RESEARCH ARTICLE

Editorial Process: Submission:08/01/2021 Acceptance:04/15/2022

Geographic Characteristics of Various Cancers in Yogyakarta Province, Indonesia: A Spatial Analysis at the Community Level

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Abstract

Background: Cancer remains a significant public health problem in Indonesia and worldwide. Yogyakarta Province has the largest number of cancer cases in Indonesia. Maps of the distribution of cancer cases are useful tools for stratification of cancer risk and for selective prevention strategies. The aim of this study was to determine the spatial distribution of cancer cases in Yogyakarta Province. **Methods:** Cancer patient data registered by the Yogyakarta Provincial Health Office during 2019-2020 were analysed in this study (n=9,933). To evaluate cancer pattern distributions, ArcGIS 10.2 and Excel 2016 software were used. **Results:** The mean participant age (± standard deviation) was 55.08 ± 15.46 years, and 79.40% were female. Breast and cervical cancer were the most frequently diagnosed, and the majority of patients were located in Sleman district. The incidence of all cancer types varied by county-level. The majority of cancer patients lived below the poverty line. Cancer screening rates were low, and screening was limited to breast and cervical cancer. **Conclusion:** Various types of cancers were identified in Yogyakarta, Indonesia; of them, breast and cervical cancer predominated. Most of the cancer patients were from Sleman district and economically poor areas. Geospatial techniques are useful for identifying environmental factors related to cancer and improving cancer control strategies and resource allocation.

Keywords: Epidemiology- cancer- Indonesia- spatial- geographic information system

Asian Pac J Cancer Prev, **23 (4)**, 1231-1238

Introduction

Non-communicable diseases (NCDs), such as heart disease, stroke, cancer, diabetes, and chronic lung disease, account for more than 70% of deaths globally. Based on data from the World Health Organization (WHO) in 2021, more than 15 million people aged 30-69 years have died because of NCDs. According to mortality data, cancer is the second most common cause of death worldwide, accounting for 9.3 million deaths, of which more than half occur in Asia (Bray et al., 2018; Sung et al., 2020) and in developing countries (Bellanger et al., 2018; Rivera-Franco and Leon-Rodriguez, 2018). In Indonesia, cancer is the third most common NCD after cardiovascular diseases and maternal, perinatal, and nutritional conditions. Data from the Indonesian Ministry of Health in 2021 indicated that breast cancer (42.1 per 100,000 population, with a mortality rate of 17 per 100,000 population) and cervical cancer (23.4 per 100,000 population, with a mortality rate of 13.9 per 100,000 population) account for the majority of cancers registered in the country (Gondhowiardjo et al., 2021). Early diagnosis of cancer through cancer screening improves treatment opportunities and reduces mortality (Seely and Alhassan, 2018; Pastorino et al., 2019) and has been shown to increase life expectancy in cancer patients (Allemani et al., 2015). However, routine cancer screening, as recommended by the WHO, is rarely performed in Indonesia. The reason is similar to that in other developing countries; resources needed for cancer screening programmes, such as mammography screening and Pap smears, are limited in Indonesian health care settings.

Cancer incidence patterns vary among different populations and are influenced by type of work, sex, lifestyle, environment, social status, cultural aspects, ethnicity, geographic characteristics, nutrition, health care access, and other unknown factors (Landrine et al., 2017; Sighoko et al., 2018; Arem and Loftfield, 2018; Jinyao et al., 2018; Zhu et al., 2019; Huang and Chen, 2020; Mathur et al., 2020). In previous studies, it was reported that cancer patients belonging to racial or ethnic minority groups and patients with very low socio-economic status had significantly lower rates of survival (Singh and Jemal, 2017; Siegel et al., 2021). The cancer distribution patterns in Indonesia vary among different provinces. Of the 34 provinces in Indonesia, Yogyakarta

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Province has the highest prevalence of cancer, at 4.86 per 1,000 population, followed by West Sumatra Province, at 2.47 per 1,000 population, and Gorontalo Province, at 2.44 per 1,000 population. Various efforts to prevent and control cancer have been implemented by the Indonesian government. One such effort is the community movement programme for healthy living, which includes attending regular health checks, avoiding smoking, performing routine physical activity, consuming a balanced diet, receiving adequate rest, and manging stress. In addition, to reduce the incidence of the most predominant cancer in Indonesia, clinical breast examinations (CBEs) in women aged 30-50 years and visual inspection with acetic acid (VIA) are performed to screen for breast cancer and cervical cancer, respectively.

