Original Article

Analyzing Global Cancer Control: Progress of National Cancer Control Programs through Composite Indicators and Regression Modeling

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Abstract

Aim: Cancer is a significant public health concern, and National Cancer Control Programs (NCCPs) are crucial for reducing its burden. However, assessing the progress of NCCPs is challenging due to the complexity of cancer control outcomes and the various factors that influence them. Composite indicators can provide a comprehensive and accurate assessment of NCCP progress. **Materials and Methods:** The dataset was compiled for 144 countries and comprised eight composite indices and two high-level comparative indicators (mortality-to-cancer incidence ratio [MIR] and 5-year cancer prevalence-to-incidence ratio [PCIR]) representing NCCP outcomes. Two large databases and six annual composite index reports were consulted. Linear regression analysis and Pearson correlation coefficients were used to establish a relationship between indicators and NCCP outcomes. A multiple regression machine learning model was generated to further improve the accuracy of NCCP outcome prediction. **Results:** High-income countries had the highest cancer incidence, whereas low-income countries had the highest MIR. Linear regression analysis indicated a negative trend between all composite indicators and MIR, whereas a positive trend was observed with PCIR. The Human Development Index and the Legatum Prosperity Index had the highest adjusted R^2 values for MIR (0.74 and 0.73) and PCIR (0.86 and 0.81), respectively. Multiple linear regression modeling was performed, and the results indicated a low mean squared error score (−0.02) and a high R^2 score (0.86), suggesting that the model accurately predicts NCCP outcomes. **Conclusions:** Overall, composite indicators can be an effective tool for evaluating NCCP, and the results of this study can aid in the development and keeping track of NCCP progress for better cancer control.

Keywords: Cancer, machine learning, oncology, radiotherapy, regression

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Introduction

Cancer is a significant global issue that demands national and international attention. Cancer incidences, prevalent cases, and morbidities are increasing worldwide. IARC report revealed 20 million new cancer incidences and 9.7 million deaths in the year 2022.[1,2] To tackle the increasing cancer burden, National Cancer Control Programs (NCCPs) have been established, and subsequent qualitative performance evaluations have been conducted.[3] The World Health Organization (WHO) has disseminated a framework for NCCPs. This framework emphasizes the integration of scientific principles into public health practice. It particularly focuses on cancer prevention and detection with the ultimate goal of reducing cancer-related morbidity.[4] The International Cancer Control Program has provided support to countries in developing their NCCPs since 2012.[5] These programs aim to discover the most effective means of cancer prevention, risk reduction, and early detection, improving the quality of cancer treatment and extending cancer patients' survival and quality of life. Therefore, it is necessary to conduct quantitative assessments of these programs to ensure their effectiveness.

Several crude indicators can be used to analyze the progress of NCCPs, such as cancer mortality rates, cancer survival

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rates, cancer screening, cancer treatment facilities, and technological innovations.[6] Literature has also suggested the use of high-level comparative indicators, such as the Mortality-to-cancer-incidence ratio (MIR) and 5-year prevalence-to-cancer-incidence ratio (PCIR) by developed countries owing to their simplified data collection process.[7,8] These indicators' simplicity allows for prompt international comparisons among countries, given the ease of availability of cancer incidence and mortality data.[9]

Various studies have shown the impact of a country's socioeconomic conditions on cancer outcomes.[10-13] Several composite indicators are published annually, providing comparative analysis of countries' performance and progress in different areas such as health, education, public sector corruption, economic factors, environment, and government will.[14-19] These composite indicators are constructed by combining two or more core indicators into a single score or ranking. These indicators aim to capture multidimensional phenomena that cannot be measured by a single indicator and can help identify patterns and trends. Several studies have shown the use of such composite indicators to track the progress of various programs.[20,21]

Previous studies have shown how composite indicators can represent cancer outcomes, such as cancer mortality and incidence rates.[22,23] This study aims to use several composite indicators to track the outcome of a country's NCCP, represented by high-level comparators such as MIR and PCIR. Our primary goal is to find a correlation between composite indicators and NCCP outcomes. Second, we aim to determine the most appropriate composite indicator representing a country's cancer control efforts. In addition, we propose a multiple linear regression machine learning model that can further improve the projection of NCCP outcomes.

The aim of this study was to enable the public and readers to assess the effectiveness of their country's cancer control program using the composite indicator scores that are published annually and reflect the progress of the NCCP of a country.

Materials and Methods

Data source

For this study, we included three economic indicators, five composite indicators, and two high-level comparators indicating cancer outcomes from the NCCP. The Global Cancer Observatory database provided data on cancer incidence, mortality, and prevalence, whereas the Global Health Expenditure Database (GHED) from the WHO was used to extract data on health expenditure, expenses, and income.[1,17] The data for five composite indicators were obtained from their published annual reports and respective websites.[14-16,18-19] Table 1 provides a summary of the data sources used in this research. We only included countries that reported in all of the cited data sources.

