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Original Research

Transitions from Infection-Related to Lifestyle-Related Cancer Burden in Kampala, Uganda: Projection of the Future Cancer Incidence up to 2030

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Keywords: Cancer incidence, Cancer surveillance, Cancer burden, Projections, Kaposi sarcoma; non-Hodgkin's lymphoma; Cervix; Breast; Prostate

ABSTRACT

Objective. In Uganda, infection-related cancers have made the greatest contribution to the cancer burden in the past; however, the burden from lifestyle-related cancers has been increased recently. Using the Kampala Cancer Registry data, we projected the incidence of top five cancers, namely, Kaposi sarcoma (KS), cervical, breast, and prostate cancer, and non-Hodgkin's lymphoma (NHL) in Uganda.

Setting. Uganda.

Main outcome measure. Cancer incidence data from 2001-2015 was used and projected to 2030. Population data was obtained from the Uganda Bureau of Statistics. Age-standardised incidence rates (ASR) and their trends over the observed and projected period were calculated. Percentage change in cancer incidence was calculated to determine whether cancer incidence changes were attributable to cancer risk changes or population changes.

Results. It was projected that the incidence of KS and NHL continue to decrease by 22.6% and 37.3%, respectively. The ASR of KS was expected to decline from 29.6 per 100,000 population to 10.4, while ASR of NHL was expected to decrease from 7.6 to 3.2. In contrast, cervical, breast, and prostate cancer incidence were projected to increase by 35.3%, 57.7%, and 33.4%, respectively. The ASRs of cervical and breast were projected to increase up to 66.1 and 48.4 per 100,000 females. The ASR of prostate cancer was estimated to increase from 41.6 to 60.5 per 100,000 males. These changes were due to changes in risk factors and population growth.

Conclusion. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in the cancer spectrum, from infection-related to lifestyle-related, yields another challenge to cancer control programs in resource-limited countries. Forthcoming cancer control programs should include a substantial focus on lifestyle-related cancers, while infectious disease control programs should be maintained.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study used the most recent cancer data available from Kampala Cancer Registry, and to our knowledge, this is the first study that predicts the future cancer incidence in Uganda.
- It was projected that there would be a rapid shift in the profile of common cancers in the next decade, including a continued decrease in the incidence of KS and NHL, and a substantial increase in the incidence of breast and prostate cancer.
- Change in the cancer spectrum projected from this study yields another challenge to cancer control programmes in Uganda: cancer control programs should include a substantial focus on lifestyle-related cancers, while infectious disease control programs should be maintained.
- A drawback of our projection is that the projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries. Hence, future studies in this regard are warranted.

INTRODUCTION

Cancer incidence and mortality are increasing worldwide.[1] The global burden of cancer is predicted to rise to nearly 22 million cases and 13 million deaths by 2030, with the major burden on low- and middle-income countries.[2] Analysis from recent cancer surveillance data shows a gradual increase in the overall incidence of cancer in both sexes in Uganda.[3 4]

The growing cancer-related burden in low and middle-income countries may be due to rising obesity rates, increasing sedentary lifestyles, dietary factors, and persistent carcinogenic infections. These countries share a concurrent burden of infection- and lifestyle-associated cancers.[5 6] Infection due to human immunodeficiency virus (HIV) and other viruses are well-established risk factors for cancer in Sub-Saharan Africa.[7] In Uganda, infection-related cancers, including Kaposi sarcoma (KS), cervical cancer, and non-Hodgkin's lymphoma (NHL), have been the cancers with the highest incidence in the past.[8 9] However, recent statistics reported an increase in the incidence of breast and prostate cancers due to changes in lifestyle-related risk factors.[8 9] Given the assumption that the transition in cancer-related lifestyle risk factors will persist, it is crucial to quantify the future cancer burden attributable to this transition.

Prediction of the future cancer burden is an essential cancer surveillance effort for planning services, policy, research, resource allocation, and to help establish cancer surveillance and control programmes.[7] Further, it informs future primary prevention strategies and research focus. However, to the best of our knowledge, the future cancer burden in Uganda has not been studied previously. Thus, this study was conducted to project the future incidence of the top five cancers in Uganda, namely, KS, cervical, breast, and prostate cancer, and NHL, to provide estimates crucial for planning future cancer surveillance systems.

MATERIALS AND METHODS

Data sources and manipulation

We obtained cancer incidence data from the Kampala Cancer Registry (2001–2015), a population-based registry covering Kampala and Kyadondo county[8], published in the International Agency for Research on Cancer report on Cancer Incidence in Five Continents.[10] Observed and projected population data was obtained from the Uganda Bureau of Statistics. The World Health Organization standard world population 2000–2025 was used for age-standardization.

Statistical analysis

First, age-standardized incidence rates (ASR) and trends over the observed period were estimated.[11] We used the Nordpred R-package, an age-period-cohort model developed by the cancer registry of Norway. A Poisson regression model with a power-link function for leveling off exponential growth was used to predict the future incidence, as recommended by Moller et al.[12-14] Data were aggregated into three observed 5-year periods (2001–2005, 2006–2010, 2011–2015) and three projected 5-year periods (2016–2020, 2021–2025, and 2026–2030). In order to maintain consistency with the population census data, we categorized the population into five-year age groups from 0–4 years to 70–74 years and 75+ years. To determine whether cancer incidence changes were attributable to cancer risk changes or population changes, we calculated the percentage change in cancer incidence over the last observed (2011–2015) and last projected periods (2026–2030), as described previously[12 15]. The percentage changes in the corresponding two periods were apportioned to the contributions of cancer risk and population structure change to help to determine whether changes in incidence are due to changes in cancer risk or due to population change.

Additionally, we performed joinpoint regression, using a segmented regression model in which the regression functions were constrained to be continuous at the joinpoints,[16] and

compared results with the results from the age-period-cohort model. The joinpoint model incorporated joinpoints, representing the year in which the most plausible trend changes occurred in cancer incidence. In order to project the future incidence, we extrapolated the ASRs based on the latest trend from the joinpoint regression.

RESULTS

Kaposi sarcoma and non-Hodgkin's lymphoma

During 2016–2030, the number of new KS cases was projected to decrease by 22.6% (19.9% in males, 17.6% in females) (Table 1). The decrease in new KS cases was primarily attributable to changes in risk factors (49.8%). Both crude and ASRs were predicted to decrease. The ASR of KS was expected to decline from 29.6 per 100,000 population in 2001–2005 to 10.4 per 100,000 by 2030 (Figure 1). The projected KS incidence rate was highest in males aged 35–39 years and females aged 30–34 years (Figure 2). Similarly, the incidence rate of NHL was expected to decrease 2-fold (from 7.6 to 3.2 per 100,000), and the number of new cases was projected to decrease by 37.3% (Figure 1 and Table 1).

Cervical cancer

We found that the burden of cervical cancer will remain high in the next decade in Uganda. The number of new cases was projected to increase to 1,781 by 2030, a 35.3% increase compared to the 2011–2015 period (Table 1). The ASR of cervical cancer was projected to increase from 52.6 to 66.1 per 100,000 population by 2030 (Figure 1). The incidence rate is expected to increase and peak among females aged 55 to 74 years (Figure 2).

Table 1. Observed and projected number of cancer cases, incidence rate, and percentage change of the top five cancers in Kampala, Uganda, 2011–2015 and 2026–2030

Cancer type (ICD-10 Code)	Sex	2011-2015 (Observed)			2026-2030 (Projected)			Percentage changes		
		Cases[a]	Crude[b]	ASR[b]	Cases[a]	Crude[b]	ASR[b]	Overall (%)[c]	Due to risk change (%)[d]	Due to population change (%)[e]
KS (C46)	Both	1,328	10.8	16.4	1,028	6.6	10.4	22.6	−49.8	27.2
	Male	777	13.3	21.4	623	8.4	14.5	19.9	−46.3	26.4
	Female	551	8.5	11.6	454	5.5	7.6	17.6	−45.6	28.0
NHL (C83)	Both	392	3.2	5.4	246	1.6	3.2	37.3	−64.5	27.2
	Male	219	3.8	5.9	144	1.9	3.1	34.4	−60.9	26.4
	Female	173	2.7	5.1	119	1.4	3.7	31.0	−59.0	28.0
Cervical (C53)	Female	1,316	20.2	60.5	1,781	21.4	66.1	35.3	7.4	28.0
Breast (C50)	Female	831	12.8	37.6	1,310	15.7	48.4	57.7	29.7	28.0
Prostate (C61)	Male	600	10.3	54.2	800	10.9	60.5	33.4	7.0	26.4

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardised rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] *Number of cancer cases of the five years*

[b] *Crude rates and ASRs were expressed as per 100,000 (Standardize population: standard world population WHO 2000-2025)*

[c] *Overall percent change in the projected cases of the period 2026–2030 compared to the observed cases of the period 2011–2015.*

[d] *Percentage change in the projected cases due to changes in the risk of each cancer site*

[e] *Percentage change in the projected cases due to changes in the size and age structure of the population.*

Breast and prostate cancers

The incidence of breast cancer was 37.6 per 100,000, with 831 cases in the years 2011-2015. According to our projection, its burden is expected to increase substantially to 48.4 per 100,000 females per year by 2030, with an expected 1,310 new cases between 2026 and 2030 (Table 1). In Uganda, female breast cancer was predicted to exceed 48 per 100,000 population per year by 2030 (Figure 1). The incidence was predicted to increase by approximately 57.7%, of which 29.7% will be attributable to change in risk factors, and 28.0% will be attributable to change in the population structure. The incidence rate was predicted to increase in all age groups older than 40 years (Figure 2).