However, public awareness of early cancer screening and the adoption of a healthy lifestyle (such as avoiding smoking, performing routine exercise, and eating a balanced diet) are still very low in Indonesia (Solikhah et al., 2021). A gap in health care facility availability among islands currently exists in Indonesia, resulting in a lack of access to health care and low health care capacity; thus, only a small number of cancer patients seek early medical care (Gondhowiardjo et al., 2021). The health care service gap may have impacts on the non-uniform distribution of cancer among various provinces in Indonesia. Data from the National Institute of Health Research and Development Indonesia (2019) showed that cancer incidence rates varied, and there was a four-fold difference between the areas with the lowest and highest incidence rates. Previous studies have reported that geographical location plays a critical role in the incidence of and mortality due to different types of cancers in patients in different locations (Roquette et al., 2019). Studies on cancer incidence trends based on patient areas in Indonesia have been limited thus far.

Geographic information systems (GIS) and spatial analyses have become hot topics worldwide with regard to elucidating disease patterns and understanding the epidemiology of diseases, including cancer. Visual displays created by GIS programs can support communications with policymakers and guide the formulation of prevention and control plans to reduce cancer incidence and cancer-related mortality, as cancer risk factors may vary among regions and islands. In Indonesia, which has many islands and ethnicities, an understanding of differences in cancer incidence and mortality among islands is crucial. GIS can help epidemiologists accurately identify and link diseases to potential causes or risk factors in a tangible and location-based manner based on descriptive and analytical data (Khashoggi and Murad, 2020; Wan et al., 2020). Indonesia, which is the fourth most populous country in the world, with more than 270 million inhabitants spread across 34 provinces and 16,056 islands, has experienced challenges in characterising the spread of diseases, including mapping the cancer incidence in each region of Indonesia. Therefore, this study aimed to determine spatial and temporal distribution of incidence of cancer cases in Yogyakarta Province, Indonesia.

Materials and Methods

Study population

This study was conducted in Yogyakarta Province, which is located on the southern part of Java Island; the province is located at 8°30' - 7°20' south latitude and 109° 40' - 111° 0' east longitude. Yogyakarta Province has a total size of 3,133.15 square kilometres. The province has one city, Yogyakarta city, and four districts (county-level): Sleman, Gunungkidul, Bantul, and Kulonprogro districts. Yogyakarta city has a population of 435,936 people, while the Sleman, Gunungkidul, Bantul, and Kulonprogo districts have population sizes of 1,232,598, 749,274, 1,029,997, and 434,483 people, respectively.

For conducting GIS-based analysis on the spatial distribution of cancer types, the county-level polygon map at 1: 1,500,000 scale was obtained, on which the county-level polygon layer containing information regarding latitudes and longitudes of central points of each county was created. All cancer cases were linked with county-level ID and polygon in ArcGIS 10.2. A county-level boundary map for the Sleman, Gunungkidul, Bantul, and Kulonprogro districts was obtained from the National Bureau of Statistics Indonesia. Geographical attributes, such as the locations of roads, hospitals, health centres, clinics, and district/city facilities; population per district; district area; topographic characteristics; and demographics, were retrieved from the regional development planning agency in Yogyakarta Province. Using county-level population as the denominator excluding breast cancer and cervical cancer, the crude incidence of each cancer cases at the county level was calculated and mapped. For cervical and breast cancer incidence, accounting from monthly numbers of confirmed of these cases divided by women aged above 30 to 50 years old. Then, incidence rate of each cancer types was grouped into three categories based on quantile, namely low incidence rate, middle incidence rate and high incidence rate, with annualized average incidence between 0 – < 0.04 per 10,000, 0.04 – 4.42 per 1,000, and 4.42 per 1,000, respectively. To assess the number of low-income families (poor family) per county-level in Yogyakarta province was retrieved from the 2019-2020 census, annually surveyed by Indonesia's National Statistics Office (Badan Pusat Statistik, BPS). This data was integrated into terms of the administrative. All cancer types were geo-coded and matched to county-level layers of polygon and point by administrative code using the software ArcGIS 10.2 to be included in the analysis.

