment (RA) (i.e., a tool to predict disease risks of the participants) is often used, especially when a program is first implemented in a population that has never been screened for cancers before (Yeoh et al., 2011; Boehm et al., 2013). Importantly, previous work has shown that the implementation of a CRC screening program should be better organized to align with the local environment in order to achieve cost-effectiveness (Lasser et al., 2008; Seeff and Rohan, 2013; Gupta et al., 2017).

Shanghai is one of the earliest cities in developing countries to introduce a large community-based colorectal cancer screening program (C-CRCSP). The program was launched in 2013 by the Shanghai government as part of essential public health services. It uses the FOBt method and covers access to screening and diagnostic follow-ups. Two rounds of the screening have been completed. The first round spanned the entire 2013 calendar year, and the second round covered the following three years from January 2014 to December 2016.

This study aims to evaluate the quality (in terms of the performance during implementation) of the C-CRCSP using standard screening measures and indicators. During 2013–2016, we followed up with the program participants in Shanghai Pudong New Area, compared the performance of the program with similar ones in the Western Pacific regions, and investigated disparities in CRC screening across age

groups, primary screening results, and geographic areas.

Pudong New Area has provided us with an original platform to study this issue. It is the largest district of Shanghai, which has about one-fifth of the land area and one-fourth of the population of Shanghai and is responsible for one-third of Shanghai's GDP. About a decade ago, a previous rural district of Shanghai was merged into Pudong, introduced substantial geographic variations in socioeconomic conditions and health service capacity to the district. Three distinct sub-regions with respective characteristics of the typical urban, suburban and rural areas of China can be clearly observed. Therefore, our analysis could provide important and extensive policy implications to other areas with similar levels of social and economic development, both inside and outside China.

2. Materials and methods

2.1. Shanghai Pudong New Area and the C-CRCSP

Shanghai Pudong New Area covers an area of 1210.41 km^2 (467.34 $mile^2$) with a resident population of 5.5 million, among which > 2.8 million are registered permanent residents, according to 2013 Household Registry. In each screening round of the C-CRCSP, a budget was allocated by the government of the district. Funds were then distributed to each of the 46 communities within the district. Residents aged 50–74 years with at least one type of Shanghai basic medical insurance (approximately, 1,092,444 individuals) were considered the target population and thus had a chance to be invited by primary care physicians at the community health centers (CHCs) that provide services to their neighborhoods. The providers were expected to send out CRC screening invitations to the entire target population by the end of the second round of the program. Residents not invited or who fell out of the target age range could also participate in the program and were not treated or charged differently because the program was provided as a basic social welfare benefit. Due to budget limitations and clinical capacity restrictions, the program set a goal of performing primary screening for 21% (approximately, 218,489 individuals) of the target population in the first round and 7% (approximately, 76,461 individuals) in each of the three years for the second screening round.

Fig. 1 diagrams the workflow of the C-CRCSP in Shanghai Pudong New Area. First, participants were invited and then asked to fill in a questionnaire (see Table S1 in Supplementary materials) to collect basic demographics. Next, primary screening that includes RA and FOBt (colloidal gold) was provided for free. Then, participants with positive results were informed and referred to designated hospitals for diagnostic COL, where polyps and adenomas were removed once diagnosed.

The program established a total of 13 one-to-more screening collaborations between designated hospitals and CHCs (Fig. 2). To balance the workloads, each designated hospital took charge of the referrals from several community health centers, which were determined according to the average travel distance of the participants to the hospital and the COL service capacity of the hospital.

Screening behaviors and results observed during each step were submitted to the program reporting system by physicians at the community health centers and designated hospitals. The CHCs were also required to submit monthly progress reports to the Center for Disease Control and Prevention (CDC) of the district.

Furthermore, the local CDC was responsible for the quality control of the whole process of the screening program, which involved annual organized training for physicians, monthly data verification, annual onsite oversight, and annual review on data entry accuracy and timeliness as well as the progress of each community health center. To increase work incentives, physicians in the program were paid with subsidies, the amount of which were associated with the quality control outcomes.

2.2. Study design and samples

To evaluate the performance of the Pudong CRC screening program during the period 2013–2016, we conducted a prospective cohort study. We followed up tested participants across their screening episodes and collected data from the program reporting system and monthly progress reports. Our final sample consists of 403,098 individuals who received primary screening in the two screening rounds.