Likewise, the projection model predicted that prostate cancer incidence will increase by 33.4% between 2011-2015 and 2026-2030. The number of new prostate cancer cases was reported as 600 in 2011–2015 and is predicted to increase to 800 new cases in 2026–2030 (Table 1). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 per year over the study period (Figure 1). The increased prostate incidence rate will be concentrated in men aged 50+ years (Figure 2).

Sensitivity analysis

Additionally, we performed joinpoint regression, and compared results with the findings from the age-period-cohort model. We extrapolated the ASRs based on the latest trend from the joinpoint regression. Findings from both approaches were consistent with an increase in the incidence rate of prostate, breast, and cervical cancers and a decreased incidence rate of KS and NHL (Table 2).

Table 2. The Age Standardized Rates by Nordpred and Joinpoint regression

Cancer type (ICD-10 Code)	Model	Observed/Fitted ASRs			Projected ASRs		
		2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
KS (C46), both male and female	Nordpred[a]	29.6	25.1	16.4	12.3	10.6	10.4
	Joinpoint[b]	28.4	29.0	19.9	12.3	7.6	4.7
KS (C46), male	Nordpred[a]	34.1	32.3	21.4	16.4	14.5	14.5
	Joinpoint[b]	32.1	34.6	26.2	15.7	9.4	5.6
KS (C46), female	Nordpred[a]	25.8	18.6	11.6	8.8	7.8	7.6
	Joinpoint[b]	24.2	23.6	14.1	8.5	5.1	3.1
NHL (C83), both male and female	Nordpred[a]	7.6	8.2	5.4	4.0	3.4	3.2
	Joinpoint[b]	5.1	8.9	6.3	4.5	3.2	2.3
NHL (C83), male	Nordpred[a]	9.1	9.5	5.9	4.2	3.3	3.1
	Joinpoint[b]	7.8	7.0	6.2	5.6	5.0	4.4
NHL (C83), female	Nordpred[a]	6.3	6.9	5.1	4.0	3.8	3.7
	Joinpoint[b]	7.0	9.9	6.9	4.0	2.4	1.4
Cervical (C53)	Nordpred[a]	52.6	56.0	60.5	63.7	65.8	66.1
	Joinpoint[b]	51.7	55.1	58.8	62.7	66.8	71.2
Breast (C50)	Nordpred[a]	33.2	35.2	37.6	40.6	44.1	48.4
	Joinpoint[b]	31.8	34.3	37.0	39.8	42.9	46.2
Prostate (C61)	Nordpred[a]	41.6	52.2	54.2	52.8	55.5	60.5
	Joinpoint[b]	42.8	47.5	52.8	58.7	65.2	72.5

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardized rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] Observed ASRs and projected ASRs from Nordpred regression model for each five-year period

[b] Joinpoint regression model was fitted using annual data from 2001-2015 and projected up to 2030. Only fitted and projected ASRs of the first year of each period (2001, 2006, 2011, 2016, 2021, 2026) were presented.

DISCUSSIONS

In this study, we projected incidence of top five cancers in Uganda using the recent data of Kampala Cancer Registry. The ongoing changes in the population structure, the transitions in the living environment, and the extent to which the government's efforts to combat cancer will jointly determine future cancer trends in Uganda. To our knowledge, this is the first study that predicts the future cancer incidence in Uganda. We predicted that the incidence rate of breast, prostate, and cervical cancers will increase, and KS and NHL incidence rates will decrease. Moreover, we found that the major shift in the incidence of the top five cancers in Uganda is mainly attributable to changes in the incidence rates of cancer-related risk factors.

Decreasing burden in infection-related cancers: Kaposi sarcoma, non-Hodgkin's lymphoma

The decreasing incidence rate of AIDS-related KS and NHL, particularly a substantial decrease in the KS incidence rate, provides indirect evidence of the success of national efforts to control infectious diseases, especially HIV infection.[18] In Uganda, many health interventions, including the early initiation of antiretroviral therapy, have been implemented to lower the risk of infectious diseases, leading to a significant decrease in the HIV incidence[19-21] and the risk of KS and NHL.[22]

Remaining burden of cervical cancer due to growing population

Cancer of the cervix uteri has been the most common cancer in Ugandan women since the 1950s.[17] A previous study reported that the average increase in Kampala's cervical cancer incidence rate was 1.5% over 25 years.[4] We found that the burden of cervical cancer will remain high in the next decade. The number of new cervical cancer cases was predicted to increase due to female population growth, indicating that a strategic plan for cervical cancer prevention and screening is needed. A cervical cancer screening programme has been proposed to be implemented, but screening in Uganda has remained erratic or opportunistic. The uptake of

cervical screening is low, and some screening modalities, such as Pap smears, are unavailable in some rural areas due to a lack of financial commitment.[4 23]

Emerging burden of lifestyle-related cancers: breast and prostate cancers

Lifestyle changes, such as older age at the first birth, reduced parity, alcohol use, smoking, and increased prevalence of obesity and physical inactivity in Uganda and other African countries, are likely to drive significant changes in future cancer statistics.[24 25] Currently, more than 80% of females with breast cancer in Uganda present with advanced disease, which accounts for the poor prognosis and low survival rate.[26] Given the substantial burden of breast cancer projected and the late presentation, the national cancer control plan should focus on prevention and early detection of breast cancer, making greater use of clinical breast examination and screening programmes.

The incidence of prostate cancer has been the most prevalent cancer type in Ugandan males since 1996[4 27], and the study results predict that the burden of this cancer will continue to increase. The projection model predicted that prostate cancer incidence would increase by 33.4% by 2030. The number of new prostate cancer cases was expected to increase to 800 in 2026–2030 (Table 1). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 over the study period (Figure 1). The increased prostate incidence rate will be concentrated in males aged 50+ years (Figure 2). A previous study suggested that the increase in prostate cancer incidence might be attributable to increased awareness, readiness to perform prostatectomy for urinary symptoms in older males, and histological examination of operative biopsies.[4 28] Thus, the implementation of prostate-specific antigen screening in Uganda could have also contributed to the increased detection of new cases in recent years.[28]

Limitation

It should be noticed that in our projection, the age-period-cohort model assumes that past trends will continue in the future, which may not be accurate in some cases. Another

drawback of our projection is that the projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries. Hence, future studies in this regard are warranted. A modelling approach to explicitly assess cancer risk factors changes and the impact of cancer prevention efforts would be a valuable complement to this study.

Directions For Future Cancer Surveillance Towards Cancer Control Program

Our findings might be helpful for cancer surveillance and planning the allocation of resources for future cancer control. Results from our projection suggest that the risk of cancer in Uganda is driven by increases in the incidence of cancers associated with westernized lifestyle changes. The rising burden of prostate and breast cancer emphasizes the primary prevention to focus on behaviors, health awareness, and the importance of healthy lifestyle-related modification, such as physical activities, diet, and reducing adiposity. While infectious-related cancers, including KS and NHL have gradually decreased, cancer of the cervix is expected to increase in both new cases and rates. Thus, prevention of cervical cancer through vaccination programs and an effective screening program to detect preinvasive cases might be needed in future cancer surveillance and control program in Uganda.

Secondary prevention on early detection, with focusing on detect early-stage breast cancer cases, is likewise required. In Uganda, secondary prevention for breast cancer has been enhanced through increased awareness and increased screening and early detection efforts. However, screening is opportunistic, mainly in nature. The Uganda cancer institute has put in more effort by sending health workers to different regions for outreaches so that all people get a chance of being screened. Screening methods have improved from self-exam to ultrasound and then mammography. Increase of activism of survivorship where survivors willingly teach other women and increased funding from various cancer societies and organizations have also boosted early detection and good outcomes.[9] Prostate cancer has exhibited increasing trends in

incidence in Uganda over the years, and many strategies have been put in place to prevent its rampant escalation. There has been an increase in prostate cancer awareness and screening. Uganda has adopted the use of prostate-specific antigens in screening, which detects cases that may not otherwise have been seen in one's lifetime.[9 29]

To reduce the growing burden of cancer the government of Uganda has put in place some cancer control programs at a national level. One example is establishing a Community Program, also called the Comprehensive Cancer Program, that takes the lead in primary cancer prevention and early detection in Uganda. The program aims to reduce cancer risk by increasing access to cancer prevention services through mass media for cancer awareness, outreach. In addition, hospital-based health education on cancer risk factors, prevention, early detection measures, and screening for the leading cancers, including cervical, breast, and prostate cancer, were also conducted.[30] However, there is limited funding for this program, so some remote and hard-to-reach areas are not outreached.

CONCLUSION

In summary, the study found that substantial changes in the burden of cancers are likely to occur during the next decade due to a transition from infection-related to lifestyle-related cancers. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in the cancer spectrum, from infection-related to lifestyle-related, yields another challenge for both cancer surveillance to capture the burden as well as cancer control programmes in resource-limited countries.