Cancer data

Confirmed cancer cases were collected retrospectively form the Yogyakarta Provincial Health Office, which were clinical examined from a major referral cancer hospital in Yogyakarta, namely Dr Sardjito, Bethesda, Hardjolukito, and Panti Rapih. The dataset as electronic spreadsheets were all cancer types admitted during 1 January 2019 to December 2020. These hospitals regularly report new cancer cases, which are diagnosed according to the International Classification of Diseases, revision 10 (ICD-10), using a unified cancer reporting

card. Yogyakarta has a highly mobile population, with 3,882,288 permanent residents; therefore, we included only registered residents during the 2019-2020 period. Cancers were defined as ICD-10 codes C50, C69, C53, C34, C18-C20, C91-C95, C61, C11, C43-C44, and C22. A total of 9,933 cancer cases were recorded at the Yogyakarta Provincial Health Office from 2019-2021.

Data analysis

Descriptive statistics were used to summarize the attributes of cancer patients. Continuous variables are reported as the mean standard deviation, while categorical variables are reported as weighted percentages. To understand the distributions of cancer cases in each district/city of Yogyakarta Province, an overlay was constructed based on the weighted matrix. Overlaying was employed to understand cancer distributions based on locality and to reveal rate patterns across districts/cities with reasonably high populations because extreme data may interfere with the evaluation of patterns. Incorporating other variables within districts or cities of the province may help reveal more stable patterns. Overlay analysis was used to determine the distribution trends of cancer cases based on the number of families with low socio-economic status and the availability of health facilities. Finally, ArcGIS version 10.2 was overlaid to produce an integrated map of epidemiological characteristics of cancer in Yogyakarta Province during 2019-2020.

Ethical consideration

The study protocol and informed consent form were approved by the Ethics Committee of Universitas Ahmad Dahlan under the ethical clearance number 012102016.

Results

A total of 9,933 cancer cases were reported in Yogyakarta Province from 2019 to 2020, of which 79.40% (n=7,887) occurred in women, and 20.60% (n=2,046) occurred in men; the cancer patients had an average age of 55.08- 15.46 years (Table 1). The most common types of cancer identified in this province were breast cancer and cervical cancer in women. Among all cancer types, the following were the most frequently reported incidence rate of each cancer cases, in descending order: breast cancer (30.707 per 1,000 population at risk), cervical cancer (3.529 per 1,000 population at risk), colorectal cancer (3.318 per 1,000 population at risk), thyroid cancer (2.372 per 1,000 population at risk), and prostate cancer (1.416 per 1,000 population at risk) (Table 2). In addition, the two most common types of cancer in the five districts in