2.3. Statistical analysis

Following Benson et al. (2012), we used standard measures and indicators to describe the performance of the program. For screening measures, we obtained the size of the target population, the size of the tested population, the number of people with positive test results (with RA, FOBt, and diagnostic COL), and the number of people with diseases diagnosed. Participants might receive primary screening more than once during our 4-year study period for two reasons. First, FOBt is recommended every three years for individuals with a negative test result according to the clinical practice guidelines (Zheng and Gong, 2013). Second, participants with a positive test result but not screened by diagnostic COL last year were invited again by their primary care physicians under the program policy.

Accordingly, we made some modifications to several measures and indicators. We acquired the total number of screening invitations, the total number of primary screening (RA and FOBt), and the total number of positive test results. Note that individuals who received a negative test result with their last primary screening but came back to participate in the screening again within 3 years were considered non-compliant with the program policy. In such cases, we dropped subsequent test results of these people if the results remained negative to obtain total number of “effective” primary screening, which is an important measure of the program performance.

For screening indicators, we calculated coverage rate (defined as the total number of screening invitations divided by the size of the target population), participation rate (defined as the total number of primary screening divided by the total number of screening invitations), primary screening/FOBt/RA positivity rates (defined as the total number of positive results with primary screening/FOBt/RA divided by the total number of “effective” primary screening), and diagnostic COL/cancer detection/polyp detection/adenoma detection/cancer detection rates (calculated in accordance with Benson et al. (2012)).

To investigate the heterogeneity in the quality of the program, the above indicators were obtained for each age category (within the target age range, or out of the target age range) and sub-regional area (urban, suburban, or rural). We used Chi-square tests to compare results across groups. Joinpoint regression analysis was performed to examine the trend of age groups. All statistical analysis was performed in the Statistical Package for the Social Sciences software version 20.0 (SPSS, Inc., Chicago, IL.).

3. Results

3.1. Screening measures

In the first two rounds of the program, a total of 1,262,214 invitations were made, and 421,384 primary screenings were performed for participants within the target age range. The total number of primary screening (including those out of the target age range) was 517,905, among which 444,106 screenings were counted as “effective”; 403,098 individuals received primary screening, and 97,781 of them obtained positive test results; 25,764 individuals who received a positive primary screening result were further screened by diagnostic COL, out of which 505 cases of CRC were diagnosed (Panel A of Table 1).

Females predominated among the tested population (58.73% vs. 41.27%) and those further screened by diagnostic COL (55.22% vs.