Contributors: JA contributed to conceptualisation, data acquisition and curation, formal analysis, methodology and writing the original draft. SL contributed to data curation, formal analysis, methodology, validation, review and editing the manuscript. TT contributed to conceptualisation, formal analysis, review and editing the manuscript. CM contributed to data acquisition and curation, writing - review and editing the manuscript. HW contributed to data acquisition, resources, writing - review and editing the manuscript. SJ contributed to validation, writing - review and editing the manuscript. YC contributed to conceptualisation, validation, writing - review and editing the manuscript. YP contributed to conceptualisation, validation, writing - review and editing the manuscript. HC contributed to conceptualisation, methodology, validation, supervision and writing the original draft.

Conflicts of Interest: The authors have no conflicts of interest to disclose.

Patient and Public Involvement: The requirement for informed consent is not applicable because this study used de-identified secondary data.

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Data Availability Statement: The data used in this study was obtained from the Kampala Cancer Registry with permission. Data that support the findings of this study can be available upon reasonable request to the Kampala Cancer Registry (E-mail: kampalacancerregistry@gmail.com).

Ethics approval: This study was approved by the Institutional Review Board of the National Cancer Centre (approval number: NCC2019-0189).

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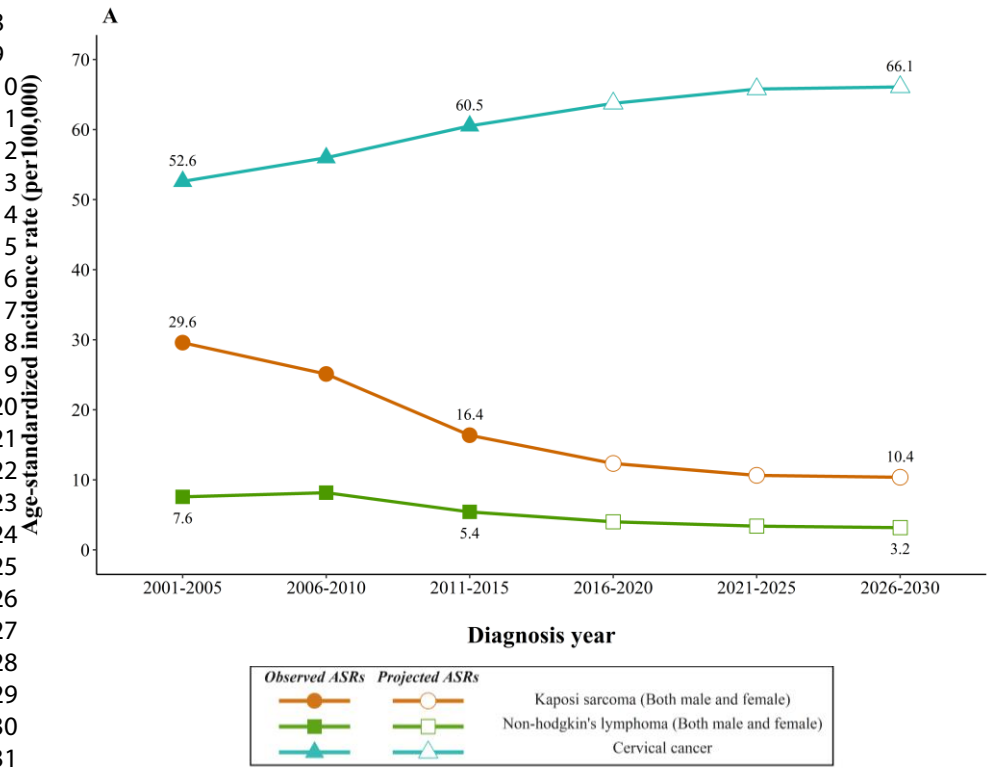
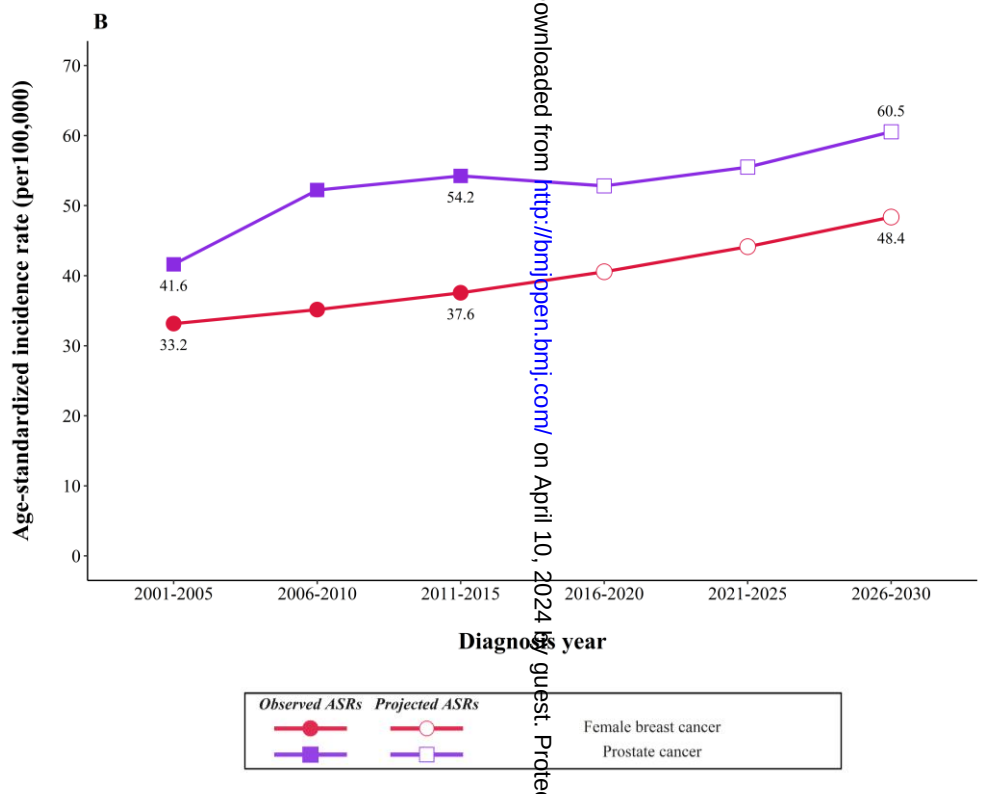
Figure legends

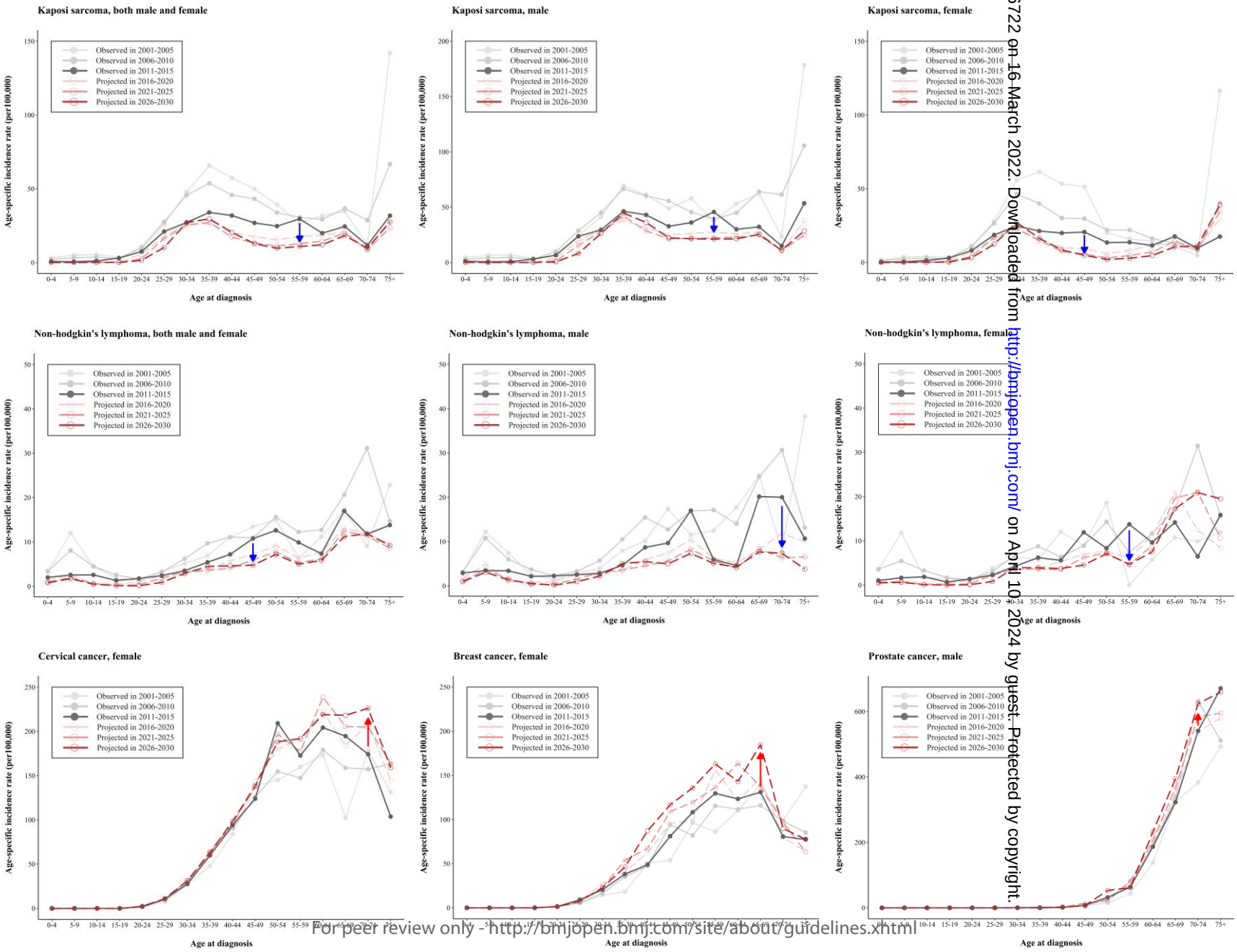
Figure 1. Current and future age-standardised rates of the five most common cancers in Uganda

(A) Observed and predicted trends in the Kaposi sarcoma, non-Hodgkin's lymphoma, and cervical cancer; (B) Observed and predicted trends in breast and prostate cancer.