Methodology

We selected MIR and PCIR as cancer control outcomes for the NCCP. MIR is often used as a high-level comparative indicator of inequities in cancer control outcomes. It is calculated by dividing the mortality count by the incidence count in a given year (Equation 1), which allows for a quick international comparison of survival rates across countries due to the availability of incidence and mortality data for most countries.

$$MIR = \frac{Mortality_{Country}}{Incidence_{Country}} \text{ in 1 year} \quad (1)$$

PCIR is defined as the number of people alive who have been diagnosed with cancer during a specified period. Prevalence is an important high-level population health indicator of the burden of cancer, which includes the number of people undergoing treatment, follow-up care, and/or ongoing cancer monitoring. PCIR is calculated by dividing the 5-year cancer prevalence count by the incidence count in a given year (Equation 2).

$$PCIR = \frac{Prevalence_{Country}}{Incidence_{Country}} \text{ in 5 years} \quad (2)$$

where $\text{Prevalence}_{\text{Country}}$ is defined as:

$$Prevalence_{Country} = Incidence_{Country} . \left(\frac{Prevalence_{Nordic}}{Incidence_{Nordic}}\right).\left(\frac{HDI_{Country}}{HDI_{Nordic}}\right) \quad (3)$$

where $\text{Incidence}_{\text{Country}}$ represents the cancer incidence of the country in a particular year, $\text{prevalence}_{\text{Nordic}}$ represents the number of prevalent cases in the last 5 years in Nordic countries, $\text{Incidence}_{\text{Nordic}}$ represents the cancer incidence in Nordic countries, $\text{HDI}_{\text{Country}}$ represents the Human Development Index (HDI) score of the country, and $\text{HDI}_{\text{Nordic}}$ represents the HDI score of Nordic countries.[24]

Statistical analysis

We summarized and tabulated the cancer incidence, mortality, and 5-year prevalence cases according to the World Bank's classification of countries based on gross national income per capita in USD (GNI).[25] We also summarized the average data for all composite indices and high-level comparative indicators of the NCCP based on world regions. The three economic and five composite indices used in the study were GNI, current health expenditure per capita in USD (CHE), out-of-pocket expenditure per capita in USD (OOPE), Legatum Prosperity Index (LPI), Corruption Perceptions Index (CPI), Happiness Index (HI), HDI, and Environmental Performance Index (EPI).[14-18]

We used the Shapiro–Wilk test to determine the normalized distribution for all economic and composite indicators. We carried out the Pearson correlation test to assess the correlation between the indicators and the NCCP outcomes (MIR and PCIR). In our analysis, we considered $P < 0.05$ as statistically significant. We performed linear regression to calculate the adjusted R^2 value and

Table 1: Summary of the data sources used in this study

Data sources	Index	Published	Countries	Factors	Score range
GCO database	MIR and PCIR	GLOBOCAN report 2020	186	Cancer mortality, incidence, and prevalence	NA
Legatum Institute (www.prosperity.com)	LPI	2021 LPI™ report	167	Wealth, economic growth, education, health, personal well-being, and quality of life	0 (low)–100 (high)
Transparency International	CPI	2021 CPI report	180	Perceived level of public sector corruption	0 (highly corrupt)–100 (very clean)
WHO GHED	GNI per capita in US$ CHE per capita in US$ OOPE in US$	GHED 2021	192	Economic and income factors	NA
Sustainable Development Solutions Network, powered by the Gallup World Poll data	HI	World Happiness Report 2022	150	GDP per capita, social support, healthy life expectancy, freedom to make life choices, generosity, perception of corruption, unexplained happiness	1 (low)–10 (high)
United Nations	HDI	Human Development Report 2021–2022	192	A long and healthy life, knowledge, and a decent standard of living	0 (low)–1 (high)
Yale Center for Environmental Law and Policy	EPI	2022 EPI	180	40 performance indicators across 11 issue categories; environmental Health, ecosystem vitality, and climate change	0 (low)–100 (high)

MIR: Mortality-to-cancer incidence ratio, PCIR: 5-year prevalence-to-cancer-incidence ratio, GCO: Global Cancer Observatory, LPI: Legatum Prosperity Index, CPI: Corruption Perception Index, GHED: Global Healthcare Expenditure Database, CHE; Current Healthcare Expenditure, OOPE: Out-of-pocket expenditure, HDI: Human Development Index, EPI: Environmental Performance Index, HI: Happiness Index, GNI: Gross national income, NA: Not available

select the best predictor from the group of indicators for cancer outcomes of the NCCP program in the country.