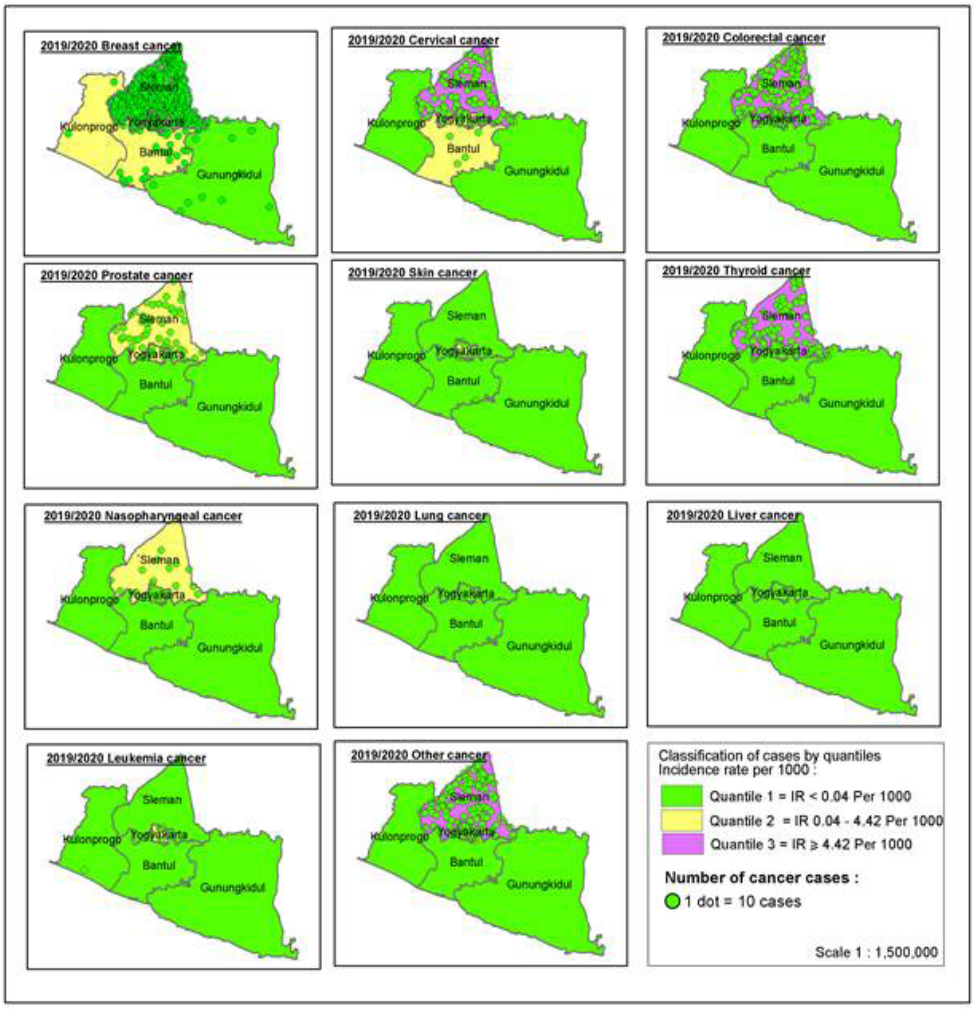

Figure 1. Cancer Distribution by Type in Yogyakarta Province

Characteristics	Number	Percentage (%)
Sex		
Female	7,887	79.4
Male	2,046	20.6
Age (Years)		
< 18	78	0.79
18 - 44	1,909	19.22
45 - 54	2,920	29.4
≥ 55	5,026	50.6
Cancer		
Breast cancer	6,035	60.76
Retinoblastoma cancer	56	0.56
Cervical cancer	636	6.4
Lung cancer	189	1.9
Colorectal cancer	982	9.89
Leukaemia	109	1.1
Prostate cancer	368	3.7
Nasopharyngeal cancer	206	2.07
Skin cancer	311	3.13
Liver cancer	163	1.64
Bone cancer	36	0.36
Brain cancer	136	1.37
Thyroid cancer	484	4.87
Others	222	2.23
District/City		
Sleman	7,553	76.04
Kulonprogo	43	0.43
Bantul	613	6.17
Yogyakarta	1,613	16.24
Gunungkidul	111	1.1

Yogyakarta Province were slightly different. In Sleman district, the dominant cancers found during 2019-2020 were breast cancer and colorectal cancer; in Bantul district, they were colorectal cancer and skin cancer; in Yogyakarta city, they were breast and colorectal cancer; and in Gunungkidul district, they were breast cancer and cervical cancer (Table 2). The district accounting for the largest number of cancer cases in Yogyakarta Province was Sleman district (64.8%) (Figure 1).

Regarding the incidence rates during the study period, Sleman district had the highest incidence rate during the study period. In contrast, in Kulonprogo district, there had a lowest rate of cancer incidence. To explore the possibility that certain settings influence the development of cancer, analyses according to socio-economic status and distance to health facilities based on postal code were performed. The results showed that the majority of cancer patients resided in low socio-economic areas (Figure 2), and most of the health facilities (such as hospitals and public health centres) were located in Sleman district, which was also the district in which the majority of cancer patients were located (Figure 3).