Figure 2. Current and future age-specific incidence rates of the five most common cancers in Uganda







STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	Not applicable
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Not applicable
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-8
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Infection-Related and Lifestyle-Related Cancer Burden in Kampala, Uganda: Projection of the Future Cancer Incidence up to 2030

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Original Research

Infection-Related and Lifestyle-Related Cancer Burden in Kampala, Uganda: Projection of the Future Cancer Incidence up to 2030

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Keywords: Cancer incidence, Cancer surveillance, Cancer burden, Projections, Kaposi sarcoma; non-Hodgkin's lymphoma; Cervix; Breast; Prostate

ABSTRACT

Objectives. In Uganda, infection-related cancers have made the greatest contribution to cancer burden in the past; however, burden from lifestyle-related cancers has been increased recently. Using the Kampala Cancer Registry data, we projected incidence of top five cancers, namely, Kaposi sarcoma (KS), cervical, breast, and prostate cancer, and non-Hodgkin's lymphoma (NHL) in Uganda.

Design: Trend analysis of cancer registry data

Setting: Kampala cancer registry, Uganda.

Main outcome measure. Cancer incidence data from 2001-2015 was used and projected to 2030. Population data was obtained from the Uganda Bureau of Statistics. Age-standardised incidence rates (ASR) and their trends over the observed and projected period were calculated. Percentage change in cancer incidence was calculated to determine whether cancer incidence changes were attributable to cancer risk changes or population changes.

Results. It was projected that the incidence of KS and NHL continue to decrease by 22.6% and 37.3%, respectively. The ASR of KS was expected to decline from 29.6 per 100,000 population to 10.4, while ASR of NHL was expected to decrease from 7.6 to 3.2. In contrast, cervical, breast, and prostate cancer incidence were projected to increase by 35.3%, 57.7%, and 33.4%, respectively. The ASRs of cervical and breast were projected to increase up to 66.1 and 48.4 per 100,000 females. The ASR of prostate cancer was estimated to increase from 41.6 to 60.5 per 100,000 males. These changes were due to changes in risk factors and population growth.

Conclusion. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in cancer spectrum, from infection-related to lifestyle-related, yields another challenge to cancer control programs in resource-limited countries. Forthcoming cancer control programs should include

a substantial focus on lifestyle-related cancers, while infectious disease control programs should be maintained.

Strengths and limitations of this study

- Using the most recent available data of the Kampala Cancer Registry, this study projected the future burden of the most common cancers in Uganda.
- The prediction was based on long-established cancer registry data in Uganda.
- Results were based on the age-period-cohort model, which is a well-known long-term prediction of cancer incidence.
- Our projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries.
- This study only assessed the current top five cancer sites in Uganda, and thus other cancer sites are needed in future studies.

INTRODUCTION

Cancer incidence and mortality are increasing worldwide.[1] The global burden of cancer is predicted to rise to nearly 22 million cases and 13 million deaths by 2030, with the major burden on low- and middle-income countries.[2] Analysis from recent cancer surveillance data shows a gradual increase in the overall incidence of cancer in both sexes in Uganda, with an overall increase in age-adjusted rates of 25% in the period of 2011-2015 compared to the period of 1991-1995.[3 4] Even though the most commonly registered cancer over the 25-years period was Kaposi sarcoma, these studies further suggested an increase in prostate, breast and cervix cancers in Uganda. [3 4] Thus, studies to predict and quantify the future burden of these cancer sites are needed.

The growing cancer-related burden in low and middle-income countries may be due to rising obesity rates, increasing sedentary lifestyles, dietary factors, and persistent carcinogenic infections. These countries share a concurrent burden of infection- and lifestyle-associated cancers.[5 6] Infection due to human immunodeficiency virus (HIV) and other viruses are well-established risk factors for cancer in Sub-Saharan Africa.[7] In Uganda, infection-related cancers, including Kaposi sarcoma (KS), cervical cancer, and non-Hodgkin's lymphoma (NHL), have been the cancers with the highest incidence in the past.[3 8] However, recent statistics reported an increase in the incidence of breast and prostate cancers due to changes in lifestyle-related risk factors.[3 8] Given the assumption that the transition in cancer-related lifestyle risk factors will persist, it is crucial to quantify the future cancer burden attributable to this transition.

Prediction of the future cancer burden is an essential cancer surveillance effort for planning services, policy, research, resource allocation, and to help establish cancer surveillance and control programmes.[7] Further, it informs future primary prevention strategies and research focus. However, to the best of our knowledge, the future cancer burden in Uganda has not been studied previously. Thus, this study was conducted to project the future incidence

of the top five cancers in Uganda, namely, KS, cervical, breast, and prostate cancer, and NHL, to provide estimates crucial for planning future cancer surveillance systems.

MATERIALS AND METHODS

Data sources and manipulation

We obtained cancer incidence data from the Kampala Cancer Registry (2001–2015), a population-based registry covering Kampala and Kyadondo county[8], published in the International Agency for Research on Cancer report on Cancer Incidence in Five Continents [9]. Observed and projected population data was obtained from the Uganda Bureau of Statistics which provided the estimates by gender and 5-year age groups. The population pyramids of years 2014 and 2030 was described in Supplementary Figure 1. The World Health Organization standard world population 2000–2025 was used for age-standardization.

Statistical analysis

First, age-standardized incidence rates (ASR) and trends over the observed period were estimated.[10] We used the Nordpred R-package, an age-period-cohort model developed by the cancer registry of Norway. A Poisson regression model with a power-link function for levelling off exponential growth was used to predict the future incidence, as recommended by Moller et al.[11-13] Data were aggregated into three observed 5-year periods (2001–2005, 2006–2010, 2011–2015) and three projected 5-year periods (2016–2020, 2021–2025, and 2026–2030). In order to maintain consistency with the population census data, we categorized the population into five-year age groups from 0–4 years to 70–74 years and 75+ years. To determine whether cancer incidence changes were attributable to cancer risk changes or population changes, we calculated the percentage change in cancer incidence over the last observed (2011–2015) and last projected periods (2026–2030), as described previously[11 14]. The percentage changes in the corresponding two periods were apportioned to the contributions of cancer risk and population

structure change to help to determine whether changes in incidence are due to changes in cancer risk or due to population change. The "cancer risk change" indicates changes in cancer profiles due to the changes in specific cancer-related risk factors (for example, HPV vaccination and cervical cancer). The change in cancer burden due to "population change" indicates the increase/decrease in cancer cases due to an increase/decrease in the population (for example, increasing elderly population and prostate cancer).[11 14]

Additionally, we performed joinpoint regression, using a segmented regression model in which the regression functions were constrained to be continuous at the joinpoints,[15] and compared results with the results from the age-period-cohort model. The joinpoint model incorporated joinpoints, representing the year in which the most plausible trend changes occurred in cancer incidence. In order to project the future incidence, we extrapolated the ASRs based on the latest trend from the joinpoint regression. There was no patient or public involvement in this study. All analyses were conducted using the R software version 3.6.1 (R Foundation for Statistical Computing), with a two-sided type I error and an alpha value of 0.05.

RESULTS

Kaposi sarcoma and non-Hodgkin's lymphoma

During 2016–2030, the number of new KS cases was projected to decrease by 22.6% (19.9% in males, 17.6% in females) (**Table 1**). The decrease in new KS cases was primarily attributable to changes in risk factors (49.8%). Both crude and ASRs were predicted to decrease. The ASR of KS was expected to decline from 29.6 per 100,000 population in 2001–2005 to 10.4 per 100,000 by 2030 (**Figure 1**). The projected KS incidence rate was highest in males aged 35–39 years and females aged 30–34 years (**Figure 2**). Similarly, the incidence rate of NHL was expected to decrease 2-fold (from 7.6 to 3.2 per 100,000), and the number of new cases was projected to decrease by 37.3% (**Figure 1 and Table 1**). The number of KS and NHL cases

showed a decreasing trend in both observed and projected study periods, and the peak age group was 3-40 years in both genders. (**Figure 3**)

Cervical cancer

We found that the burden of cervical cancer will remain high in the next decade in Uganda. The number of new cases was projected to increase to 1,781 by 2030, a 35.3% increase compared to the 2011–2015 period (**Table 1**). The ASR of cervical cancer was projected to increase from 52.6 to 66.1 per 100,000 population by 2030 (**Figure 1**). The incidence rate is expected to increase and peak among females aged 55 to 74 years (**Figure 2**). Cervical cancer cases are expected to increase across all age groups and there were more cases among women aged 30 to 54. (**Figure 3**)