We created a multiple regression model using the collected data from various data sources and combined them into a single dataset. We used Python, the Pandas library, and the Seaborn library to preprocess and visualize the data. We used the Python scikit-learn library to build a multiple linear regression model to predict the value of the dependent variables (MIR/PCIR) based on the values of the independent variables (GNI/CHE/OOPE/HDI/LPI/HI/CPI/EPI). To evaluate the performance of the multiple linear regression model, we used five-fold cross-validation. We calculated the mean squared error (MSE), root mean squared error (RMSE), mean absolute error (MAE), and *R*-squared (R^2) scores for the model.

Results

Epidemiology of cancer incidences, mortality, and 5-year prevalence across different World Health Organization classifications and world's region

After applying the inclusion criteria, a total of 144 countries were included in the study. Table 2 summarizes the cancer incidence, mortality, and 5-year prevalence cases according to the World Bank's classification of countries based on their GNI. In the year 2020, there were in-total 18.9 million new cancer incidences reported worldwide, with 9.7 million cancer-related mortalities and 49.7 million 5-year prevalent cancer cases. Approximately 45% of the world's population lives in low-income countries (LICs). Cancer incidence was reported highest in high-income countries (HIC) (7.6 million) with the highest PCIR ratio (3.12) and lowest MIR ratio (0.43). In contrast, LICs had the least cancer incidences (0.33 million) but the highest MIR ratio (0.7) and lowest PCIR ratio (1.63).

Table 3 presents the epidemiological data and composite indicators summary for the world's regions. Africa had the largest MIR and lowest PCIR values (0.66 and 1.89), respectively, whereas Oceania had the lowest MIR and highest PCIR values (0.27 and 4). Africa had the lowest GNI (2291 USD) and the lowest CHE (126 USD), whereas the Oceania region had the highest GNI (51050 USD) and highest OOPE (691.50 USD). North America had the highest CHE (5638.66 USD). The results show that Oceania has the highest average values for all five indices, whereas Africa has the lowest.

Correlation between economic, composite indicators with National Cancer Control Program outcomes

Figure 1 presents the linear regression plots of the MIR and the PCIR with all eight indicators, respectively. Regression analysis was performed to examine the relationship between the different indicators and the MIR and the PCIR. The

Table 2: Summary of the cancer incidence, mortality, and 5-year prevalence cases according to the World Bank Classification of countries based on gross national income per capita (USD)

Category	WHO criteria	Countries	Population (million)	Cancer incidence (million)	Mortality (million)	5-year prevalence (million)	MIR	PCIR
HIC	GNI per capita ≥$12,696	44	1118.67	7.64	2.78	25.15	0.43	3.12
UMIC	$4096 ≤ GNI per capita ≤$12,695	40	2448.64	7.38	4.46	16.55	0.56	2.49
LMIC	$1046 ≤ GNI per capita ≤$4095	41	3325.39	3.59	2.28	7.50	0.65	1.99
LIC	GNI per capita ≤$1045	19	505.40	0.33	0.22	0.55	0.71	1.63
Grand total		144	7398.11	18.93	9.75	49.75	0.56	2.43

LIC: Low-income countries, LMIC: Low-middle-income countries, UMIC: Upper-middle-income countries, HIC: High-income countries, GNI: Gross national income, MIR: Mortality-to-incidence ratio, PCIR: 5-year prevalence-to-cancer-incidence ratio

Table 3: Summary of the economic indicators, composite indicators, and National Cancer Control Program outcomes for the six world regions

Continent	Countries	Economic indicators			Composite indicators					NCCP outcomes	
		GNI	CHE	OOPE	CPI	LPI	HI	EPI	HDI	MIR	PCIR
Africa	42	2291.67	126.17	36.60	33.33	46.88	4.49	35.37	0.56	0.66	1.89
Asia	38	11,380.53	675.56	181.42	38.55	56.55	5.30	36.02	0.74	0.60	2.29
Europe	40	33,084.75	2842.29	526.49	59.33	72.15	6.42	58.45	0.88	0.46	2.98
Latin America and the Caribbean	19	7963.68	608.13	168.98	36.95	58.32	6.03	42.00	0.74	0.54	2.47
North America	3	40,053.33	5638.66	670.89	53.67	65.26	5.89	42.40	0.80	0.44	3.00
Oceania	2	51,050	4819	691.50	80.50	79.85	7.23	58.40	0.94	0.27	4.00

GNI: Gross national income per capita in USD, CHE: Current healthcare expenditure per capita in USD, OOPE: Out-of-pocket-expenditure per capita in USD, CPI: Corruption Perception Index, LPI: Legatum Prosperity Index, HI: Happiness Index, EPI: Environment Performance Index, HDI: Human Development Index, MIR: Mortality-to-incidence ratio, PCIR: 5-year prevalence-to-cancer-incidence ratio, NCCP: National Cancer Control Program