Discussion

Cancer remains the NCD that causes the largest number of deaths worldwide, especially in developing countries; this may be because most cancer patients in these countries are diagnosed at an advanced stage. Although cancer screening is recommended by the WHO for the early detection of cancer, as well as the prevention cancer-related deaths, complex challenges such as inadequate health care infrastructure (Anderson et al., 2015), poverty (Jagsi et al., 2018), insufficient budget allocation for cancer (Voda and Bostan, 2018), and low awareness of breast cancer risk and community cancer screening programmes (Solikhah et al., 2019) have driven resource-limited countries towards alternative approaches for cancer prevention. These low-cost cancer prevention

Table 2. The Incidence Rate (IR) Per 1000 of Cancer Cases during the 2019-2020 Period (n=9,933)

Cancer types	District									
	Sleman		Kulonprogo		Bantul		Yogyakarta		Gunungkidul	
	n (cases)	IR	n (cases)	IR	n (cases)	IR	n (cases)	IR	n (cases)	IR
Breast cancer	158,012 (4,852)	30.707	60,105 (25)	0.425	1,361,345 (326)	0.239	30,601 (831)	27.156	107,387 (1)	0.009
Retinoblastoma cancer	-	-	-	-	-	-	123,9271 (55)	0.044	511,015 (1)	0.009
Cervical cancer	158,012 (838)	3.031	-	-	1,361,345 (49)	0.036	30,601 (108)	3.529	-	-
Lung cancer	204,039 (96)	0.47	738,915 (2)	0.003	197,464 (17)	0.086	123,9271 (74)	0.06	-	
Colorectal cancer	204,039 (677)	3.318	738,915 (1)	0.001	197,464 (90)	0.456	123,9271 (214)	0.173	-	-
Leukaemia	-	-	738,915 (8)	0.011	-	-	123,9271 (101)	0.081	-	-
Prostate cancer	204,039 (289)	1.416	738,915 (1)	0.001	197,464 (24)	0.122	123,9271 (54)	0.044	-	-
Nasopharyngeal cancer	204,039 (151)	0.74	738,915 (1)	0.001	197,464 (3)	0.015	123,9271 (51)	0.041	-	-
Skin cancer	204,039 (99)	0.485	738,915 (5)	0.007	197,464 (99)	0.501	123,9271 (108)	0.087	-	-
Liver cancer	204,039 (141)	0.691	-	-	197,464 (5)	0.025	123,9271 (17)	0.014	-	-
Bone cancer	204,039 (36)	0.176	-	-	-	-	-	-	-	
Brain cancer	204,039 (136)	0.667	-	-	-	-	-	-	-	
Thyroid cancer	204,039 (484)	2.372	-	-	-	-	-	-		
Others	204,039 (113)	0.554	-	-	-	-	-	-	511,015 (109)	0.213

n, Population at risk; excluding for breast cancer and cervical cancer aged 30-50 years old; IR, Incidence rate per 1000