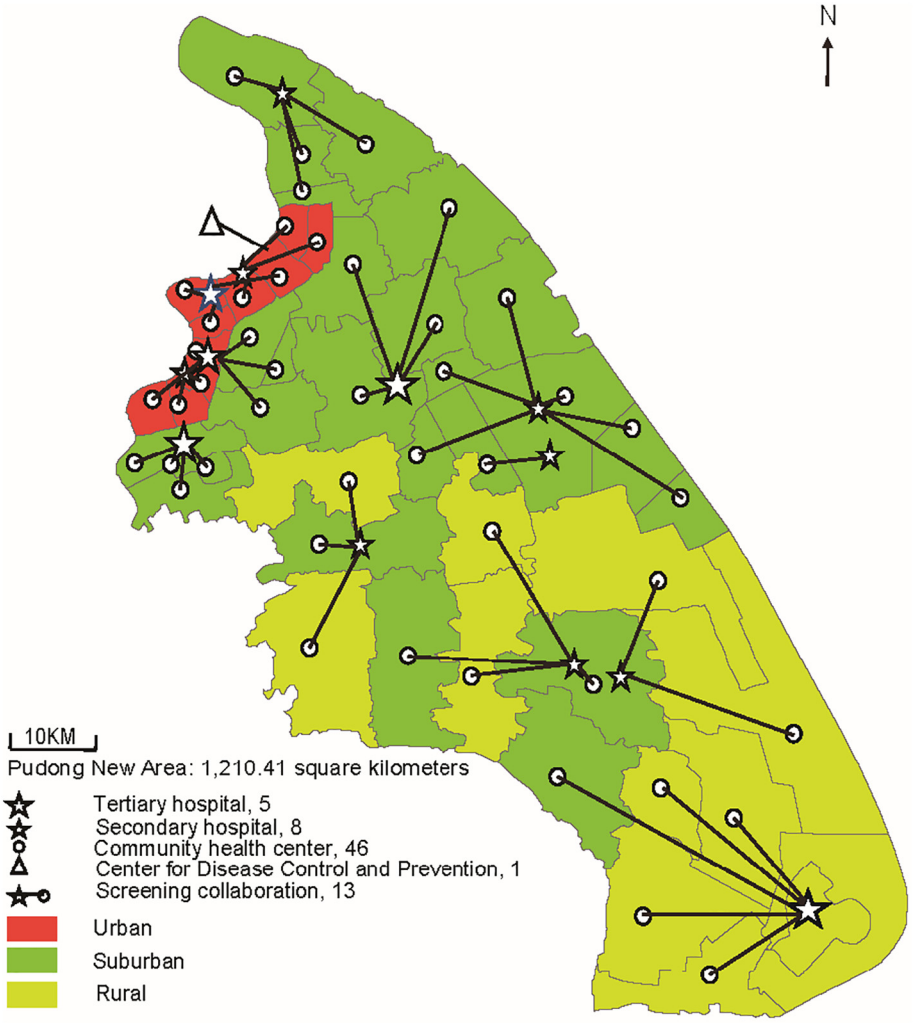

Fig. 2. One-to-more screening collaborations between designated hospitals and community health centers in the Pudong colorectal cancer screening program, 2013–2016.

44.78%). However, the proportion of males diagnosed with lesions by the program exceeded that of females (55.77% vs. 44.23%). Among the tested population, participants underwent diagnostic COL, and participants diagnosed with lesions, the proportion of individuals aged 60–74 years was much more than that of the other age groups. Moreover, among participants diagnosed with lesions, those who received a positive result with FOBt only predominated with a proportion of 68.57% ($N = 5970$). 14.34% ($N = 1249$) of the diagnosis was correctly predicted by RA only (Table 2).

3.2. Screening indicators

The participation rate and FOBt inadequacy rate of the program were 35.18%, and 3.46%, respectively. Overall, the primary screening positivity rate was 24.89%, the diagnostic COL rate was 6.37%, and the cancer detection rate was 1.25‰ (1.97 for polyps and 5.71 for adenomas). Compared to participants of the target population, those out of the target age range had a higher probability of obtaining a positive result with primary screening ($p < 0.001$) and a larger cancer detection rate ($p < 0.001$), but were less likely to follow up the screening test ($p < 0.001$) (Panel B of Table 1).

For participants aged below 70 years, the positivity rate of primary screening increased significantly as age increases ($p < 0.001$). In contrast, the rate was stable for those aged above 70 years (Panel A of Fig. 3, Table 3). The positivity primary screening follow-up rate substantially decreased for those aged above 75 years ($p < 0.001$) (Panel B of Fig. 3, Table 3). However, the cancer detection rate for those aged above 75 years continued to increase (Panel C of Fig. 3, Table 3).

The quality of the program also differed by marital status, education levels, and employment status of the participants (see Table S2 in Supplementary materials). The cancer detection rate was significantly higher ($p < 0.05$) among participants with at least a college equivalent degree (32.54%). In contrast, the positive primary screening follow-up rate was significantly higher ($p < 0.001$) among participants without a college equivalent degree (26.81%) and the unemployed (32.48%).

Substantial variations in program performance were observed in all screening indicators ($p < 0.05$) across areas with different economic development levels (Table 4). Compared to suburban and rural areas, urban areas had the highest coverage rate of 173.82%, the lowest participation rate and diagnostic COL rate (20.30% and 5.49%, respectively), and the highest primary screening positivity rate and cancer detection rate (26.99% and 1.48‰, respectively).

4. Discussion

We used standard measures and indicators with modifications to investigate the performance of the large community-based colorectal cancer screening program implemented in Shanghai Pudong New Area during 2013–2016. Our results show that a total of 403,098 people participated in the program and 505 cases of CRC were diagnosed as a

Table 1
Screening measures and indicators stratified according to whether the participants were within the target age range of the Pudong colorectal cancer screening program, 2013–2016.