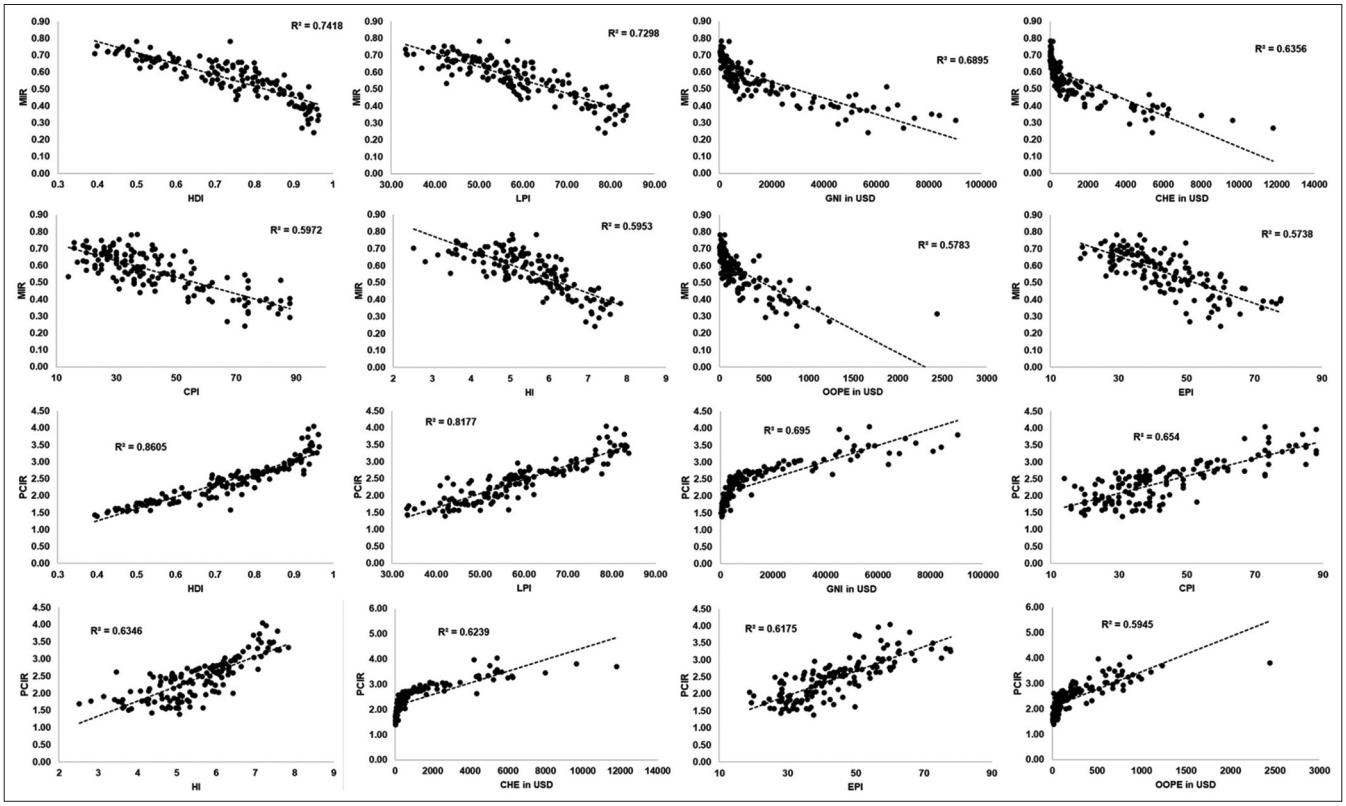

Figure 1: Linear regression plots representing a relationship between economic indicators, composite indicators, and National Cancer Control Program outcomes (MIR and PCIR). Human Development Index and Legatum Prosperity Index showed the highest R^2 value among all indicators for both MIR and PCIR. MIR: Mortality-to-cancer-incidence ratio, HDI: Human Development Index, LPI: Legatum Prosperity Index, GNI in USD: Gross national income per capita in USD, CHE in USD: Current health expenditure per capita in USD, CPI: Corruption Perceptions Index, HI: Happiness Index, OOPE in USD: Out-of-pocket expenditure per capita in USD, EPI: Environmental Performance Index, PCIR: 5-year prevalence-to-cancer-incidence ratio

results indicated a negative trend between all indices and MIR and a positive trend with PCIR. The HDI and the LPI showed the highest adjusted R^2 values for both MIR and PCIR, with values of 0.7418 and 0.7298 and 0.8605 and 0.8177, respectively. Table 4 shows the Pearson correlation value for each index with MIR and PCIR. The HDI and LPI showed the highest negative Pearson correlation values (−0.861 and −0.854) with MIR and the highest positive Pearson correlation values with PCIR (0.928 and 0.904).