Breast cancer

The incidence of breast cancer was 37.6 per 100,000, with 831 cases in the years 2011-2015. According to our projection, its burden is expected to increase substantially to 48.4 per 100,000 females per year by 2030, with an expected 1,310 new cases between 2026 and 2030 (**Table 1**). In Uganda, female breast cancer was predicted to exceed 48 per 100,000 population per year by 2030 (**Figure 1**). The incidence was predicted to increase by approximately 57.7%, of which 29.7% will be attributable to change in risk factors, and 28.0% will be attributable to change in the population structure. The incidence rate was predicted to increase in all age groups older than 40 years (**Figure 2**). The number of breast cancer cases are expected to increase across all age groups and more cases are predicted among women aged 30 to 55 years. (**Figure 3**)

Table 1. Observed and projected number of cancer cases, incidence rate, and percentage change of the top five cancers in Kampala, Uganda, 2011–2015 and 2026–2030

Cancer type (ICD-10 Code)	Sex	2011-2015 (Observed)			2026-2030 (Projected)			Percentage changes		
		Cases[a]	Crude[b]	ASR[b]	Cases[a]	Crude[b]	ASR[b]	Overall (%)[c]	Due to risk change (%)[d]	Due to population change (%)[e]
KS (C46)	Both	1,328	10.8	16.4	1,028	6.6	10.4	22.6	−49.8	27.2
	Male	777	13.3	21.4	623	8.4	14.5	19.9	−46.3	26.4
	Female	551	8.5	11.6	454	5.5	7.6	17.6	−45.6	28.0
NHL (C83)	Both	392	3.2	5.4	246	1.6	3.2	37.3	−64.5	27.2
	Male	219	3.8	5.9	144	1.9	3.1	34.4	−60.9	26.4
	Female	173	2.7	5.1	119	1.4	3.7	31.0	−59.0	28.0
Cervical (C53)	Female	1,316	20.2	60.5	1,781	21.4	66.1	35.3	7.4	28.0
Breast (C50)	Female	831	12.8	37.6	1,310	15.7	48.4	57.7	29.7	28.0
Prostate (C61)	Male	600	10.3	54.2	800	10.9	60.5	33.4	7.0	26.4

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardised rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] *Number of cancer cases of the five years*

[b] *Crude rates and ASRs were expressed as per 100,000 (Standardize population: standard world population WHO 2000-2025)*

[c] *Overall percent change in the projected cases of the period 2026–2030 compared to the observed cases of the period 2011–2015.*

[d] *Percentage change in the projected cases due to changes in the risk of each cancer site*

[e] *Percentage change in the projected cases due to changes in the size and age structure of the population.*

Prostate cancer

Likewise, the projection model predicted that prostate cancer incidence will increase by 33.4% between 2011-2015 and 2026-2030. The number of new prostate cancer cases was reported as 600 in 2011–2015 and is predicted to increase to 800 new cases in 2026–2030 (**Table 1**). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 per year over the study period (**Figure 1**). The increased prostate incidence rate will be concentrated in men aged 50+ years (**Figure 2**). More cases were observed among men aged 60 and above and the number of cases is expected to continually increase in the future across all age groups. (**Figure 3**)

Sensitivity analysis

Additionally, we performed joinpoint regression, and compared results with the findings from the age-period-cohort model. The joinpoint model incorporated joinpoints, representing the year in which the most plausible trend changes occurred in cancer incidence. We extrapolated the ASRs based on the latest trend from the joinpoint regression. Findings from the main analysis and joinpoint regression were consistent with an increase in the incidence rate of prostate, breast, and cervical cancers and a decreased incidence rate of KS and NHL (**Table 2**).

Table 2. The Age Standardized Rates by Nordpred and Joinpoint regression

Cancer type (ICD-10 Code)	Model	Observed/Fitted ASRs			Projected ASRs		
		2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
KS (C46), both male and female	Nordpred[a]	29.6	25.1	16.4	12.3	10.6	10.4
	Joinpoint[b]	28.4	29.0	19.9	12.3	7.6	4.7
KS (C46), male	Nordpred[a]	34.1	32.3	21.4	16.4	14.5	14.5
	Joinpoint[b]	32.1	34.6	26.2	15.7	9.4	5.6
KS (C46), female	Nordpred[a]	25.8	18.6	11.6	8.8	7.8	7.6
	Joinpoint[b]	24.2	23.6	14.1	8.5	5.1	3.1
NHL (C83), both male and female	Nordpred[a]	7.6	8.2	5.4	4.0	3.4	3.2
	Joinpoint[b]	5.1	8.9	6.3	4.5	3.2	2.3
NHL (C83), male	Nordpred[a]	9.1	9.5	5.9	4.2	3.3	3.1
	Joinpoint[b]	7.8	7.0	6.2	5.6	5.0	4.4
NHL (C83), female	Nordpred[a]	6.3	6.9	5.1	4.0	3.8	3.7
	Joinpoint[b]	7.0	9.9	6.9	4.0	2.4	1.4
Cervical (C53)	Nordpred[a]	52.6	56.0	60.5	63.7	65.8	66.1
	Joinpoint[b]	51.7	55.1	58.8	62.7	66.8	71.2
Breast (C50)	Nordpred[a]	33.2	35.2	37.6	40.6	44.1	48.4
	Joinpoint[b]	31.8	34.3	37.0	39.8	42.9	46.2
Prostate (C61)	Nordpred[a]	41.6	52.2	54.2	52.8	55.5	60.5
	Joinpoint[b]	42.8	47.5	52.8	58.7	65.2	72.5

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardized rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] Observed ASRs and projected ASRs from Nordpred regression model for each five-year period

[b] Joinpoint regression model was fitted using annual data from 2001-2015 and projected up to 2030. Only fitted and projected ASRs of the first year of each period (2001, 2006, 2011, 2016, 2021, 2026) were presented.

DISCUSSION

In this study, we projected incidence of top five cancers in Uganda using the recent data of Kampala Cancer Registry. The ongoing changes in the population structure, the transitions in the living environment, and the extent to which the government's efforts to combat cancer will jointly determine future cancer trends in Uganda. To our knowledge, this is the first study that predicts the future cancer incidence in Uganda. We predicted that the incidence rate of breast, prostate, and cervical cancers will increase, and KS and NHL incidence rates will decrease. Moreover, we found that the major shift in the incidence of the top five cancers in Uganda is mainly attributable to changes in the incidence rates of cancer-related risk factors.

Decreasing burden in infection-related cancers: Kaposi sarcoma, non-Hodgkin's lymphoma

The decreasing incidence rate of AIDS-related KS and NHL, particularly a substantial decrease in the KS incidence rate, provides indirect evidence of the success of national efforts to control infectious diseases, especially HIV infection.[16] In Uganda, many health interventions, including the early initiation of antiretroviral therapy, have been implemented to lower the risk of infectious diseases, leading to a significant decrease in the HIV incidence[17-19] and the risk of KS and NHL.[20] As a result, Uganda is one of the countries that has managed to curb down the growing burden of HIV infection. There has been a drastic decrease in the prevalence rates of HIV infections from 30% in the 1990s to 6.5% in the 2016.[21 22]

Remaining burden of cervical cancer due to growing population

Cancer of the cervix uteri has been the most common cancer in Ugandan women since the 1950s.[23] A previous study reported that the average increase in Kampala's cervical cancer incidence rate was 1.5% over 25 years.[4] We found that the burden of cervical cancer will remain high in the next decade. The number of new cervical cancer cases was predicted to increase due to female population growth, indicating that a strategic plan for cervical cancer prevention and screening is needed. A cervical cancer screening programme has been proposed to be

implemented, but screening in Uganda has remained erratic or opportunistic. The uptake of cervical screening is low, and some screening modalities, such as Pap smears, are unavailable in some rural areas due to a lack of financial commitment.[4 24]

Emerging burden of lifestyle-related cancers: breast and prostate cancers

Lifestyle changes, such as older age at the first birth, reduced parity, alcohol use, smoking, and increased prevalence of obesity and physical inactivity in Uganda and other African countries, are likely to drive significant changes in future cancer statistics.[25 26] Currently, more than 80% of females with breast cancer in Uganda present with advanced disease, which accounts for the poor prognosis and low survival rate.[27] Given the substantial burden of breast cancer projected and the late presentation, the national cancer control plan should focus on prevention and early detection of breast cancer, making greater use of clinical breast examination and screening programmes.

The incidence of prostate cancer has been the most prevalent cancer type in Ugandan males since 1996[4 28], and the study results predict that the burden of this cancer will continue to increase. The projection model predicted that prostate cancer incidence would increase by 33.4% by 2030. The number of new prostate cancer cases was expected to increase to 800 in 2026–2030 (Table 1). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 over the study period (Figure 1). The increased prostate incidence rate will be concentrated in males aged 50+ years (Figure 2). A previous study suggested that the increase in prostate cancer incidence might be attributable to increased awareness, readiness to perform prostatectomy for urinary symptoms in older males, and histological examination of operative biopsies.[4 29] Thus, the implementation of prostate-specific antigen screening in Uganda could have also contributed to the increased detection of new cases in recent years.[29]

Strengths and Limitations

This study was, to our knowledge, the first study to predict the future cancer burden in Uganda. Data quality of the Kampala Cancer Registry has been qualified by the International Agency for Research on Cancer. Therefore, its data has been published in all Cancer Incidence in Five Continents recent volumes [9]. However, it should be noted that despite the increase in the annual number of cases, data quality indicators, including percentage of morphologically verified and death certificate only cases, have remained relatively low over time. Despite these drawbacks in data quality, data from Kampala Cancer Registry still has its strong point as the longest standing registry in Africa. Thus, projection of cancer burden from this cancer registry might help provide evidence on the cancer burden of Uganda and other African countries. Another strong point of this study is that we performed join point regression [15], and compared results with the results from the age-period-cohort model as a sensitivity analysis. Findings from both approaches were consistent with an increase in the incidence rate of prostate, breast, and cervical cancers and a decreased incidence rate of KS and NHL.