	Total	Within target age range	Out of target age range
	(1)	(2)	(3)
Panel A: Screening measures			
(a) Target population	1,092,444	1,092,444	0
(b) Total number of invitations	1,262,214	1,262,214	0
(c) Total number of primary screening	517,905	421,384	96,521
(d) Total number of "effective" primary screening[a]	444,106	359,592	84,514
(e) Tested population	403,098	326,602	76,496
(f) Total number of inadequate FOBt	17,933	NA	NA
(g) Total number of positive results with RA or FOBt	110,523	87,621	22,902
(h) Total number of people received positive results with primary screening	97,781	77,473	20,308
(i) Total number of positive results with FOBt	68,030	53,559	14,471
(j) Total number of people received positive results with FOBt	62,085	48,966	13,119
(k) Total number of positive results with RA	52,554	41,646	10,908
(l) Total number of people received positive results with RA	44,270	34,986	9284
(m) Total number of people further screened by diagnostic COL	25,674	21,876	3798
(n) Total number of people diagnosed with cancer	505	348	157
(o) Total number of people diagnosed with polyp	4386	3731	655
(p) Total number of people diagnosed with adenomas	2301	1915	386
Panel B: Screening indicators (%, if not otherwise indicated)			
Coverage rate (=row(b)/row(a))	115.54	115.54	NA
Participation rate (=row(d)/row(b))	35.18	28.49	NA
FOBt inadequacy rate (=row(f)/row(c))	3.46	NA	NA
Primary screening positivity rate (=row(g)/row(d))**	24.89	24.37	27.10
FOBt positivity rate (=row(i)/row(d))**	15.32	14.89	17.12
RA positivity rate (=row(k)/row(d))**	11.83	11.58	12.91
Diagnostic COL rate (=row(m)/row(e))**	6.37	6.70	4.96
Positive primary screening follow-up rate (=row(m)/row(h))**	26.26	28.24	18.70
Cancer detection rate (=row(n)/row(e)) (‰)**	1.25	1.07	2.05
Positive predictive value for cancer detection (=row(n)/row(m))**	1.97	1.59	4.13
Polyp detection rate (=row(o)/row(e)) (‰)**	10.88	11.42	8.56
Positive predictive value for polyp detection (=row(o)/row(m))	17.08	17.06	17.25
Adenoma detection rate (=row(p)/row(e)) (‰)*	5.71	5.86	5.05
Positive predictive value for adenoma detection (=row(p)/row(m))*	8.96	8.75	10.16

Abbreviations: RA (risk assessment), FOBt (fecal occult blood test (colloidal gold)), COL (colonoscopy).

[a] Individuals who received negative test results with their last primary screening but came back to the program again within 3 years were considered non-compliant with the program policy (Zheng and Gong, 2013). To obtain the total number of "effective" primary screening (row (d) of Panel A), we dropped the subsequent test results of these people, if the results remained negative.

* The *p*-values of chi-square tests for comparisons between within and out of target age range < 0.05.

** The *p*-values of chi-square tests for comparisons between within and out of target age range < 0.001.

result of the program by the end of the second screening round. The program produced the following rates: participation (35.18%), primary screening positivity (24.89%), positive primary screening follow-up (26.26%), diagnostic COL (6.37%), and cancer detection (1.25‰). Great heterogeneity in program performance was observed across sub-regions with different socioeconomic backgrounds.

Compared to similar programs in the Western Pacific regions, the cancer detection rate of the program in Pudong was higher than that in Australia (0.1‰) and Taiwan (1.1‰). However, the positive primary screening follow-up rate of the program in Pudong was only a half of that in Australia (50%) and less than one-third of that in Taiwan (85%) (Benson et al., 2012). This compliance rate was also lower than that of the CRC screening program in Shanghai as a whole over the first-round screening (Gong et al., 2018).

Since the program also opened to individual screening requests for those out of the target age range, we were able to observe the screening behavior and outcomes of these participants. We find that the cancer detection rate for participants aged above 75 years was significantly higher, though they had lower compliance rate. The results imply that the screening may also be beneficial for those more elderly. More cost-effectiveness evidence specific to the study population will be needed to inform a decision on whether to expand the program to additional age cohorts. However, the current practice of the Pudong program was consistent with the US Preventive Services Task et al. (2016), which recommends that screening for CRC cancer in those aged above 75 years should be an individual decision, with personal health and prior screening history taking into account.