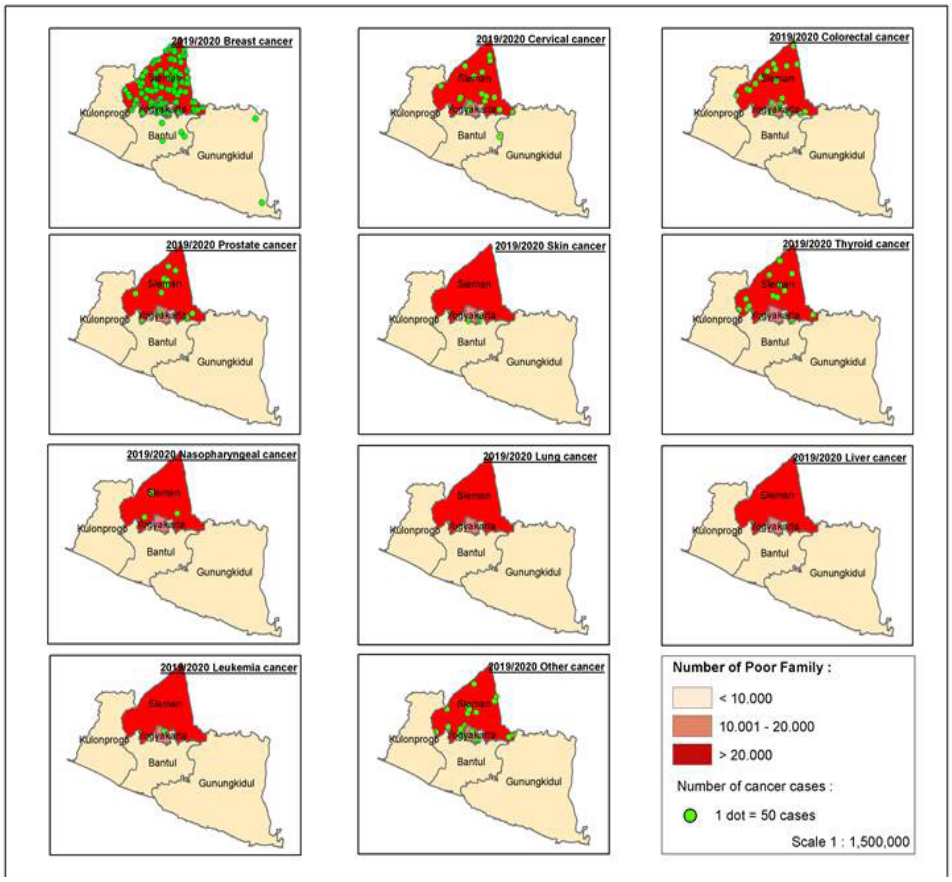

Figure 2. Geographical Distribution of Cancer by Low Socio-Economic Status

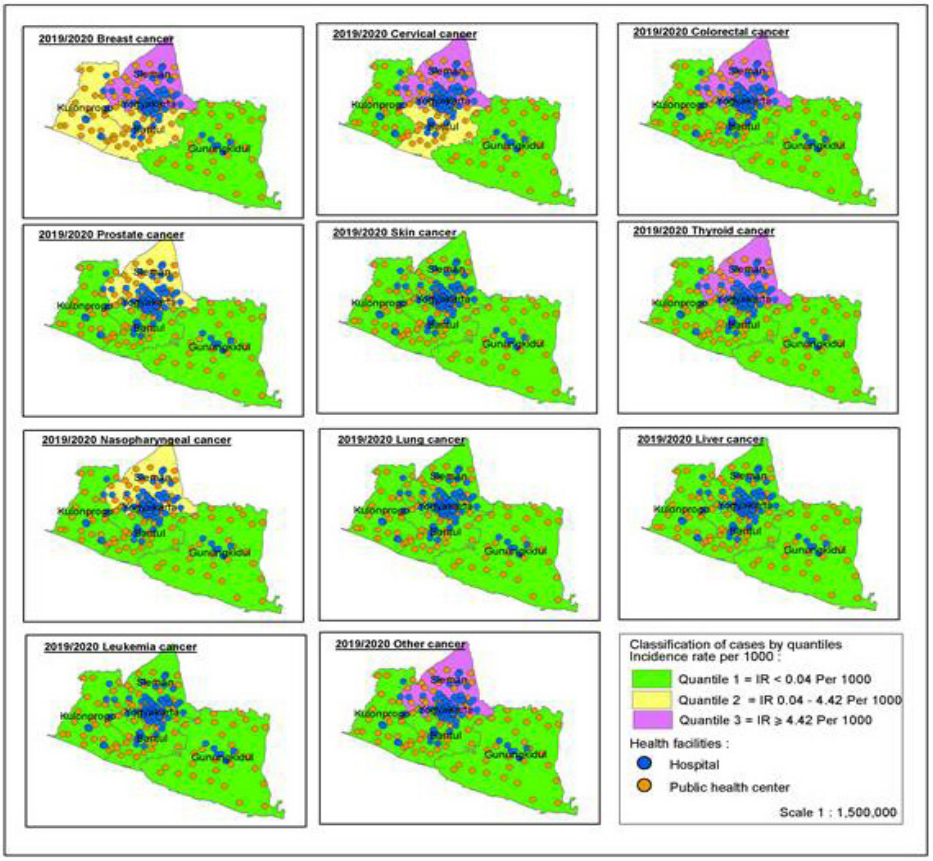

Figure 3. Geographical Distribution of Cancer by Availability of Health Care Facilities

