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Review

Noteworthy impacts of COVID-19 pandemic on cancer screening: A systematic review

Huilin Wang[a,1], Min Yang[b,1], Wei Xiong[c], Quan Wang[d], Bobo Zheng[e], Yang Bai[f], Kaiyong Zou[a], Jibin Li[a], Jiansong Ren[a], Wanqing Chen[a], Jingbo Zhai[g,*], Jiang Li[a,*]

[a] Office for Cancer Screening, National Cancer Center/National Clinical Research Center for Cancer/Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing 100021, China
[b] Department of Comprehensive Intervention, National Cancer Center/National Clinical Research Center for Cancer/Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing 100021, China
[c] Department of Gynecology Endocrine & Reproductive Center, National Clinical Research Center for Obstetric & Gynecologic Diseases Department of Obstetrics and Gynecology, Peking Union Medical College Hospital, Peking Union Medical College/Chinese Academy of Medical Sciences, Beijing 100005, China
[d] Ambulatory Surgery Center of Xijing Hospital, Fourth Military Medical University, Xi'an 710068, China
[e] Department of General Surgery, Shaanxi Provincial People' s Hospital, Xi'an 710068, China
[f] College of Clinical Medicine, Capital Medical University, Beijing 100069, China
[g] School of Public Health, Tianjin University of Traditional Chinese Medicine, Tianjin 301617, China

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ABSTRACT

The sudden onset of the coronavirus disease 2019 (COVID-19) in January 2020 has affected essential global health services. Cancer-screening services that can reduce cancer mortality are strongly affected. However, the specific role of COVID-19 in cancer screening is not fully understood. This study aimed to assess the efficiency of global cancer screening programs before and during the COVID-19 pandemic and to promote potential cancer-screening strategies for the next pandemic. Electronic searches in PubMed, Embase, and Web of Science, and manual searches were performed between January 1, 2020 and March 1, 2023. Cohort studies that reported the number of participants who underwent cancer screening before and during the COVID-19 pandemic were included. The methodological quality of the included studies was assessed using the Newcastle-Ottawa Scale. Differences in cancer-screening rates were estimated using the incidence rate ratio (IRR). Fifty-five cohort studies were included in this meta-analysis. The screening rates of colorectal cancer using invasive screening methods (Pooled IRR = 0.52, 95% CI: 0.42 to 0.65, $p < 0.01$), cervical cancer (Pooled IRR = 0.56, 95% CI: 0.47 to 0.67, $p < 0.01$), breast cancer (Pooled IRR = 0.57, 95% CI: 0.49 to 0.66, $p < 0.01$) and prostate cancer (Pooled IRR = 0.71, 95% CI: 0.56 to 0.90, $p < 0.01$) during the COVID-19 pandemic were significantly lower than those before the COVID-19 pandemic. The screening rates of lung cancer (Pooled IRR = 0.77, 95% CI: 0.58 to 1.03, $p = 0.08$) and colorectal cancer using noninvasive screening methods (Pooled IRR = 0.74, 95% CI: 0.50 to 1.09, $p = 0.13$) were reduced with no statistical differences. The subgroup analyses revealed that the reduction in cancer-screening rates varied across economies. Our results suggest that the COVID-19 pandemic has had a noteworthy impact on colorectal, cervical, breast, and prostate cancer screening. Developing innovative cancer-screening technologies is important to promote the efficiency of cancer-screening services in the post-COVID-19 era and prepare for the next pandemic.

1. Introduction

The sudden occurrence of the coronavirus disease 2019 (COVID-19) pandemic in January 2020 has had a significant impact on global health systems [1]. Given its global spread, the World Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020 [2]. In August 2020, the WHO released its first interim report of the Pulse Survey on Continuity of Essential Health Services during the COVID-19 pandemic, which showed that essential health services had been affected in 90% of the countries worldwide since the outbreak of COVID-19 [3]. Multiple routine and non-urgent services have been suspended in most countries to preserve available resources and prevent the transmission of COVID-19 [4].

Cancer is the first or second leading cause of death before the age of 70 years in most countries [5]. Cancer screening can reduce mortality from cancers such as lung, breast, and colorectal cancer [6–8].

* Corresponding authors.
E-mail addresses: zhaijingbo@foxmail.com (J. Zhai), lij@cicams.ac.cn (J. Li).
[1] These authors contributed equally to this work.

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The COVID-19 pandemic may have had an important impact on cancer screening [9]. In March 2020, the National Health Service Scotland announced the suspension of cervical, bowel, and breast cancer screening programs [10]. On April 3, 2020, the British Society of Gastroenterology recommended stopping all non-emergency and non-essential endoscopy services [11]. Subsequently, the frequency of colonoscopies in April 2020 decreased by 92% in England compared with the monthly average in 2019 [12]. The absolute deficit of cancer screening related to the COVID-19 pandemic in the United States was approximately 3.9 million for breast cancer, 3.8 million for colorectal cancer, and 1.6 million for prostate cancer [13]. The lockdown caused a sharp decline in the number of requests for prostate cancer screening during the COVID-19 outbreak in Verona, Italy [14].

The fourth Round of the Global Pulse Survey on Continuity of Essential Health Services during the COVID-19 Pandemic, published by the WHO in May 2023, showed that more than 50% countries still reported increased backlogs across many tracer non-communicable diseases services compared to 2021, especially the screening, diagnosis and treatment of cancers [15]. Although some countries or regions have adjusted restrictions and resumed screening services according to the temporal pandemic trends, their impact on cancer screening is not fully understood [16]. Consequently, this scenario is not conducive for formulating effective strategies to reduce the impact of the COVID-19 pandemic on cancer screening.

The present systematic review aimed to assess the changes in the efficiency of global cancer screening programs before and during the COVID-19 pandemic and explore the potential impacts of COVID-19 pandemic on cancer screening.

2. Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [17]. It was registered with PROSPERO (No: CRD42022321069).

2.1. Eligibility criteria

The inclusion and exclusion criteria were developed based on the Population, Intervention, Comparison, Outcomes and Study principles. Cohort studies assessing the impacts of COVID-19 on cancer screening were included. The number of individuals screened during and before the COVID-19 pandemic should be reported for a specific period as well as the data sources. The cancer type, age, sex, race, country, and sample size of the included studies were unrestricted.