Our results also suggest room for improvement in the quality of the C-CRCSP program along several dimensions. First, by the end of the second screening round, only 29.90% (326,602/1,092,444) of the target population was screened, which was lower than the screening goal. Although 18.97% (76,496/403,098) of the screened participants were from the non-target population, however the low response rate to screening invitations was responsible for the failure to meet the goal.

Second, the observed difference between total and "effective" screening suggests less efficient use of resource. Individuals received the primary screening more frequently than the clinical practice guidelines recommended (Zheng and Gong, 2013). And their latter screening didn't provide them with any new information since their primary screening results remained negative. There are two possible reasons for the inefficient use of resource. First, physicians at CHCs failed to carefully check the screening history of the participants via the program reporting system because this step was considered time-consuming given the large participant volumes. Second, usually physicians found it hard to decline screening requests by uninvited individuals because they afraid this might lead to intense physician-patient relationships and lower the participation rate of invited individuals.

Third, among the target population, people aged 60–74 years participated in the program disproportionately. During the same period of our study, there was another public health program on-going, i.e., free

Table 2
Screening measures of the Pudong colorectal cancer screening program, by genders, age groups, and primary screening results of the participants, 2013–2016.

	Tested population		Participants screened by diagnostic COL		Participants diagnosed with lesions	
	n	(%)	n	(%)	n	(%)
	(1)	(2)	(3)	(4)	(5)	(6)
Total	403,098	(100)	25,674	(100)	8707	(100)
Gender						
Male	166,354	(41.27)	11,497	(44.78)	4856	(55.77)
Female	236,744	(58.73)	14,177	(55.22)	3851	(44.23)
Age						
50–59 yrs	62,400	(15.48)	3273	(12.75)	859	(9.87)
60–74 yrs	264,202	(65.54)	18,603	(72.46)	6392	(73.41)
Out of target age range	33,956	(8.42)	3798	(14.79)	1456	(16.72)
Primary screening results						
Negative	305,326	(75.74)	520	(2.03)	152	(1.75)
Positive with RA only	35,687	(8.85)	4867	(18.96)	1249	(14.34)
Positive with FOBt only	53,511	(13.27)	16,896	(65.81)	5970	(68.57)
Positive with both RA and FOBt	8574	(2.13)	3391	(13.21)	1336	(15.34)

Abbreviations: RA (risk assessment), FOBt (fecal occult blood test (colloidal gold)), COL (colonoscopy).

physical examinations for those aged above 60 years. Some primary care physicians promoted the screening program to the target population when people came to their offices for free physical examinations, contributing to more people aged 60–74 years being invited and participating in the program. The results suggest that incorporating the screening program with other public health campaign may effectively increase the participation rate. This strategy may be used to increase the participation rate of other age groups.

Fourth, a comparison with similar programs in the Western Pacific regions suggests that the low participant compliance has been a major challenge of our program. Interestingly, inconsistent with studies from developed countries (Pornet et al., 2010; Ioannou et al., 2003), low CRC screening adherence of the Pudong program was closely linked with higher socioeconomic status of the participants in terms of education levels and employment status.

Moreover, we also observe that the compliance rate was associated with results of the primary screening. Ratios between column (5) and column (3) of Table 2 show the likelihoods of the participants to follow up primary screening after receiving their results. We find that the probability was the highest for those with both positive results (39.55%, 3391/8574), followed by positive result with FOBt only (31.57%, 16,896/53,511). The probability to follow up primary screening was the lowest for those who received positive results with RA only (13.64%, 4867/35,687). The result suggests a low confidence in RA among the public, which is probably due to the relatively higher false-positivity rate of the test. False-positivity may not only lead to the chance of over-diagnosis and over-treatment but also harm the quality of the screening program by discouraging people from following up a positive primary screening result (Esserman et al., 2013; Corte et al., 2016). Our findings suggest that well-developed risk assessment tools tailored to the characteristics of the local population are needed.