strategies include increasing public awareness through cancer-related education, increasing the acceptance of cancer screening, offering low-cost cancer screening, and addressing preventable risk factors for cancer (e.g., avoiding smoking, increasing physical activity, losing weight, and reducing alcohol consumption) (Meyskens et al., 2016; Stewart et al., 2016;Britt et al., 2020) Cancer education is one of the key elements in the fight against cancer (DePinho and Hawk, 2016); however, low literacy rates in developing countries are a major obstacle in the implementation of programmes (Gupta et al., 2015). Cancer mapping using GIS enables the timely updating of information, and the georeferenced data are easily accessible to policymakers for the implementation of cost-effective cancer prevention measures. GISs are also useful tools for analysing morbidity and mortality within an area, as well as assessing the distribution of, utilization of, and disparities among health services; these data can be used plan interventions and determine priorities in cancer prevention (Wan et al., 2020). To the best of our knowledge, the present study is the first community-based study reporting on the spatio-temporal distributions of various cancers, particularly in Indonesia.

According to this study during the 2019-2020 period, 9,933 cancer cases were reported from different areas. Of these, most cancer patients were from Sleman district, which is an area located in the northern part of Yogyakarta Province; the cancer detection rate in Sleman district was higher than the provincial rate. The geospatial analysis demonstrated that most of the cancer patients living in Sleman district suffered from breast cancer, followed by cervical cancer. However, the initial screening rates for both cancers were lower in Sleman district, as demonstrated by the low VIA and CBE screening rates, than those in Yogyakarta city, the capital of Yogyakarta Province. This finding will help guide policymakers and public health practitioners in targeting specific areas for the maximum allocation of cancer prevention resources. The benefit of cancer screening is measured by the number of life-years gained from the prevention or early diagnosis of cancer. Previous studies have provided guidelines for screening recommendations (White et al., 2017), which have been proven to be effective in reducing the burden of various cancer. These screening recommendations include 1) cytology (Pap smears) for women aged 30-65 years old to detect cervical cancer; 2) mammography for women aged 50-74 years, with a 2-year interval, to detect breast cancer; 3) a faecal occult blood test (FOBT) once a year, sigmoidoscopy once every 5 years, colonoscopy once a year, and faecal immunochemical testing once every 10 years to detect colorectal cancer; and 4) low-dose helical computed tomography to detect lung cancer (Wang et al., 2018). However, almost all of these screening approaches are unaffordable in countries with inadequate health care infrastructure, such as Indonesia (Tabrizi et al., 2018). Therefore, in Indonesia, CBE and VIA to detect breast cancer and pre-cervical cancer, respectively, are the only screening strategies implemented. A previous study also revealed that the level of knowledge and the availability of information about screening are factors that affect the early detection of cancer (Nuryana et al., 2020).

The current study demonstrated that the predominant cancers differed by sex. In women, the most dominant cancers in the province were breast cancer and cervical cancer, while in men, the dominant cancers were colorectal cancer, nasopharyngeal cancer, skin cancer, and lung cancer. Our findings are in line with those of previous study conducted in the United States in 2019 that showed that the incidence rates of cancers were different between males and females (Siegel et al., 2021). Sex disparities are important factors that are potentially influenced by biological processes and have an impact on cancer incidence, prognosis, and mortality. These differences have the potential to influence the immune response to foreign antigens and self-antigens, including chronic inflammatory diseases such as cancer (Carè et al., 2018). The fact that the most prevalent cancers in women in this study were breast cancer and cervical cancer (79.40%) supports the results of a global study that also found breast and cervical cancer to be the leading causes of cancer-related deaths (Fitzmaurice et al., 2017; Siegel et al., 2021).