2.2. Search strategy

PubMed, Embase, and Web of Science were searched independently from January 1, 2020, to March 1, 2023, by two authors. They manually reviewed the list of references for all included studies and relevant reviews to identify other studies. The authors of the original articles were contacted to obtain the required information, if necessary. Medical subject headings combined with free words were used to identify potentially eligible studies regardless of language. The search terms included "early detection of cancer", "cancer screening", "cancer early detection", "cancer screening tests", "early diagnosis of cancer", "cancer early diagnosis", "COVID-19", "SARS CoV 2 infection", "COVID 19 virus disease", "Coronavirus Disease 19", and "2019-nCoV". The detailed search strategy is listed in Table S1–3. Any disagreements were resolved through consultation with a third author.

2.3. Study screening

The studies obtained through the comprehensive search were imported into the Endnote X9 software. Duplicate studies were removed and unqualified studies were excluded according to the inclusion and exclusion criteria. The full texts of the remaining studies were further screened. The process of screening eligible studies was presented in a PRISMA flow chart. Two authors independently screened the selected studies. Disagreements were resolved by consultation with a third author.

2.4. Data collection

A form was prepared to collect the information. Before formally collecting data, the consistency of the data collected by the two authors was evaluated. Collected information included the first author, study site, data source, screening methods, screening events, and length of the screening period before and during the COVID-19 pandemic. Two investigators independently extracted the data and encoded into Excel 2010 software. Any disagreements were resolved through discussion or consultation with a third author.

2.5. Quality assessment

The methodological quality of the included studies was assessed using the Newcastle-Ottawa Scale (NOS). NOS is a tool to assess the methodological quality of non-randomized studies and includes three domains (selection, comparability and outcome) and eight specific items. The level of methodological quality is expressed as 1 to 9 stars. More stars indicate higher methodological quality [18]. Studies with scores (stars) ≥ 7 were considered to have high methodological quality [19]. No studies were excluded owing to low methodological quality. The effects of low methodological quality on the results were assessed using sensitivity analysis, where possible.

2.6. Statistical analysis

The cancer screening rate refers to the number of screened participants within a time interval. The difference in cancer screening rates before and during the COVID-19 pandemic was estimated using incidence rate ratio (IRR). IRR refers to the ratio of the two incidence rates. It is often used to compare the difference in the number of cases per unit person-time between two groups [20]. IRR < 1 indicates that the screening rate during the COVID-19 pandemic was reduced compared to that before the COVID-19 pandemic. The pooled IRR was estimated using the metainc function of meta-package in R Studio software, version 4.2.1. Statistical heterogeneity across the included studies was assessed using the chi-square test and I^2 statistic. A meta-analysis with a fixed-effect model was used to estimate the pooled IRR when $p > 0.10$ and $I^2 < 50\%$. Otherwise, meta-analysis with a random-effect model was used. The global economies were divided into two major groups: advanced economies, and emerging market and developing economies, according to the World Economic Outlook published in 2022 by the International Monetary Fund [21]. Subgroup analyses were conducted to investigate the differences in cancer screening rates between the two economies before and during the COVID-19 pandemic. For sensitivity analysis, a leave-one-out analysis was conducted to assess the stability and reliability of the results. The Egger's test was used to evaluate publication bias.

3. Results

3.1. Selection of literature

Five thousand seven hundred and thirty-one articles were identified from the electronic databases, and two articles were manually included. Of which, 1193 duplicates were excluded using Endnote X9 software and 4396 ineligible articles were deleted according to the inclusion and exclusion criteria. The full texts of the remaining 144 studies were checked. Overall, 55 studies were included in the final analysis (Fig. 1).

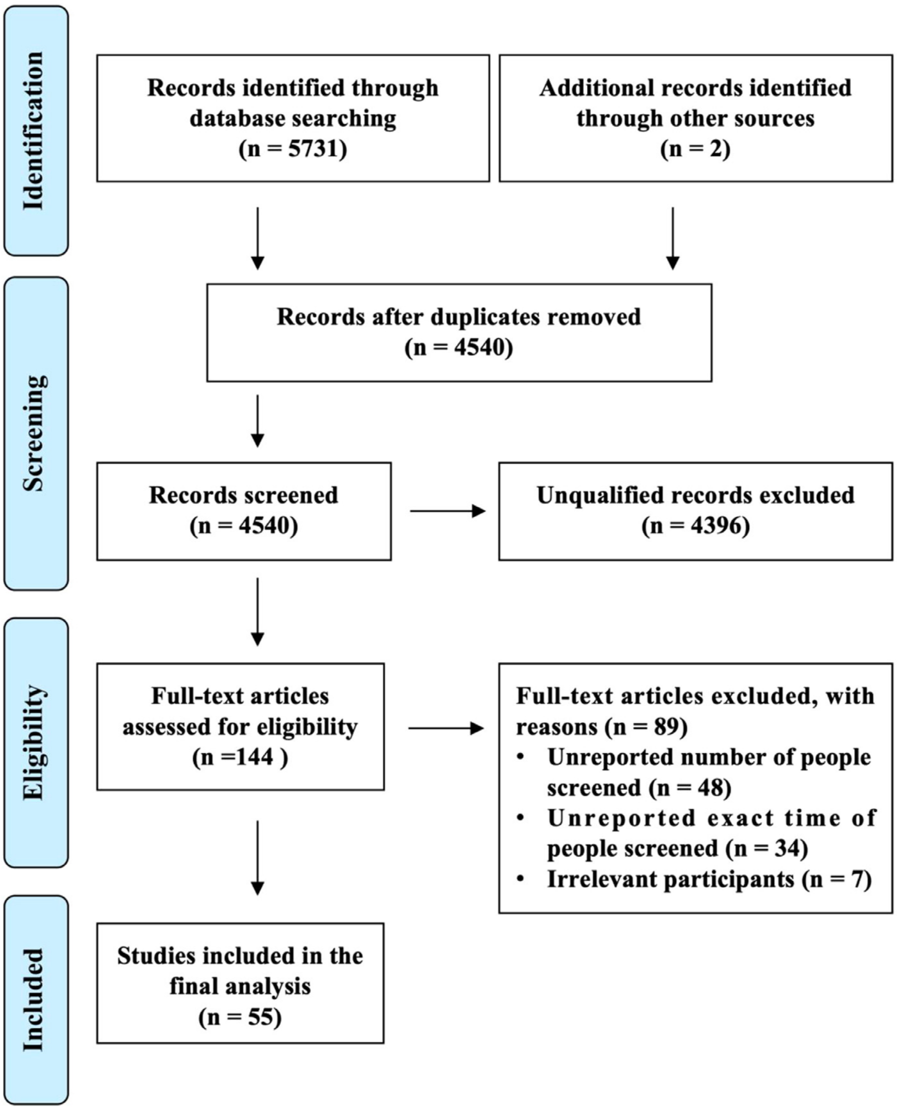

Fig. 1. PRISMA flow diagram of screening studies.