There are several limitations of this study. First, it should be noticed that in our projection, both the age-period-cohort model and joint point regression assume that past trends will continue in the future, which may not be accurate in some cases. Another drawback of our projection is that the projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries. Hence, future studies in this regard are warranted. A modelling approach to explicitly assess cancer risk factors changes and the impact of cancer prevention efforts would be a valuable complement to this study. In addition, the most recent cancer statistics of Uganda[30] indicates that oesophagus and liver cancers have surpassed Non-Hodgkin lymphoma cancer and were among the most commonly diagnosed cancers. Thus, trends in these cancer sites are needed in future research to provide a more comprehensive cancer burden prediction of Uganda.

Directions For Future Cancer Surveillance Towards Cancer Control Program

Our findings might be helpful for cancer surveillance and planning the allocation of resources for future cancer control. Results from our projection suggest that the risk of cancer in Uganda is driven by increases in the incidence of cancers associated with westernized lifestyle changes. The rising burden of prostate and breast cancer emphasizes the primary prevention to focus on behaviours, health awareness, and the importance of healthy lifestyle-related modification, such as physical activities, diet, and reducing adiposity. While infectious-related cancers, including KS and NHL have gradually decreased, cancer of the cervix is expected to increase in both new cases and rates. Thus, prevention of cervical cancer through vaccination programs and an effective screening program to detect preinvasive cases might be needed in future cancer surveillance and control program in Uganda.

Secondary prevention on early detection, with focusing on detect early-stage breast cancer cases, is likewise required. In Uganda, secondary prevention for breast cancer has been enhanced through increased awareness and increased screening and early detection efforts. However, screening is opportunistic, mainly in nature. The Uganda cancer institute has put in more effort by sending health workers to different regions for outreaches so that all people get a chance of being screened. Screening methods have improved from self-exam to ultrasound and then mammography. Increase of activism of survivorship where survivors willingly teach other women and increased funding from various cancer societies and organizations have also boosted early detection and good outcomes.[3] Prostate cancer has exhibited increasing trends in incidence in Uganda over the years, and many strategies have been put in place to prevent its rampant escalation. There has been an increase in prostate cancer awareness and screening. Uganda has adopted the use of prostate-specific antigens in screening, which detects cases that may not otherwise have been seen in one's lifetime.[3 31]

To reduce the growing burden of cancer the government of Uganda has put in place some cancer control programs at a national level. One example is establishing a Community Program, also called the Comprehensive Cancer Program, that takes the lead in primary cancer prevention and early detection in Uganda. The program aims to reduce cancer risk by increasing access to cancer prevention services through mass media for cancer awareness, outreach. In addition, hospital-based health education on cancer risk factors, prevention, early detection measures, and screening for the leading cancers, including cervical, breast, and prostate cancer, were also conducted.[32] However, there is limited funding for this program, so some remote and hard-to-reach areas are not outreached.

CONCLUSION

In summary, the study found that substantial changes in the burden of cancers are likely to occur during the next decade due to a transition from infection-related to lifestyle-related cancers. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in the cancer spectrum, from infection-related to lifestyle-related, yields another challenge for both cancer surveillance to capture the burden as well as cancer control programmes in resource-limited countries.

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Data Availability Statement: The data used in this study was obtained from the Kampala Cancer Registry with permission. Data that support the findings of this study can be available upon reasonable request to the Kampala Cancer Registry (E-mail: kampalacancerregistry@gmail.com).

Ethics approval: This study was approved by the Institutional Review Board of the National Cancer Centre (approval number: NCC2019-0189). The requirement for informed consent is not applicable because this study used de-identified secondary data.

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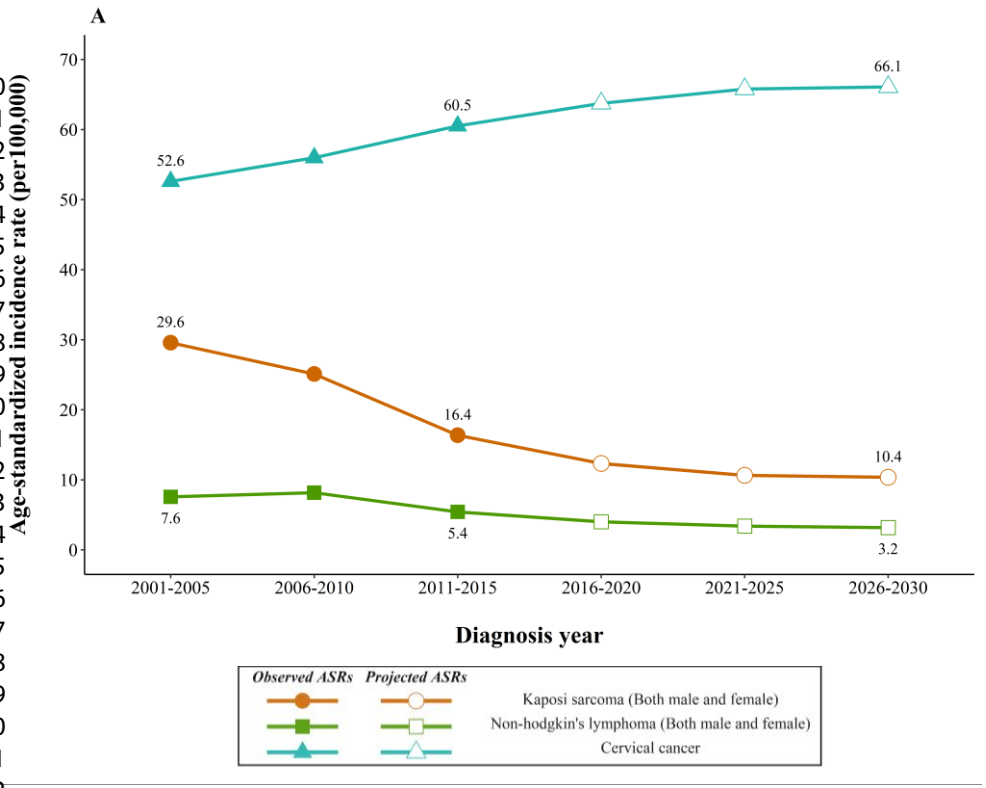
Figure legends

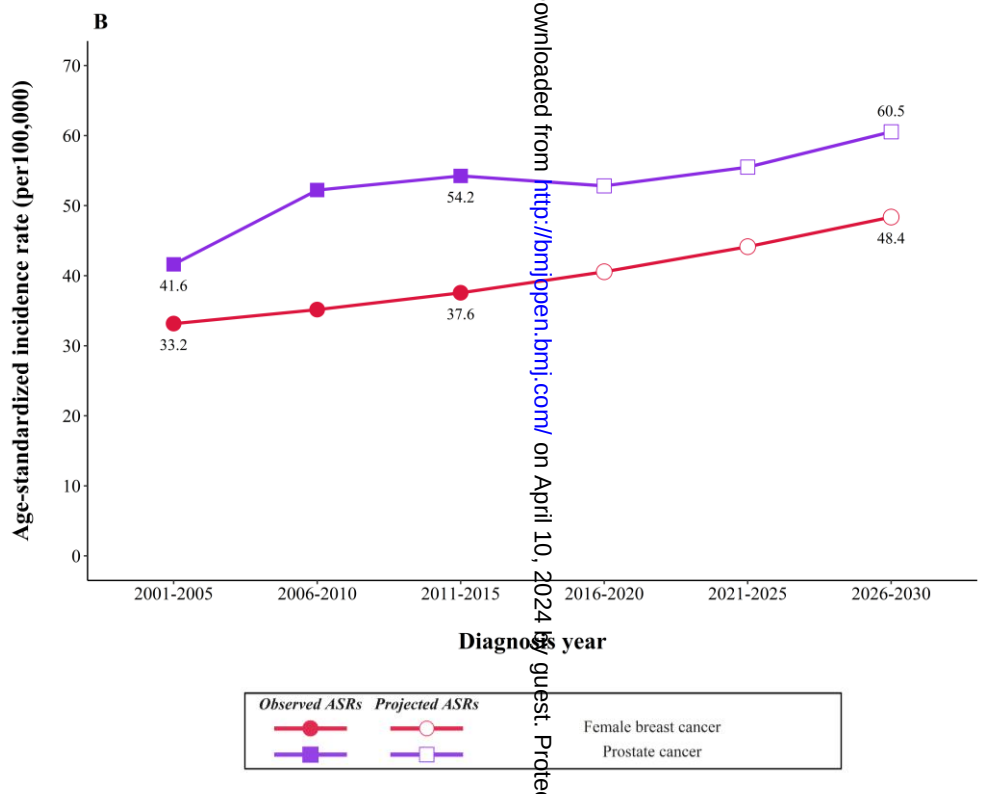
Figure 1. Current and future age-standardised rates of the five most common cancers in Uganda