Multiple linear regression model

The model has a low MSE score of −0.02 and an RMSE score of 0.13, indicating accurate predictions with low error rates. The MAE score is −0.08, indicating that predicted values are within 0.08 units of actual values. The high R^2 scores with an average of 0.86 suggest that the model explains a high proportion of the data variability. The predicted versus actual plots of MIR and PCIR in Figure 2 show a strong positive correlation between the actual and predicted values, supporting the accuracy of the model in predicting both MIR and PCIR.

Table 4: Pearson correlation coefficient of economic and composite indicators versus mortality-to-incidence ratio and PCIR

Global indices	MIR	PCIR
LPI	−0.854	0.904
HI	−0.772	0.797
EPI	−0.757	0.786
GNI	−0.830	0.834
CHE	−0.797	0.790
OOPE	−0.760	0.771
CPI	−0.773	0.809
HDI	−0.861	0.928

LPI: Legatum Prosperity Index, HI: Happiness Index, EPI: Environment Performance Index, GNI: Gross national income per capita in USD, CHE: Current health-care expenditure per capita in USD, OOPE: Out-of-pocket-expenditure per capita in USD, CPI: Corruption Perception Index, HDI: Human Development Index, MIR: Mortality-to-incidence ratio, PCIR: 5-year prevalence-to-cancer-incidence ratio, NCCP: National Cancer Control Program

Discussion

This is the first study to predict and quantify the results of a country's NCCP program using a multiple regression machine learning model. In addition, the relationship between composite indicators and NCCP outcomes was determined. This study demonstrated that only a small number of composite indices, such as HDI and LPI, or a combination of composite indices, can be used as proxies to monitor the progress of NCCP efforts. For 144 countries, we compiled a dataset consisting of eight composite indices as independent variables and two high-level comparative indicators (MIR and PCIR) as dependent variables. Two large databases (Global Health Observatory (GHO) and Global Health Expenditure Database (GHED)) and six annual complex index reports were consulted for the data.

Our research revealed statistically significant differences in NCCP outcomes between countries with different income levels, indicating differences in health-care facilities and care quality. Our research revealed that countries with low incomes have low cancer incidence rates but high MIR rates, indicating a lack of early cancer detection and screening programs. In addition, low PCIR rates indicate a lack of advanced treatments and cutting-edge technology in low-income nations.[26] In HIC, however, high cancer incidence rates are due to a high average age and a changing lifestyle.[27] African nations had the worst MIR and PCIR ratios in the world's region, indicating a lack of health-care infrastructure, newer treatment modalities, cancer screening programs, etc., which is supported by the findings of the studies.[28]

In this study, a significant correlation was found between several composite indices and NCCP outcomes. Composite

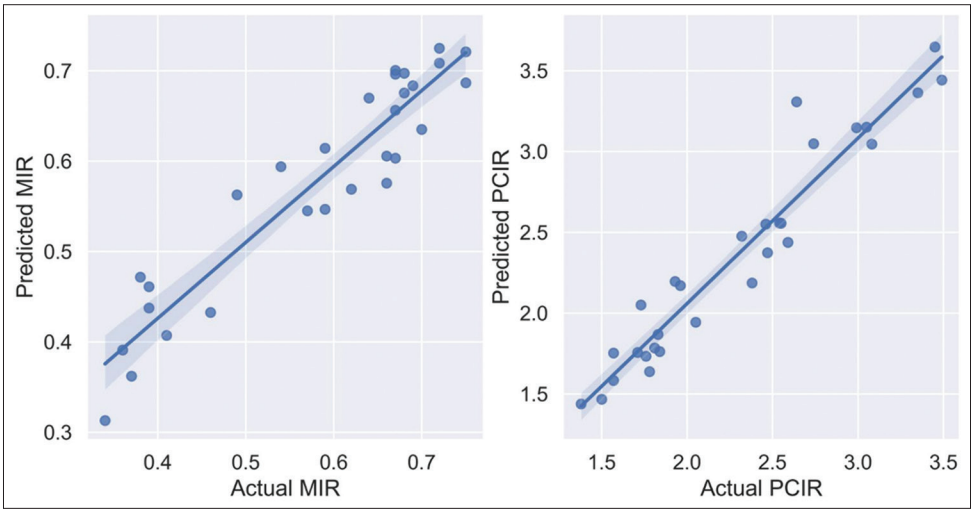

Figure 2: Plot representing predicted versus actual MIR and PCIR for multiple regression machine learning model. MIR: Mortality-to-cancer-incidence ratio, PCIR: 5-year prevalence-to-cancer-incidence ratio

indices such as HDI/LPI/CPI/HI/EPI exhibited a negative correlation with MIR and a positive correlation with PCIR, which is consistent with previous findings published in the literature.[29,30] This suggests that factors such as education, health, prosperity, economy, public sector corruption, and the environment, among others, have a substantial impact on the NCCP outcomes (MIR and PCIR). Previous studies have consistently shown a correlation between economic indicators such as GNI/CHE/OOPE and NCCP outcomes. This suggests that lower personal income, reduced government health expenditure, and higher out-of-pocket expenses are significantly linked to high MIR and low PCIR.[31,32]