3.2. Characteristics of the included studies

The characteristics of the included studies are presented in Table 1. Of the 55 included cohort studies, eight were published in 2020, 23 in 2021, 22 in 2022, and two in 2023. Twenty-one studies were conducted in the United States; seven in China; four in Canada; three each in Italy, Brazil, and France; two each in Spain and Australia; and one each in the Netherlands, Austria, Turkey, Argentina, Slovenia, the United Kingdom, Lithuania, Korea, Romania, and Pakistan. Colorectal cancer screening was reported in 26 studies, cervical cancer screening in 18, breast cancer screening in 31, prostate cancer screening in six, lung cancer screening in five, and oral cancer screening in two.

3.3. Assessment of the methodological quality

The NOS scores of all included studies were ≥ 7, as shown in Table S4. All data in the included studies were extracted from electronic medical records, public health databases, and healthcare systems. Full scores were awarded in the selection and outcome domains for all included studies because they met the scoring criteria. Three studies [35,52,66] scored 2 points because of the control of the most and second-most important factors. Seven studies [31,32,36,39,58,65,74] scored 1 point because of statistical differences in the most or second-most important factors. Forty-five studies [22-30,33,34,37,38,40-51,53-57,59-64,67-73,75,76] scored 0 point in view of the lack of control over the most or second-most important factors in the comparability domain.

3.4. Meta-analysis

3.4.1. Meta-analysis of cancer screening rate

The screening methods for colorectal cancer can be divided into two categories: invasive and noninvasive screening. Invasive screening methods mainly refer to colonoscopy and gastrointestinal endoscopy, whereas noninvasive screening methods mainly include stool-based screening methods such as FIT and FOBT. The cancer screening rate using noninvasive screening methods during the COVID-19 pandemic was reduced with no significantly difference (Pooled IRR = 0.74, 95% CI: 0.50 to 1.09, p = 0.13, Fig. 2). The cancer screening rate using invasive screening methods during the COVID-19 pandemic was significantly lower than that before the COVID-19 pandemic (Pooled IRR = 0.52, 95% CI: 0.42 to 0.65, $p < 0.01$, Fig. 3). Similar results were found in cervical cancer (Pooled IRR = 0.56, 95% CI: 0.47 to 0.67, $p < 0.01$, Fig. 4), breast cancer (Pooled IRR = 0.57, 95% CI: 0.49 to 0.66, $p < 0.01$, Fig. 5) and prostate cancer (Pooled IRR = 0.71, 95% CI: 0.56 to 0.90, $p < 0.01$, Fig. 6). In sensitivity analyses, no significant changes in the pooled IRR

Table 1
Characteristics of included studies.

Author, year	Country, data source	Cancer, screening methods	Screening period before the COVID-19 (days)	Screening period during the COVID-19 (days)	References
Song, 2023	China, Shanghai General Hospital	Cervical cancer, HPV or TCT	365	366	[22]
Milgrom, 2023	US, Indiana Network for Patient Care	Breast cancer, Mammography	272	272	[23]
Carroll, 2022	US, health information exchange	Colorectal cancer, stool tests or colonoscopy Cervical cancer, PAP or HPV Breast cancer, Mammography Lung cancer, LDCT Prostate cancer, PSA	453	38	[24]
Walker, 2022	Canada, provincial health administrative databases	Colorectal cancer, FOBT or FIT Cervical cancer, Cervical cytology test Breast cancer, Mammography Lung cancer, LDCT	365	364	[25]
Shen, 2022	China, Taiwan, cancer screening registry	Colorectal cancer, FIT Cervical cancer, PAP Breast cancer, Mammography Oral cancer, oral mucosal examination	119	120	[26]
Battisti, 2022	Italy, National Centre for Screening Monitoring	Colorectal cancer, Colonoscopy or FIT Cervical cancer, PAP or HPV Breast cancer, Mammography	365	366	[27]
Amram, 2022	US, Healthcare System	Colorectal cancer, Colonoscopy Cervical cancer, PAP	365	364	[28]
Benjamin, 2022	France, administrative healthcare database	Colorectal cancer, FOBT Cervical, HPV or cytopathology	365	366	[29]
Laurent, 2022	France, regional screening center	Colorectal cancer, FIT Breast cancer, Mammography	365	366	[30]
Lee, 2022	US, electronic medical record	Colorectal cancer, FIT and Colonoscopy	182	182	[31]
Gangcuangco, 2022	US, electronic medical record	Colorectal cancer, stool tests and colonoscopy	365	366	[32]
Bright, 2022	United Kingdom, national trusted research	Colorectal cancer, FIT	273	272	[33]
Nwankwo, 2022	US, electronic health records	Colon cancer, Colonoscopy	366	365	[34]
Choy, 2022	US, electronic health records	Colorectal cancer, Colonoscopy	113	113	[35]
Holland, 2022	Canada, Academic Tertiary-Care Center	Colorectal cancer, Colonoscopy	183	183	[36]
Vives, 2022	Spain, Information System for Monitoring Colorectal Cancer Screening	Colorectal cancer, FIT and Colonoscopy	89	90	[37]
Ribeiro, 2022	Brazil, Hospital and Cancer Information System	Cervical cancer, PAP Breast cancer, Mammography	365	366	[38]
Popescu, 2022	Romania, administrative database	Cervical cancer, PAP	730	731	[39]
Grimm, 2022	US, National Mammography Database	Breast cancer, Mammography	91	182	[40]
Bessa, 2022	Brazil, an open access database	Breast cancer, Mammography	365	366	[41]
Bosch, 2022	Spain, multicenter database	Breast cancer, Mammography	365	366	[42]
Lehman, 2022	US, electronic medical records	Breast cancer, Mammography	61	61	[43]
Hyeda, 2022	Brazil, Public Health System	Breast cancer, Mammography	365	366	[44]
Siyez, 2022	Turkey, hospital database	Prostate cancer, PSA	365	366	[45]
Labaki, 2021	US, healthcare system	Colorectal cancer, Colonoscopy Cervical cancer, PAP Breast cancer, Mammography Lung cancer, LDCT Prostate cancer, PSA	366	278	[46]
Degani, 2021	Argentina, National Screening Information System	Colorectal cancer, FOBT Cervical cancer, PAP Breast cancer, Mammography	184	184	[47]
Walker, 2021	Canada, provincial health databases	Colorectal cancer, Colonoscopy or FIT Cervical cancer, PAP Breast cancer, Mammography or Magnetic Resonance Imaging	305	305	[48]
Dabkeviciene, 2021	Lithuania, Hospital Information System and the National Health Insurance Fund	Colorectal cancer, Colonoscopy Breast cancer, Mammography Prostate cancer, PSA	333	334	[49]
Hinterberger, 2021	Austria, database of national screening program	Colorectal cancer, Colonoscopy	184	184	[50]
Chirayath, 2021	US, endoscopy suite	Colorectal cancer, Colonoscopy	29	29	[51]
D'Ovidio, 2021	Italy, database of the hospital	Colorectal cancer, Colonoscopy	56	56	[52]
Lantinga, 2021	Netherlands, multicenter database	Colorectal cancer, Gastrointestinal Endoscopy	61	61	[53]
Challine, 2021	France, national database	Colorectal cancer, Colonoscopy	365	366	[54]
DeGroff, 2021	US, U.S. Centers for Disease Control and Prevention	Cervical cancer, PAP or HPV Breast cancer, Mammography	60	60	[55]
Ivanuš, 2021	Slovenia, cancer screening registry database	Cervical cancer, PAP	202	202	[56]
Martellucci, 2021	Italy, database of the hospital	Cervical cancer, PAP	180	181	[57]
Miller, 2021	US, Southern California, Integrated Health Care System	Cervical cancer, PAP or HPV	84	84	[58]
Kang, 2021	Korea, medical records	Breast cancer, Mammography	180	181	[59]
Chiarelli, 2021	Canada, Integrated Client Management System	Breast cancer, Mammography	424	91	[60]