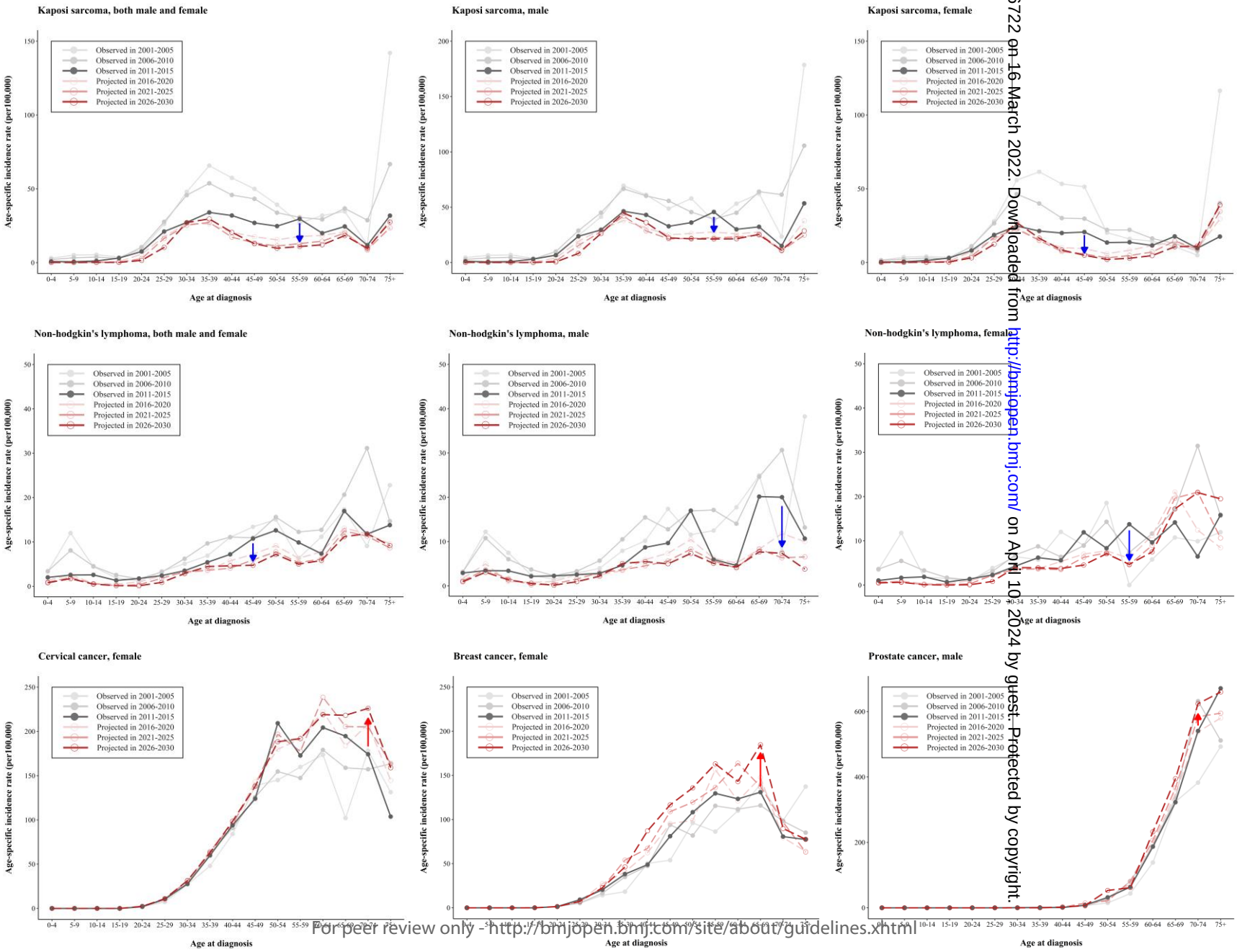
(A) Observed and predicted trends in the Kaposi sarcoma, non-Hodgkin's lymphoma, and cervical cancer; (B) Observed and predicted trends in breast and prostate cancer.

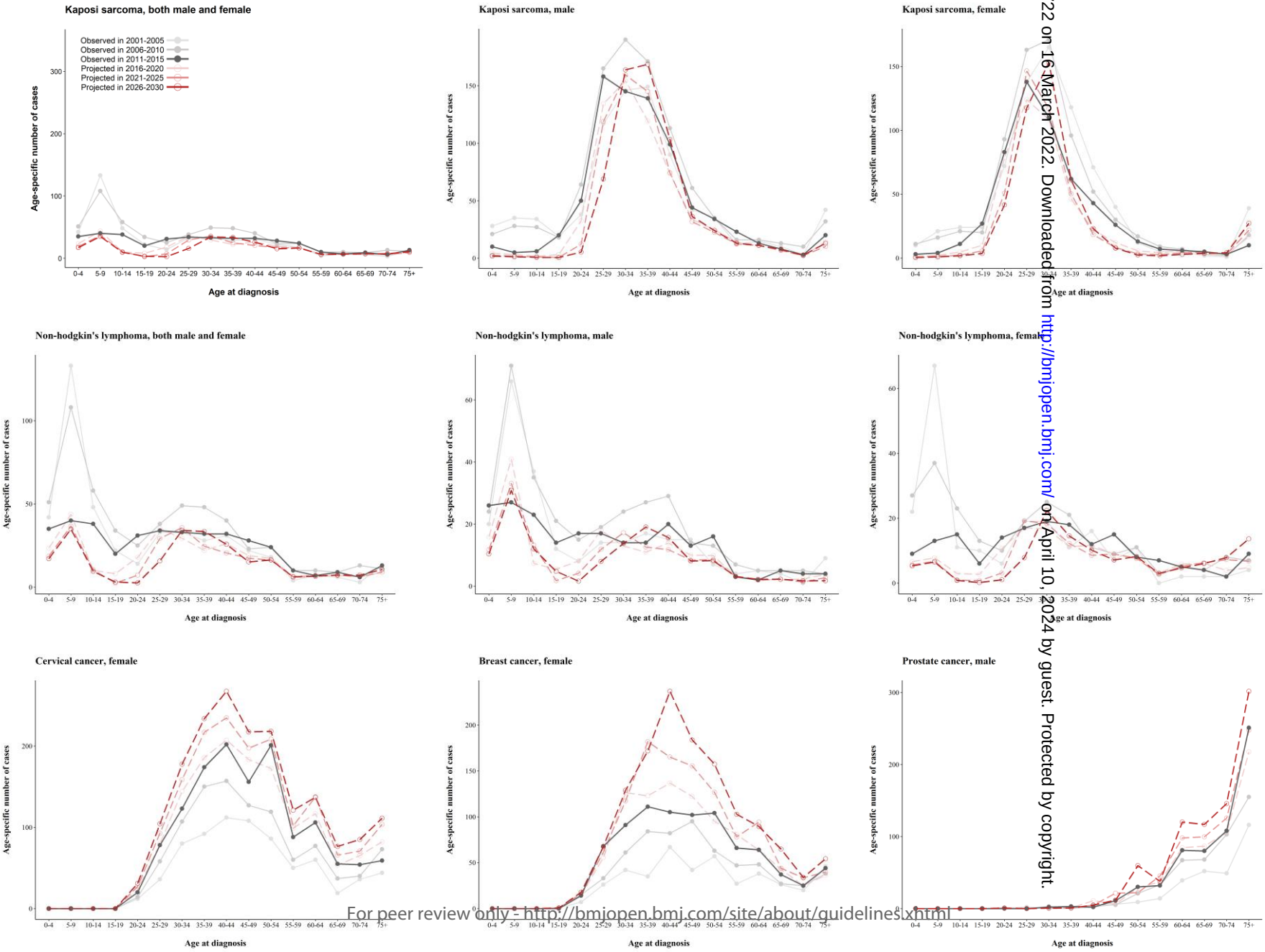
Figure 2. Current and future age-specific incidence rates of the five most common cancers in Uganda

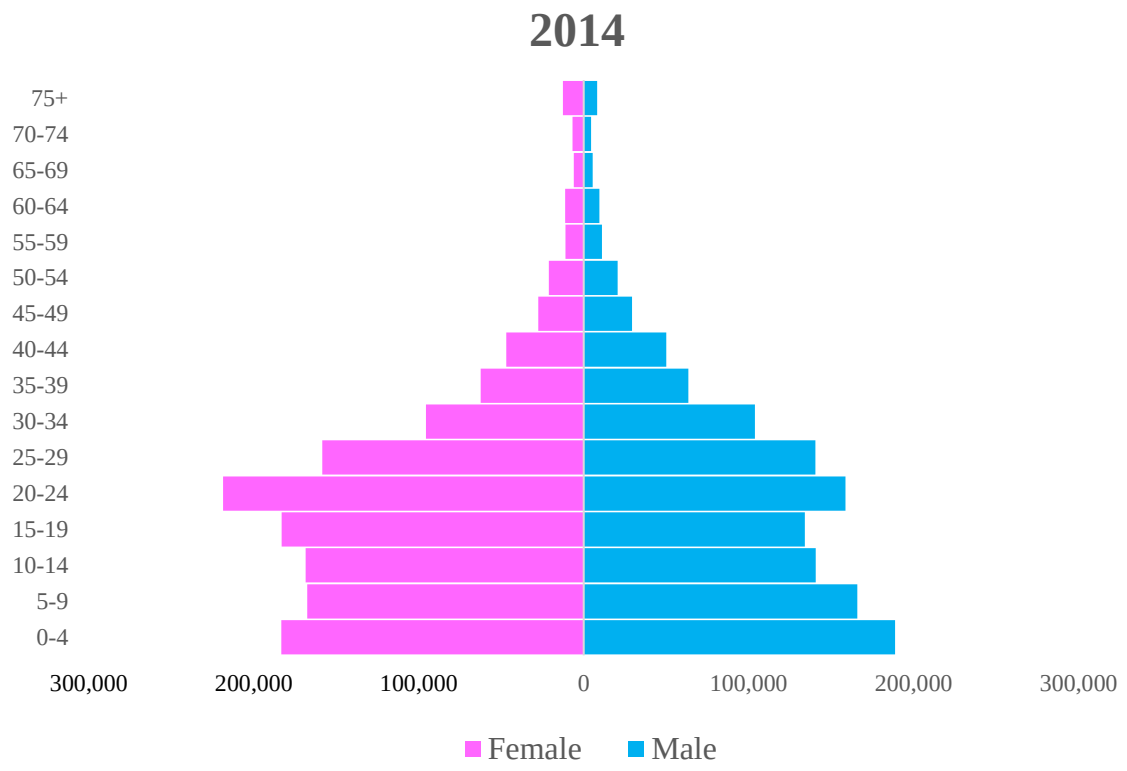
Figure 3. Current and future age-specific number of cases of the five most common cancers in Uganda