According to our study, the HDI and the LPI have the highest correlation and R^2 value with the NCCP outcomes, indicating that these composite indicators take into account all of the necessary parameters and criteria for predicting NCCP outcomes.[23,29] A multiple regression model based on all indicators utilized in our study enhanced the ability to predict NCCP outcomes with a higher R^2 value and lower MSE (0.86, −0.02). This further demonstrates that by combining multiple economic and composite indicators, an improved understanding of NCCP progress can be projected.

Cancer is a significant global public health issue with increasing incidence rates and cancer-related mortality.[33] The influence of socioeconomic factors on cancer control outcomes varies considerably between nations.[34] In 2020, breast cancer overtook lung cancer as the most prevalent cancer diagnosed worldwide, and demographic and lifestyle changes have been identified as the leading contributors to the rise in cancer incidence.[35] Various nations have developed NCCPs to address the rising incidence of cancer.[3,36,37] However, LICs and Lower middle income countries (LMICs) face significant obstacles in implementing effective cancer control strategies due to a lack of reliable data and limited resources.[38] The annually published composite indicators used in our study can assist LICs/LMICs in estimating their NCCP program and making informed decisions to improve cancer control. Our research provides predicted MIR and PCIR values based on composite indicators, enabling policymakers to evaluate the efficacy of their cancer control programs and make data-driven decisions to improve cancer outcomes.

It is necessary to acknowledge the limitations of our study. The complete picture describing the outcomes of NCCP cannot solely rely on MIR and PCIR ratios. These two ratios provide a useful estimate of cancer burden, but a comprehensive evaluation of NCCP outcomes requires additional indicators such as cancer screening rates, stage of cancer diagnosis, survival rates, access to treatment, and patient satisfaction with care.[39] Furthermore, qualitative continuous evaluation of the NCCP needs to be performed timely to keep track of the progress.[40]

Our estimates are based on composite indices, and the accuracy of our projections is limited by the availability and quality of the data used to construct these indices. There may be significant inaccuracies in the representation of data for low-income nations as a result of inadequate data collection systems.[41,42] Several studies also expressed their concerns about using composite indices as reliable tools for guiding national policies on cancer control.[43,44]

There are a number of other annual composite indicators that were not included in this study.[45,46] In addition, additional research is necessary to validate and refine our predictive model using more precise and up-to-date data in order to provide more accurate cancer outcome estimates. Our study provides valuable insights into global cancer control outcomes and can help policymakers in LICs/LMICs estimate and improve cancer control programs. In addition, the research can be expanded to include data from additional countries.

Conclusions

Our research demonstrates that composite indicators can be used as a valid proxy for estimating NCCP outcomes' progress. We discovered a strong correlation between cancer outcomes and composite indicators describing income, government spending, prosperity, environmental performance, corruption, happiness, and quality of life. According to our research, the HDI and the LPI are the two best indicators of a country's cancer control efforts. A multiple regression machine learning model created with multiple composite and economic indicators improved the accuracy of predicting cancer control outcomes. This study can be used by policymakers to guide their strategies and improve the management of cancer control initiatives, thereby reducing the cancer burden.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Ferlay J, Ervik M, Lam F, Laversanne M, Colombet M, Mery L, *et al*. Global Cancer Observatory: Cancer Today. Lyon, France: International Agency for Research on Cancer; 2024. Available from: https://www.gco.iarc.who.int/today. [Last accessed on 2024 Mar 05].
2. Sarkar B, Munshi A, Rastogi K, Ganesh T, Bansal K, Manikandan A, *et al.* Cancer care medical tourism in the national capital region of India – Challenges for overseas patients treated in two private hospitals. Health Policy Technol 2022;11:100659.
3. Romero Y, Trapani D, Johnson S, Tittenbrun Z, Given L, Hohman K, *et al.* National cancer control plans: A global analysis. Lancet Oncol 2018;19:e546-55.
4. World Health Organization. National Cancer Control Programmes: Policies and Managerial Guidelines. 2nd ed. WHO, Geneva: World Health Organization; 2002. Available from: https://www.apps.who.int/iris/handle/10665/42494. [Last accessed on 2022 Dec 15].
5. International Cancer Control Partnership (ICCP) | UICC. Available from: https://www.uicc.org/who-we-work/networks/international-cancer-control-partnership-iccp. [Last accessed on 2022 Dec 15].
6. Progress – NCI. Available from: https://www.cancer.gov/research/progress. [Last accessed on 2022 Dec 15].
7. Yang TW, Wang CC, Hung WC, Liu YH, Sung WW, Tsai MC. Improvement in the mortality-to-incidence ratios for gastric cancer in developed countries with high health expenditures. Front Public Health