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country, data source	Cancer, screening methods	Screening period before the COVID-19 (days)	Screening period during the COVID-19 (days)	References
Amram, 2021	US, community health care system	Breast cancer, Mammography	274	274	[61]
Miller, 2021	US, electronic health records	Breast cancer, Mammography	331	332	[62]
Velazquez, 2021	US, electronic health records	Breast cancer, Mammography	31	31	[63]
Sprague, 2021	US, breast imaging registries	Breast cancer, Mammography	211	212	[64]
Nyante, 2021	US, Health system	Breast cancer, Mammography	426	211	[65]
Walker, 2021	Canada, provincial health database	Lung cancer, LDCT	274	274	[48]
Henderson, 2021	US, multiple screening centers	Lung cancer, LDCT	398	212	[66]
Ahmed, 2021	Pakistan, multiple databases	Prostate cancer, PSA	365	365	[67]
Christopher, 2021	Australia, item Reports	Prostate cancer, PSA	365	366	[68]
Gorin, 2020	US, Michigan Medicine	Colorectal cancer, Colonoscopy Cervical cancer, PAP or HPV testing Breast cancer, Mammography	51	51	[69]
Tsai, 2020	China, Taiwan, Kaohsiung City Community Hospital	Colorectal cancer, FOBT Cervical cancer, PAP Breast cancer, Mammography Oral cancer, oral mucosal examination	58	59	[70]
Cheng, 2020	China, National Taiwan University Hospital	Colorectal cancer, FIT	150	151	[71]
Peng, 2020	China, Taiwan, multiple databases	Breast cancer, Mammography	150	151	[72]
Tsai, 2020	China, Taiwan, cancer screening database	Breast cancer, Mammography	119	120	[73]
Song, 2020	US, medical claims	Breast cancer, Mammography	799	139	[74]
Chou, 2020	China, Taiwan, academic medical center	Breast cancer, Mammography	154	154	[75]
Sutherland, 2020	Australia, New South Wales, multiple databases	Breast cancer, Mammography	121	121	[76]

HPV, human papillomavirus; TCT, thinprep cytologic test; PAP, papanicolaou smear test; LDCT, low-dose computed tomography; PSA, prostate specific antigen testing; FOBT, fecal occult blood test; FIT, fecal immunochemical test.

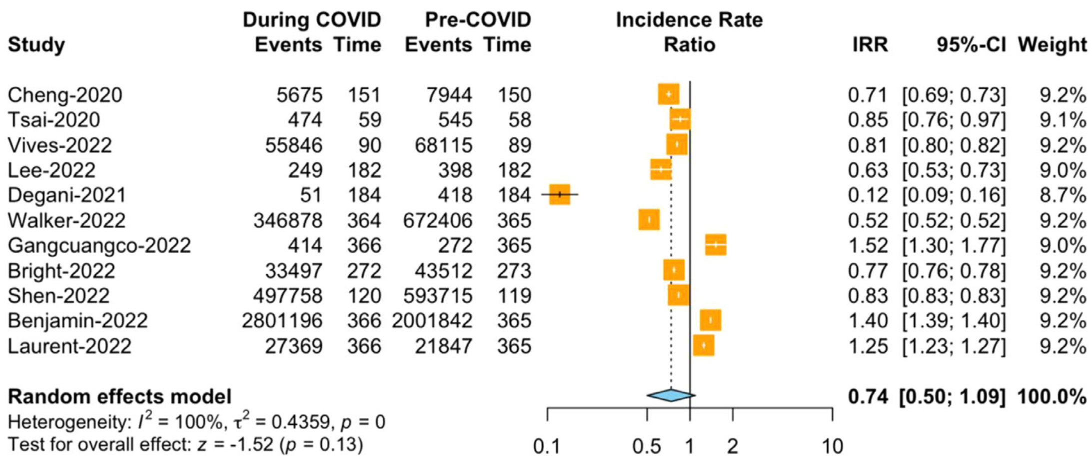

Fig. 2. Forest plot of the pooled incidence rate ratio on colorectal cancer screening via noninvasive screening methods.

were observed after omitting any of the included studies (Figs. S1–S5). Gorin et al. found [69] the screening rates of colorectal, cervical, and breast cancers during the COVID-19 pandemic were significantly lower than those before the COVID-19 pandemic, and these extreme values were excluded from the meta-analysis according to a previous study [77].

In addition, the lung cancer screening rate was reduced with no statistical differences (Pooled IRR = 0.77, 95% CI: 0.58 to 1.03, p = 0.08, Fig. 7). However, a statistically significant reduction in the lung cancer screening rate was identified after excluding one study [24] from the sensitivity analysis (Fig. S6).

3.4.2. Subgroup analyses based on advanced economies and emerging market and developing economies

The decline in cervical cancer screening rate in advanced economies was 43% (Pooled IRR = 0.57, 95% CI: 0.46 to 0.72, p < 0.01, Fig. 8). Meanwhile, the decline in cervical cancer screening rate in emerging market and developing economies was 47% (Pooled IRR = 0.53, 95% CI: 0.46 to 0.61, p < 0.01, Fig. 8).