Age is also an important risk factor for some types of cancer, and most cancer patients in this study were diagnosed when they were ≥ 55 years old. However, approximately 19.22% and 0.79% of the cancer cases in this study occurred in patients who were < 45 years old and <18 years old, respectively. This is in line with the results of a previous study by Partridge et al. (Partridge et al., 2016), who evaluated the association between age and breast cancer in women and found that young women aged <40 years had lower odds of survival than women aged 51-60 years (HR: 1.9; 95% CI: 1.6 to 2.3). Another study conducted in women in Southeast Asia showed that among breast cancer risk factors, age over 40 years was associated with a 1.5 times increased risk of breast cancer development (Nindrea et al., 2017). In addition, patients who are diagnosed with colon cancer at an age ≥ 50 years have a higher risk of advanced-stage cancer than older patients (≥ 60 years old) (Gabriel et al., 2018). This supports the results of previous studies that found that most young patients tended to have poorer adherence to adjuvant endocrine therapy than older patients, leading to a lower survival rate (Eraso, 2019).

This study also explored socio-economic characteristics and travel distances to health care facility sites for cancer screening (i.e., hospitals and public health centres), which have been recognized as key factors influencing significant geographic inequities and accessibility to cancer screening. Our study revealed that most cancer patients lived in lower socio-economic areas (Figure 3), although their homes were relatively close to cancer screening sites. It is worth noting that cancer patients belonging to lower socio-economic classes tend to have low screening rates worldwide; low rates have been reported for cervical cancer screening in China (Bao et al., 2018), prostate cancer in Switzerland (Guessous et al., 2016), breast cancer screening in different races in the United States (Singh and Jemal, 2017; Elewonibi et al., 2018), and breast cancer screening in Kurdish women in Iran (Aminisani et al., 2016). According to previous studies, the incidence rate of cancer, especially in low-resource countries (LRCs), is

influenced by demographic transitions, changing disease patterns, unhealthy lifestyles, and community behaviour (Drake et al., 2020). Further, the mortality rate of cancer is higher in LRCs than in developed countries (Ghoncheh and Salehiniya, 2016). Therefore, it is necessary to implement appropriate alternative and sustainable programmes, including routine health services such as VIA for pre-cervical cancer screening, breast self-examination, and CBE for breast cancer screening in these countries, especially countries with limited health care resources, such as Indonesia (Denny et al., 2017).

We acknowledge that this study had some limitations. First, regarding the geographic analysis, shifts in the geographic characteristics of variables, such as patient location, county, district/city, hospital location, and others, should be considered. Mitigation efforts have been applied; however, using tools to check postal codes and district assignments may help in the updating of target areas. The second limitation is that the data used in this study were obtained from a national passive surveillance system; these systems are known to grossly under-report the number of cancer cases. This could potentially affect the estimates of the mean incidence, proportion of cancer cases, and observed spatial patterns in this study. Nevertheless, this study still has major strengths. It is the first study in Indonesia to analyse routine cancer data collected by health offices and produce a cancer distribution map by cancer type for each district/city in the entire province. Additionally, the proportion of cancer cases in this study reflects the incidence of cancer in the study area and can be used to identify environmental risks associated with this disease, as the data were obtained from a population-based survey in the community.

In conclusion, several types of cancers were identified in Yogyakarta Province, with breast cancer and cervical cancer being the most common. Moreover, Sleman district was the district with the largest number of cancer cases in the province. Despite the fact that the incidence rates of different cancer types vary by sex, most cancer cases were diagnosed at a young age. Additionally, the majority of the patients had a low socio-economic status, which was related to the low cancer screening rate. This study provides basic knowledge about geographical and environmental attributes that might be valuable in the implementation of focused control measures targeting vulnerable populations. This enables the optimal utilization of available resources, which is essential in developing countries with limited health screening resources such as Indonesia. The overlaid cancer case map is an easy-to-use tool that can guide the implementation of targeted and cost-effective control measures by relevant health authorities.

Author Contribution Statement

None.

Acknowledgments

We would like to acknowledge the Ministry of Research and Technology/National Research and Innovation Agency, Republic of Indonesia (No. 3279.6/LL5/PG/2021 and No.001/SKP.PJD/LPPM/VII/2021) for grant funding in this study.

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