2021;9:713895.
8. Amini M, Looha MA, Zarean E, Pourhoseingholi MA. Global pattern of trends in incidence, mortality, and mortality-to-incidence ratio rates related to liver cancer, 1990-2019: A longitudinal analysis based on the global burden of disease study. BMC Public Health 2022;22:604.
9. Wang CC, Sung WW, Yan PY, Ko PY, Tsai MC. Favorable colorectal cancer mortality-to-incidence ratios in countries with high expenditures on health and development index: A study based on GLOBOCAN database. Medicine (Baltimore) 2021;100:e27414.
10. Mathew A, George PS, Ramadas K, Mathew BS, Kumar A, Roshni S, *et al.* Sociodemographic factors and stage of cancer at diagnosis: A population-based study in South India. J Glob Oncol 2019;5:1-10.
11. Lin SW, Anisa KN. Effects of socioeconomic status on cancer patient survival: Counterfactual event-based mediation analysis. Cancer Causes Control 2021;32:83-93.
12. Tabuchi T. Cancer and socioeconomic status. In: Social Determinants of Health in Non-communicable Diseases: Case Studies from Japan. Springer, Japan; 2020. p. 31-40.
13. Clegg LX, Reichman ME, Miller BA, Hankey BF, Singh GK, Lin YD, *et al.* Impact of socioeconomic status on cancer incidence and stage at diagnosis: Selected findings from the surveillance, epidemiology, and end results: National longitudinal mortality study. Cancer Causes Control 2009;20:417-35.
14. Legatum Prosperity Index; 2021. Available from: https://www.prosperity.com/. [Last accessed on 2022 Dec 15].
15. Helliwell JF, Layard R, Sachs JD, De Neve JE, Aknin LB, Wang S, editors. World Happiness Report 2022. New York: Sustainable Development Solutions Network; 2022. Available from: https://www.worldhappiness.report/ed/2022. [Last accessed on 2023 Jan 10].
16. Corruption Perceptions Index – Explore; 2021. Available from: https://www.transparency.org/en/cpi/2021. [Last accessed on 2022 Dec 15].
17. Global Health Expenditure Database. Available from: https://www.apps.who.int/nha/database/. [Last accessed on 2022 Dec 15].
18. UNDP (United Nations Development Programme). Human Development Report 2021-22: Uncertain Times, Unsettled Lives: Shaping our Future in a Transforming World. New York; 2022. Available from: https://www.hdr.undp.org/informe-sobre-desarrollo-humano-2021-22. [Last accessed on 2022 Dec 15].
19. Wolf MJ, Emerson JW, Esty DC, de Sherbinin A, Wendling ZA, *et al*. 2022 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law and Policy; 2022. Available from: https://www.epi.yale.edu/. [Last accessed on 2022 Dec 15].
20. National Program for Prevention and Control of Cancer, Diabetes, CVD and Stroke (NPCDCS) | National Health Portal of India. Available from: https://www.nhp.gov.in/national-programme-for-prevention-and-control-of-c_pg. [Last accessed on 2022 Dec 15].
21. Bansal AK, Kulshrestha N, Nagaraja SB, Rade K, Choudhary A, Parmar M, *et al.* Composite indicator: New tool for monitoring RNTCP performance in India. Int J Tuberc Lung Dis 2014;18:840-2.
22. Lara-Carrillo E, Herrera-Serna BY, Conzuelo-Rodríguez G, do Amaral RC, Aguilera-Eguía RA, Toral-Rizo VH. Effect of human development index and other socioeconomic factors on mortality-to-incidence ratio of lips and oral cavity cancer in Mexican states: An ecological study. BMJ Open 2021;11:e042376.
23. Fidler MM, Bray F, Soerjomataram I. The global cancer burden and human development: A review. Scand J Public Health 2018;46:27-36.
24. Engholm G, Ferlay J, Christensen N, Bray F, Gjerstorff ML, Klint A, *et al.* NORDCAN – A Nordic tool for cancer information, planning, quality control and research. Acta Oncol 2010;49:725-36.
25. How Does the World Bank Classify Countries? World Bank Data Help Desk. Available from: https://www.datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries. [Last accessed on 2024 Mar 05].
26. Lortet-Tieulent J, Georges D, Bray F, Vaccarella S. Profiling global cancer incidence and mortality by socioeconomic development. Int J Cancer 2020;147:3029-36.