The decline in breast cancer screening rate in advanced economies was 41% (Pooled IRR = 0.59, 95% CI: 0.50 to 0.68, p < 0.01, Fig. 9). Meanwhile, the decline in breast cancer screening rate in emerging market and developing economies was 55% (Pooled IRR = 0.45, 95% CI: 0.28 to 0.75, p < 0.01, Fig. 9).

In addition, the decline in prostate cancer screening rate in advanced economies was 29% (Pooled IRR = 0.71, 95% CI: 0.51 to 0.98, p = 0.04, Fig. 10). The screening rate of prostate cancer in emerging market and developing economies (Pooled IRR = 0.72, 95% CI: 0.44 to 1.15, p = 0.17, Fig. 10) was reduced with no statistical significance.

In the sensitivity analyses of cervical and breast cancers, no significant changes in the pooled IRR were found after omitting any of the included studies in the economic subgroup (Figs. S7–S10). The results of the sensitivity analyses for prostate cancer were not robust in any economy subgroups (Figs. S11–S12).

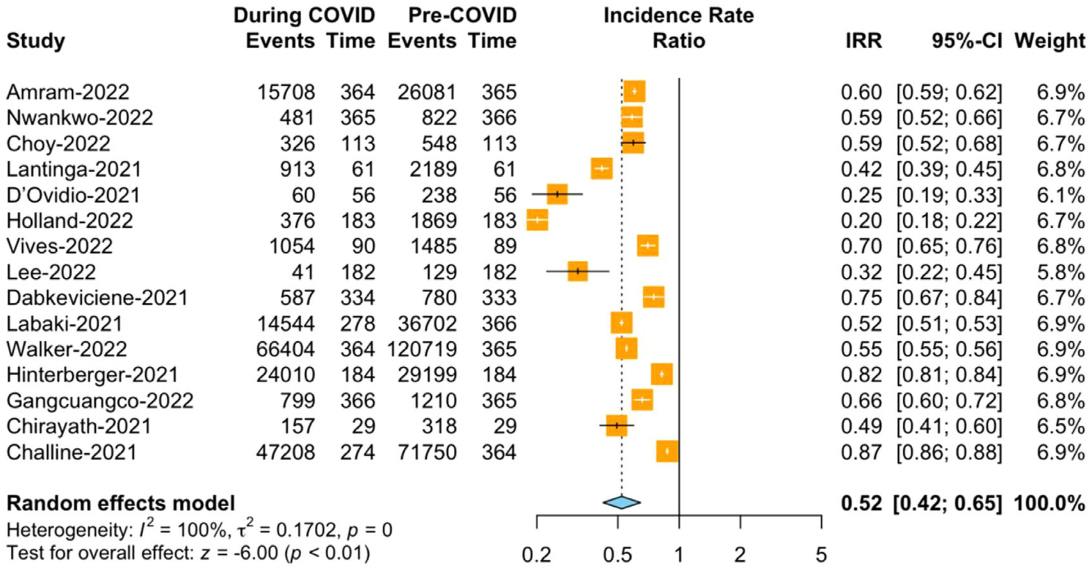

Fig. 3. Forest plot of the pooled incidence rate ratio on colorectal cancer screening via invasive screening methods.

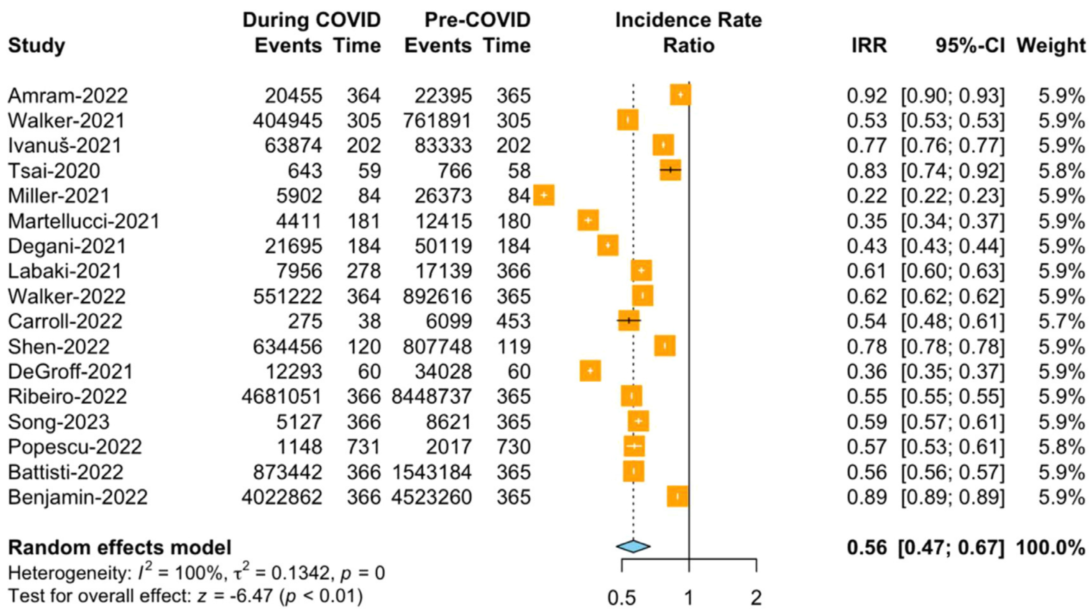

Fig. 4. Forest plot of the pooled incidence rate ratio on cervical cancer screening.

3.5. Publication bias

Because articles on lung and prostate cancer screening were too limited in number to complete the Egger's test, no publication bias analysis was conducted. The Egger's test was conducted for noninvasive colorectal cancer (p = 0.3354), invasive colorectal cancer (p = 0.5425), cervical cancer (p = 0.6977), and breast cancer screening (p = 0.9208), and no significant publication bias was found.

4. Discussion

This study evaluated the effects of the COVID-19 pandemic on the efficiency of global cancer screening. The screening rates of invasive screening methods for colorectal, cervical, breast, and prostate cancers decreased by 48% (Pooled IRR = 0.52), 44% (Pooled IRR = 0.56), 43% (Pooled IRR = 0.57) and 29% (Pooled IRR = 0.71), respectively, during the COVID-19 pandemic, and showed statistical significance. However, the screening rates for lung and colorectal cancers using noninvasive screening methods did not decrease significantly. The reduction in cancer screening rates may vary across economies. Our results revealed a greater reduction in cervical and breast cancer screening rates in emerging and developing economies than in advanced economies.