Last, we observed vast variations in the performance of the screening across urban, suburban, and rural geographic areas, which is less focused in previous studies. Unlike the conjecture that implementation of CRC screening should be easier in more developed regions (Shi et al., 2016), our results show that the participation rate in urban areas was less than half of that in town and rural areas. The diagnostic COL rate and the primary screening follow-up rate were also lower despite more designated hospitals for screening located in urban areas. Two reasons may be responsible for this: first, the screening resources per capita in the urban area were actually more limited,

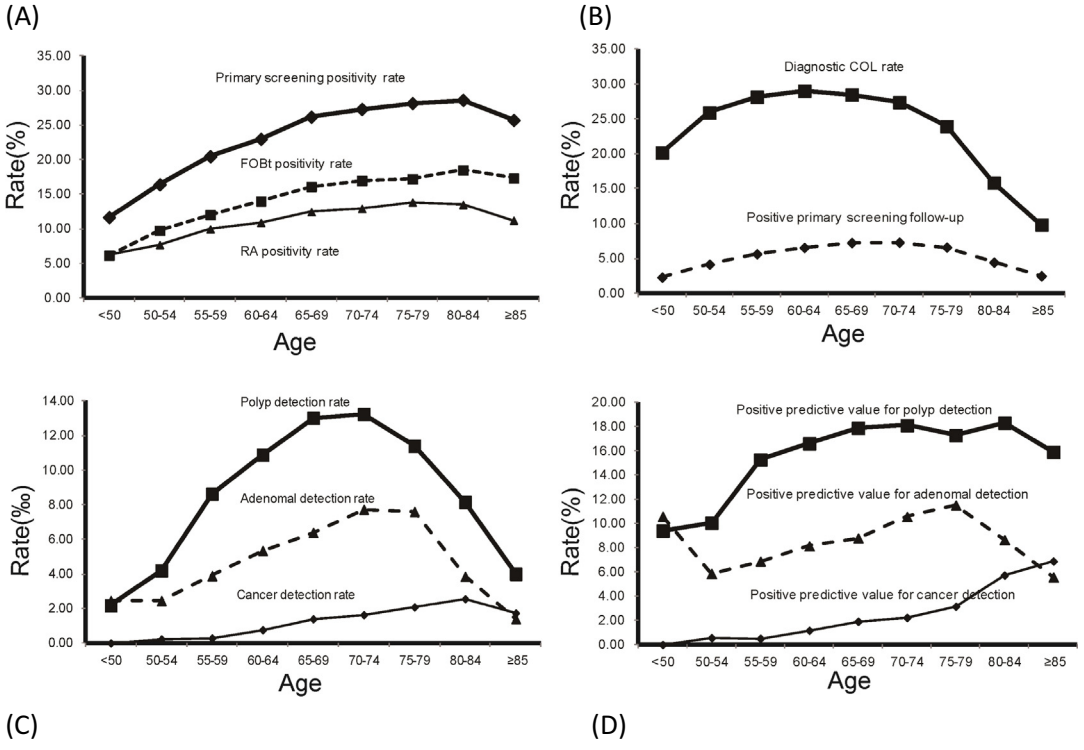

Fig. 3. Screening indicators for the Pudong colorectal cancer screening program, by age categories, 2013–2016.

Table 3
Trends of age categories in screening indicators of the Pudong colorectal cancer screening program, 2013–2016.

Screening indicators	Trend 1		Trend 2	
	Age groups	PC	Age groups	PC
Primary screening positivity rate (%)	< 50 y to 65–69 y	4.04**	65–69 y to ≥85 y	−0.20
FOBt positivity rate (%)	< 50 y to 60–64 y	5.75**	60–64 y to ≥85 y	0.70
RA positivity rate (%)	< 50 y to 65–69 y	3.73**	65–69 y to ≥85 y	−0.41
Diagnostic COL rate (%)	< 50 y to 70–74 y	4.64**	70–74 y to ≥85 y	−7.82**
Positive primary screening follow-up rate (%)	< 50 y to 70–74 y	1.29	70–74 y to ≥85 y	−7.04**
Cancer detection rate (‰)	< 50 y to 55–59 y	78.51**	55–59 y to ≥85 y	4.12**
Polyp detection rate (‰)	< 50 y to 65–69 y	10.18**	65–69 y to ≥85 y	−6.06**
Adenoma detection rate (‰)	< 50 y to 75–79 y	4.59*	75–79y to ≥85 y	−16.86**
Positive predictive value for cancer detection (%)	< 50 y to ≥85 y	16.82**		
Positive predictive value for polyp detection (%)	< 50 y to 60–64 y	4.64**	60–64 y to ≥85 y	−0.15
Positive predictive value for adenoma detection (%)	< 50 y to ≥85 y	−0.04		