27. Cancer Rates Decline in Many High-Income Countries, but Rise in Lower-Income Countries-Ecancer. Available from: https://www.ecancer.org/en/news/8351-cancer-rates-decline-in-many-high-income-countries-but-rise-in-lower-income-countries. [Last accessed on 2023 Jan 10].
28. Sharma R, Aashima, Nanda M, Fronterre C, Sewagudde P, Ssentongo AE, *et al.* Mapping cancer in Africa: A comprehensive and comparable characterization of 34 cancer types using estimates from GLOBOCAN 2020. Front Public Health 2022;10:839835.
29. Xie L, Shang ZJ. Oral cancer incidence, mortality, and mortality-to-incidence ratio are associated with human development index in China, 1990-2019. Biomed Res Int 2022;2022:6457840.
30. Rezaeian S, Khazaei S, Khazaei S, Mansori K, Sanjari Moghaddam A, Ayubi E. Human development inequality index and cancer pattern: A global distributive study. Asian Pac J Cancer Prev 2016;17:201-4.
31. Su CC, Chen BS, Chen HH, Sung WW, Wang CC, Tsai MC. Improved trends in the mortality-to-incidence ratios for liver cancer in countries with high development index and health expenditures. Healthcare (Basel) 2023;11:159.
32. Choi HC, Lam KO, Pang HH, Tsang SK, Ngan RK, Lee AW. Global comparison of cancer outcomes: Standardization and correlation with healthcare expenditures. BMC Public Health 2019;19:1065.
33. Arnold M, Rutherford MJ, Bardot A, Ferlay J, Andersson TM, Myklebust TÅ, *et al.* Progress in cancer survival, mortality, and incidence in seven high-income countries 1995-2014 (ICBP SURVMARK-2): A population-based study. Lancet Oncol 2019;20:1493-505.
34. Sarkar B, Munshi A, Ganesh T, Manikandan A, Bhattacharjee B, Pun R, *et al.* Growth characteristics of female radiation/clinical oncologists in South Asia: Assessment of gender neutrality and leadership position. Clin Oncol (R Coll Radiol) 2022;34:e437-45.
35. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, *et al.* Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 2021;71:209-49.
36. Gulia S, Sengar M, Badwe R, Gupta S. National cancer control programme in India: Proposal for organization of chemotherapy and systemic therapy services. J Glob Oncol 2017;3:271-4.
37. National Cancer Control Programme | Ministry of Health and Family Welfare | GOI. Available from: https://www.main.mohfw.gov.in/Organisation/Departments-of-Health-and-Family-Welfare/national-cancer-control-programme. [Last accessed on 2023 Jan 15].
38. Shah SC, Kayamba V, Peek RM Jr., Heimburger D. Cancer control in low- and middle-income countries: Is it time to consider screening? J Glob Oncol 2019;5:1-8.
39. Oar A, Moraes FY, Romero Y, Ilbawi A, Yap ML. Core elements of national cancer control plans: A tool to support plan development and review. Lancet Oncol 2019;20:e645-52.
40. Rath GK, Gandhi AK. National cancer control and registration program in India. Indian J Med Paediatr Oncol 2014;35:288-90.
41. Lemma S, Janson A, Persson LÅ, Wickremasinghe D, Källestål C. Improving quality and use of routine health information system data in low- and middle-income countries: A scoping review. PLoS One 2020;15:e0239683.
42. Bezuidenhout L, Chakauya E. Hidden concerns of sharing research data by low/middle-income country scientists. Glob Bioeth 2018;29:39-54.
43. Barclay M, Dixon-Woods M, Lyratzopoulos G. The problem with composite indicators. BMJ Qual Saf 2019;28:338-44.
44. Kaiser M, Chen AT, Gluckman P. Should policy makers trust composite indices? A commentary on the pitfalls of inappropriate indices for policy formation. Health Res Policy Syst 2021;19:40.
45. World Health Organization. 2018 Global Reference List of 100 Core Health Indicators (Plus Health-Related SDGs). "WHO 100 core indicators 2018." World Health Organization; 2018. Available from: https://www.apps.who.int/iris/handle/10665/259951. [Last accessed on 2023 Jan 15].
46. Prinja S, Gupta R, Bahuguna P, Sharma A, Kumar Aggarwal A, Phogat A, *et al*. A composite indicator to measure universal health care coverage in India: Way forward for post-2015 health system performance monitoring framework. Health Policy Plan 2017;32:43-56.