COVID-19 mainly infects the lungs, eventually leading to acute respiratory distress syndrome and lung failure [78]. A previous review did not report changes in the lung cancer screening rate during the COVID-19 pandemic [77]. Our pooled results from five studies showed that the lung cancer screening rate did not decrease significantly during the COVID-19 pandemic. LDCT is one of the main methods used for lung cancer screening [79]. The COVID-19 pandemic has heightened the likelihood of individuals undergoing chest CT scans, leading to an upsurge in opportunistic lung cancer screening. The increased use of chest CT offers a unique opportunity for early detection, potentially enhancing the

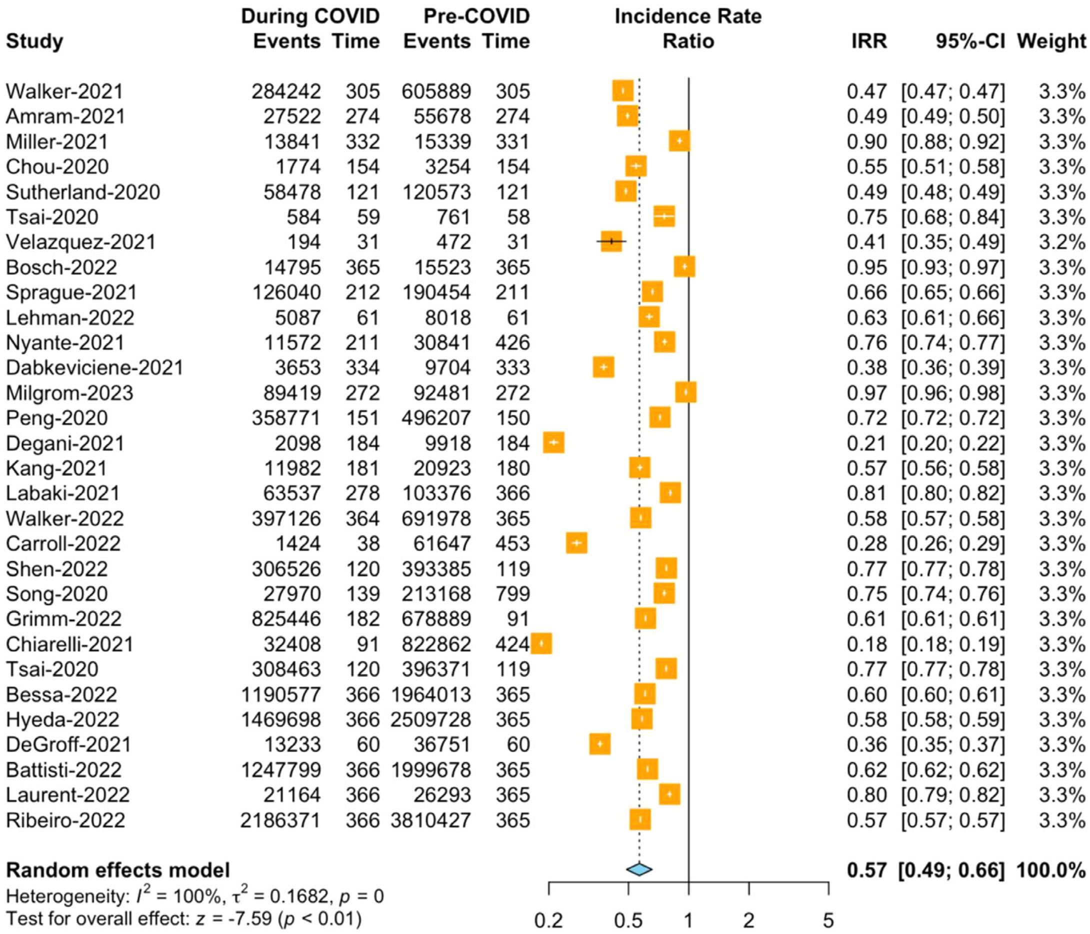

Fig. 5. Forest plot of the pooled incidence rate ratio on breast cancer screening.

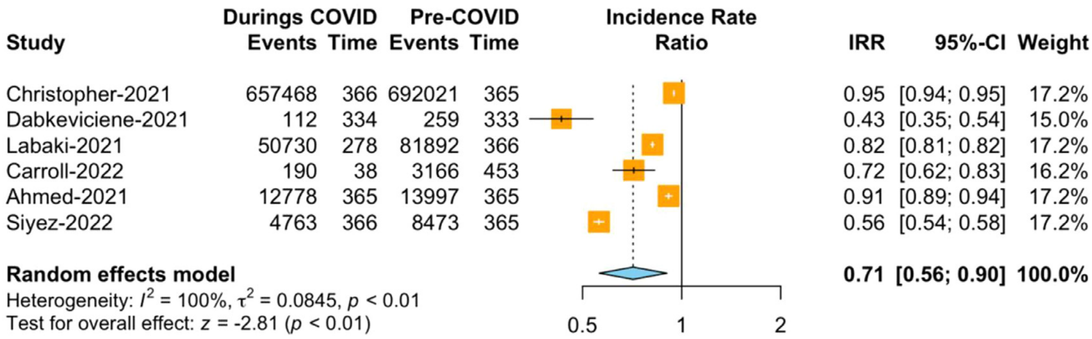

Fig. 6. Forest plot of the pooled incidence rate ratio on prostate cancer screening.

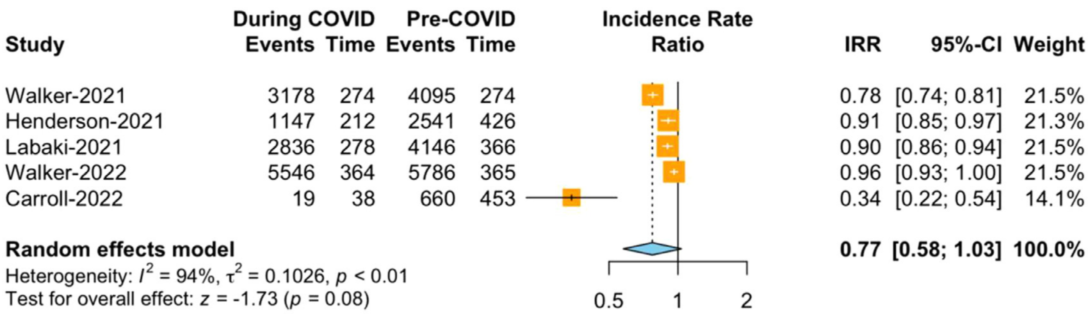

Fig. 7. Forest plot of the pooled incidence rate ratio on lung cancer screening.