PC, percentage change from one age group to the next.
RA, risk assessment; FOBt, fecal occult blood test (colloidal gold); COL, colonoscopy.
** p-Value < 0.001
* p-Value < 0.05.

Table 4
Screening indicators for the Pudong colorectal cancer screening program, by sub-regions, 2013–2016.

	Urban	Suburban	Rural
	(1)	(2)	(3)
Coverage rate (%)**	173.82	75.32	72.16
Participation rate (%)**	20.30	58.80	62.11
FOBt inadequacy rate (%)**	3.15	4.61	0.93
Primary screening positivity rate (%)**	26.99	25.40	18.93
FOBt positivity rate (%)**	15.42	16.01	13.14
RA positivity rate (%)**	14.11	11.81	7.05
Diagnostic COL rate (%)**	5.49	6.97	6.52
Positive primary screening follow-up rate (%)**	20.98	27.98	34.86
Cancer detection rate (‰)*	1.48	1.15	1.07
Positive predictive value for cancer detection (%)**	2.69	1.66	1.64
Polyp detection rate (‰)**	11.82	10.13	11.05
Positive predictive value for polyp detection (%)**	21.53	14.54	16.97
Adenoma detection rate (‰)**	3.06	6.60	8.59
Positive predictive value for adenoma detection (%)**	5.58	9.48	13.18

Notes: Results of Chi-square tests for comparisons across sub-regions were reported in the table. * denotes p-value < 0.05; ** denotes p-value < 0.001. The urban, suburban, and rural areas were classified according to social and economic development levels as suggested in Fig. 2.
Abbreviations: RA (risk assessment), FOBt (fecal occult blood test (colloidal gold)), COL (colonoscopy).

because the number of providers in community health centers who were responsible for the C-CRCSP was similar across sub-regions, but more developed areas were more densely populated (Pruitt et al., 2014; Li et al., 2016; Burnett-Hartman et al., 2016); second, due to the convenience of travel to a hospital where diagnostic COL could be provided in urban areas, people might go for a body check without following the whole workflow of the C-CRCSP and thus might not be observed in the data from the program reporting system (Sun et al., 2015; Lemon et al., 2006).

Our study may have limitations. The availability of the information on the number of polyps, diameter of adenoma and TNM stage of CRC was relatively low, although we asked the physicians in designated hospitals to report this information through the program reporting system. There are three possible reasons. First, the reporting system of the program was designed to be complicated for security reasons so that doctors had to log in to it via a crowded Virtual Private Network in order to input records, which discourages timely reporting. Second, some participants chose to have a diagnostic COL without referral so that their names were not disclosed to us, probably for privacy reasons (Li et al., 2013). Third, some senior participants suffering from memory impairment were unable to provide sufficient information when physicians followed up with them to collect the result after they were screened by diagnostic COL in non-designated hospitals (Day and Velayos, 2015). Such limitations are common in other CRC programs, and we expect that the data quality will improve as informatization advances in the health field in the future.

In conclusion, we investigated the performance of the large community-based CRC screening program implemented in Shanghai Pudong New Area using standard screening measures and indicators with modifications. Participants of the program were followed up across the entire workflow of the program. Data from the program reporting system and monthly progress reports were collected. We also examined the disparities in the quality of the screening by age groups, primary screening results, and geographic areas. The experience and lessons from the Pudong program suggest that allowing individual screening decisions for those aged above the target, incorporating screening with other public health campaigns, using better-developed risk assessment tools are possible practical ways to promote a better delivery of organized CRC screening programs. Our findings yield important policy implications to other developing areas, where CRC screening has just been initiated or has been under consideration.

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Conflict of interest statement

The authors declare no potential conflicts of interest.

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