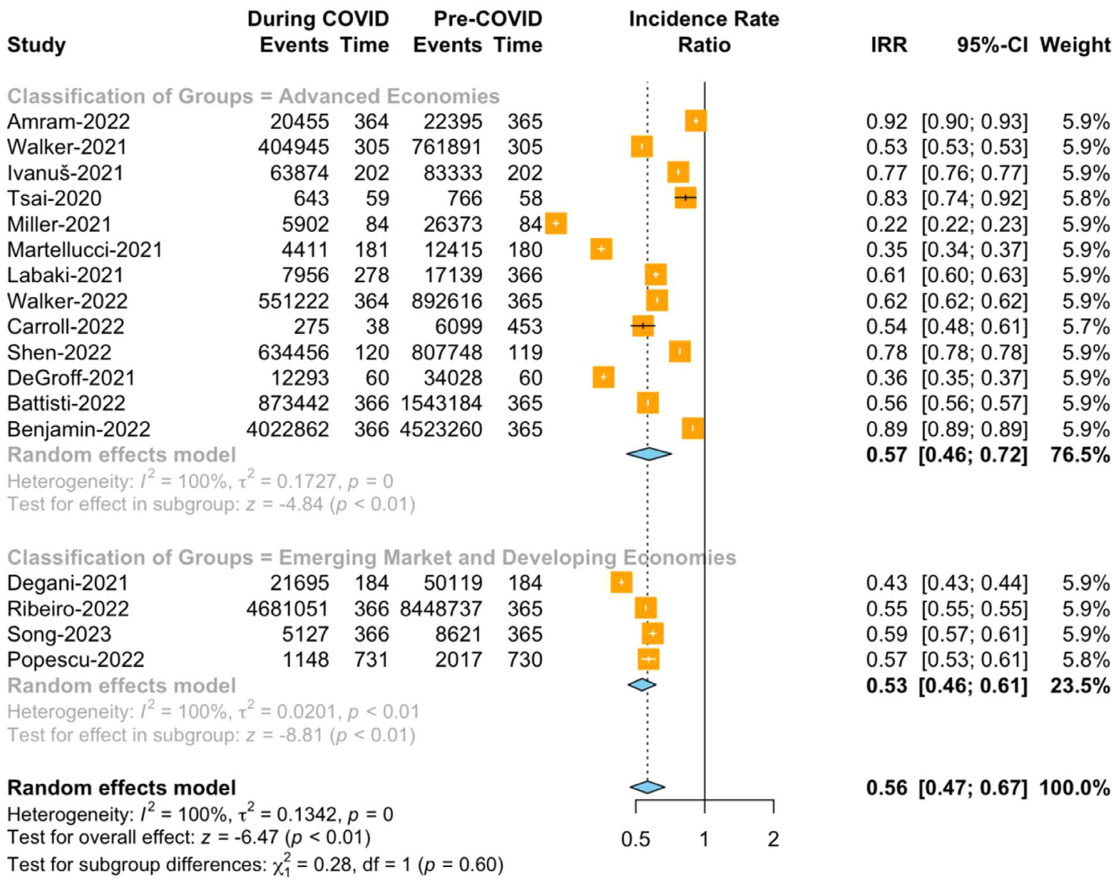

Fig. 8. Subgroup analysis of cervical cancer screening rate based on different economies.

effectiveness of lung cancer screening initiatives [80]. Sensitivity analysis showed that lung cancer screening decreased significantly during the COVID-19 pandemic, after excluding one study [24]. The number of cancer screening days during the COVID-19 pandemic was considerably shorter than before the COVID-19 pandemic in the excluded study [24]. This may be the reason for the instability in the sensitivity analysis.

Our results show that the reduction in the breast cancer screening rate (point estimate of pooled IRR = 0.57) during the COVID-19 pandemic was similar to that reported by Mayo et al. (point estimate of pooled IRR = 0.63) in 2021 [77]. They found that the pooled screening rates for both colon and cervical cancers decreased by approximately 90% during the COVID-19 pandemic. However, our meta-analysis involving more studies found that the screening rates of colorectal cancer using invasive screening methods (point estimate of pooled IRR = 0.52) and cervical cancer (point estimate of pooled IRR = 0.56) decreased by approximately 50% during the COVID-19 pandemic. These changes may be related to the adjustment and implementation of preventive and control policies.

The impact of the COVID-19 pandemic on cancer screening may vary depending on the screening method and the economic level. Most cancer screening procedures in hospitals rely on medical equipment, such as B-ultrasound for breast cancer screening and colonoscopy for colorectal cancer screening. Because of lockdowns and concerns about fecal-oral transmission of COVID-19, the screening methods for prostate cancer might be adjusted from digital rectal examination (DRE) to prostate-specific antigen (PSA) testing [81]. All cancer screening studies used PSA measurements. One study found that it was feasible to screen for colorectal cancer using fecal immunochemical tests and multitarget stool DNA tests at home when hospital visits were restricted [69]. Our results also showed that during the COVID-19 pandemic, the screening rate based on invasive screening methods, such as colonoscopy, which required hospital visits significantly decreased, while the screening rate based on stool-based screening methods did not significantly decrease. *Helicobacter pylori* infection is one of the main risk factors for gastric cancer. Many types of *Helicobacter pylori* antibody detection kits on the market have high sensitivity and specificity and may meet the requirement of self-testing at home [82]. Breast self-examination and clinical breast examination play important roles in the early detection of breast cancer [83]. The above-mentioned evidence indicates that cancer screening at home may be an alternative approach to hospital visits for some cancers during an infectious disease pandemic. Our study found that cervical and breast cancer screening in emerging markets and developing economies was more seriously affected than that in advanced economies during the COVID-19 pandemic. This is consistent with the relative scarcity of medical resources in emerging market and developing economies.

Some public health specialists have pointed out that the pandemic provides an opportunity to transform and improve cancer screening services through innovation [16,84,10]. In light of the COVID-19 pandemic, 80%–85% of clinical consultations have been conducted through telehealth [85]. Tele-mammography has been demonstrated to be a cost-effective breast cancer screening approach [86]. Social media and mHealth technologies play a role in recalling delayed and missing cancer detections [87]. It is advisable to broaden the use of telehealth in cancer screening and establish an administrative system before the next pandemic.

This study had some limitations that should be considered before drawing any conclusions. First, the heterogeneity of meta-analyses may have been caused by some factors such as different population and the level of COVID-19 transmission, which were not considered in our statistical analysis. Second, no additional subgroup analyses were conducted because of insufficient information.

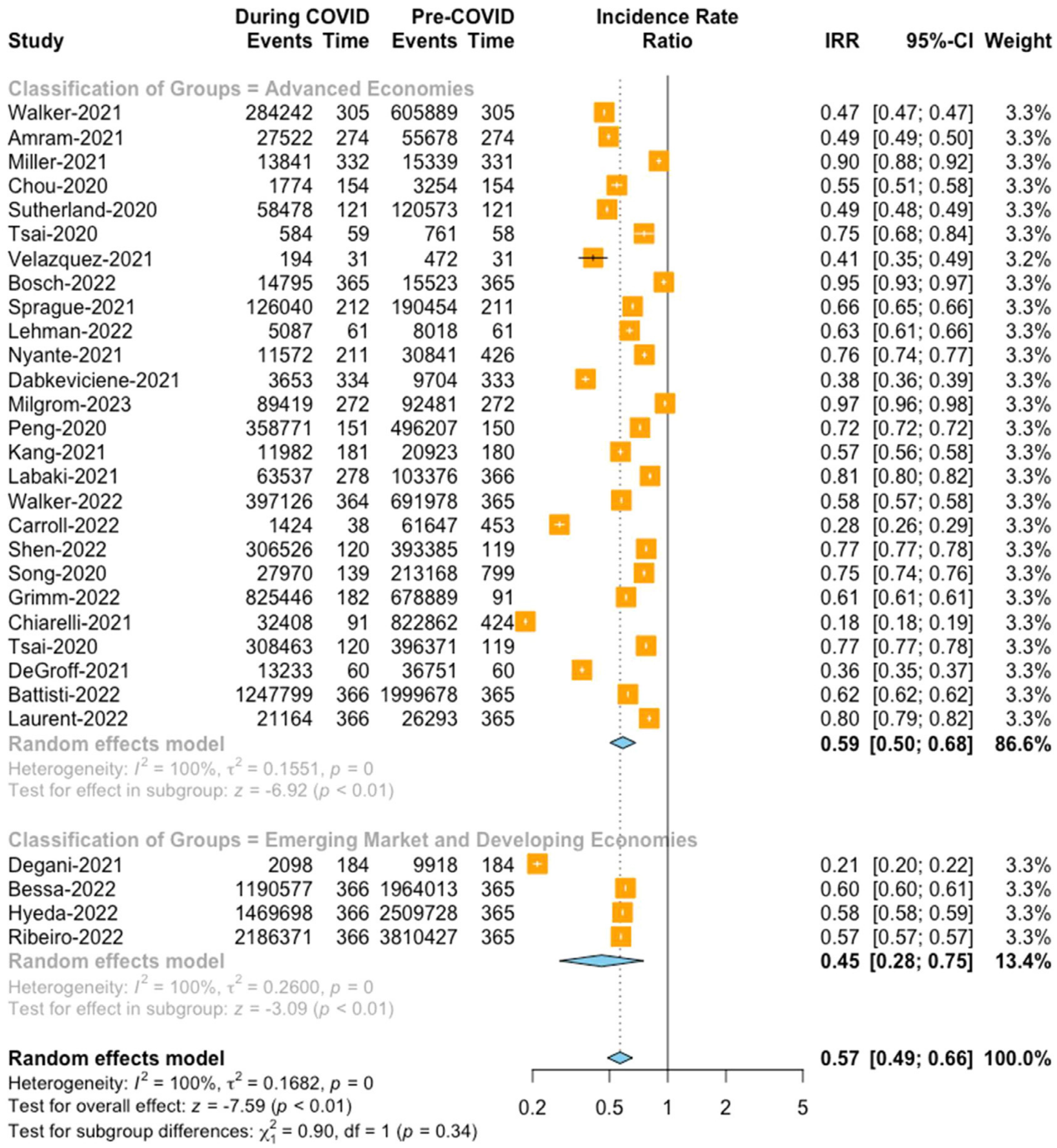

Fig. 9. Subgroup analysis of breast cancer screening rate based on different economies.

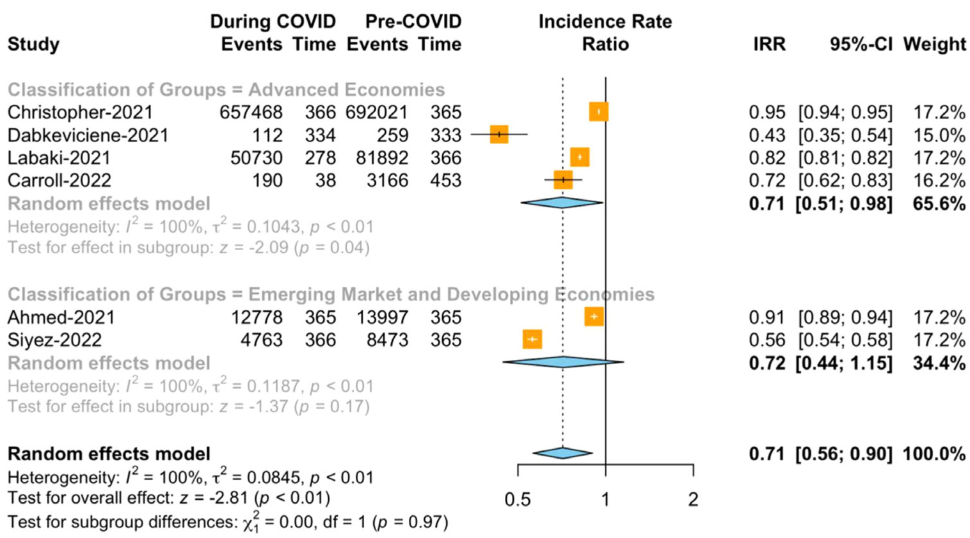

Fig. 10. Subgroup analysis of prostate cancer screening rate based on different economies.

5. Conclusion

Our results suggest that the COVID-19 pandemic has had a noteworthy impact on colorectal, cervical, breast, and prostate cancer screening. Developing innovative cancer-screening technologies are important to promote the efficiency of cancer-screening services in the post-COVID-19 era and prepare for the next pandemic.

Declaration of competing interest

The authors declare that they have no conflicts of interest in this work.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.fmre.2023.12.016.

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Huilin Wang received the bachelor's degree from Capital Medical University in 2022. She is currently pursuing the MPH degree with Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College.

Jiang Li (BRID: 05672.00.82092) received her Ph.D. in clinical medicine from Lanzhou University in 2015. She has been working in Office for Cancer Screening in Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College since 2015 and was employed as an associate research fellow in 2019. Her research interests included cancer epidemiology and prediction model technology. She has published more than 100 articles which were supported by programs from National Natural Science Foundation of China and Beijing Nova Program from Beijing Municipal Science & Technology Commission, etc.