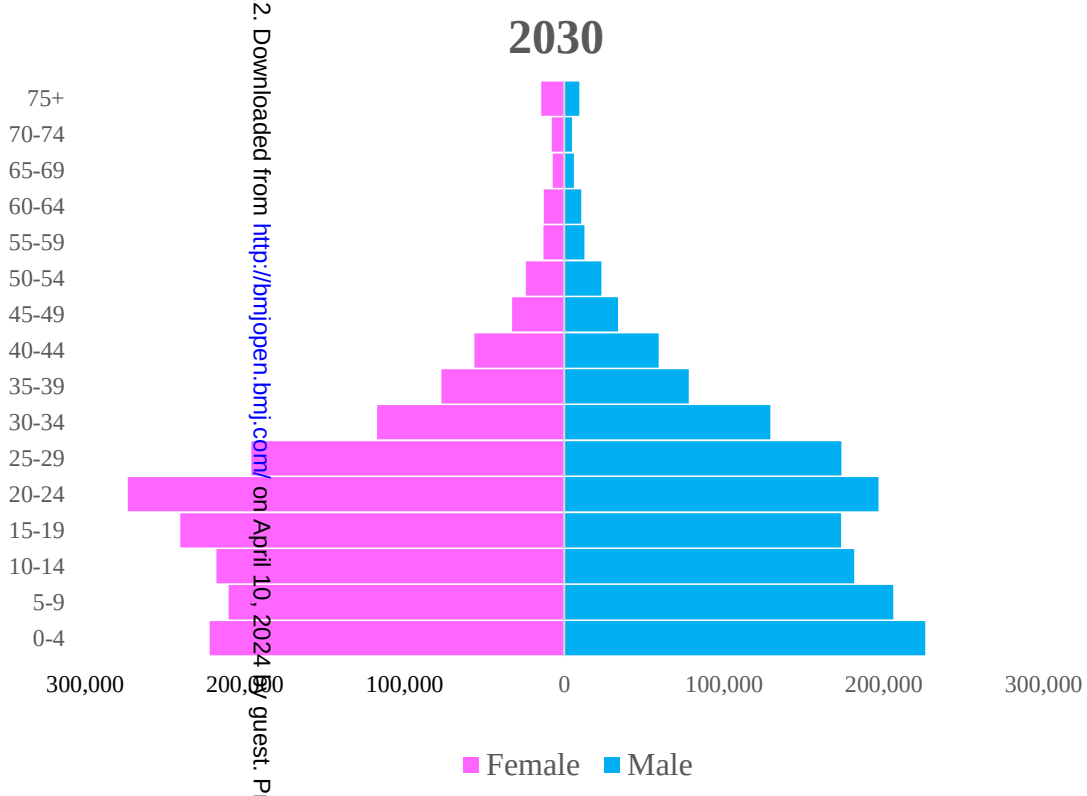












STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	Not applicable
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Not applicable
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-8
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Infection-Related and Lifestyle-Related Cancer Burden in Kampala, Uganda: Projection of the Future Cancer Incidence up to 2030

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Original Research

Infection-Related and Lifestyle-Related Cancer Burden in Kampala, Uganda: Projection of the Future Cancer Incidence up to 2030

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Keywords: Cancer incidence, Cancer surveillance, Cancer burden, Projections, Kaposi sarcoma; non-Hodgkin's lymphoma; Cervix; Breast; Prostate

ABSTRACT

Objectives. In Uganda, infection-related cancers have made the greatest contribution to cancer burden in the past; however, burden from lifestyle-related cancers has been increased recently. Using the Kampala Cancer Registry data, we projected incidence of top five cancers, namely, Kaposi sarcoma (KS), cervical, breast, and prostate cancer, and non-Hodgkin's lymphoma (NHL) in Uganda.

Design: Trend analysis of cancer registry data

Setting: Kampala cancer registry, Uganda.

Main outcome measure. Cancer incidence data from 2001-2015 was used and projected to 2030. Population data was obtained from the Uganda Bureau of Statistics. Age-standardised incidence rates (ASR) and their trends over the observed and projected period were calculated. Percentage change in cancer incidence was calculated to determine whether cancer incidence changes were attributable to cancer risk changes or population changes.

Results. It was projected that the incidence of KS and NHL continue to decrease by 22.6% and 37.3%, respectively. The ASR of KS was expected to decline from 29.6 per 100,000 population to 10.4, while ASR of NHL was expected to decrease from 7.6 to 3.2. In contrast, cervical, breast, and prostate cancer incidence were projected to increase by 35.3%, 57.7%, and 33.4%, respectively. The ASRs of cervical and breast were projected to increase up to 66.1 and 48.4 per 100,000 females. The ASR of prostate cancer was estimated to increase from 41.6 to 60.5 per 100,000 males. These changes were due to changes in risk factors and population growth.

Conclusion. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in cancer spectrum, from infection-related to lifestyle-related, yields another challenge to cancer control programs in resource-limited countries. Forthcoming cancer control programs should include

a substantial focus on lifestyle-related cancers, while infectious disease control programs should be maintained.

Strengths and limitations of this study

- Using the most recent available data of the Kampala Cancer Registry, this study projected the future burden of the most common cancers in Uganda.
- The prediction was based on long-established cancer registry data in Uganda.
- Results were based on the age-period-cohort model, which is a well-known long-term prediction of cancer incidence.
- Our projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries.
- This study only assessed the current top five cancer sites in Uganda, and thus other cancer sites are needed in future studies.

INTRODUCTION

Cancer incidence and mortality are increasing worldwide.[1] The global burden of cancer is predicted to rise to nearly 22 million cases and 13 million deaths by 2030, with the major burden on low- and middle-income countries.[2] Analysis from recent cancer surveillance data shows a gradual increase in the overall incidence of cancer in both sexes in Kampala, Uganda, with an overall increase in age-adjusted rates of 25% in the period of 2011-2015 compared to the period of 1991-1995.[3] Even though the most commonly registered cancer over the 25-years period was Kaposi sarcoma, these studies further suggested an increase in prostate, breast and cervix cancers in Uganda.[3 4] Thus, studies to predict and quantify the future burden of these cancer sites are needed.

The growing cancer-related burden in low and middle-income countries may be due to rising obesity rates, increasing sedentary lifestyles, dietary factors, and persistent carcinogenic infections. These countries share a concurrent burden of infection- and lifestyle-associated cancers.[5 6] Infection due to human immunodeficiency virus (HIV) and other viruses are well-established risk factors for cancer in Sub-Saharan Africa.[7] In Uganda, infection-related cancers, including Kaposi sarcoma (KS), cervical cancer, and non-Hodgkin's lymphoma (NHL), have been the cancers with the highest incidence in the past.[4 8] However, recent statistics reported an increase in the incidence of breast and prostate cancers due to changes in lifestyle-related risk factors.[4 8] Given the assumption that the transition in cancer-related lifestyle risk factors will persist, it is crucial to quantify the future cancer burden attributable to this transition.

Prediction of the future cancer burden is an essential cancer surveillance effort for planning services, policy, research, resource allocation, and to help establish cancer surveillance and control programmes.[7] Further, it informs future primary prevention strategies and research focus. However, to the best of our knowledge, the future cancer burden in Uganda has not been studied previously. Thus, this study was conducted to project the future incidence

of the top five cancers in Uganda, namely, KS, cervical, breast, and prostate cancer, and NHL, to provide estimates crucial for planning future cancer surveillance systems.

MATERIALS AND METHODS

Data sources and manipulation

We obtained cancer incidence data from the Kampala Cancer Registry (2001–2015), a population-based registry covering Kampala and Kyadondo county [8]. Observed and projected population data was obtained from the Uganda Bureau of Statistics which provided the estimates by gender and 5-year age groups. The population pyramids of years 2014 and 2030 was described in Supplementary Figure 1. The World Health Organization standard world population 2000–2025 was used for age-standardization.

Statistical analysis

First, age-standardized incidence rates (ASR) and trends over the observed period were estimated.[9] To estimate the projected incident cases and incidence rates, we used the Nordpred R-package, an age-period-cohort model developed by the cancer registry of Norway. A Poisson regression model with a power-link function for levelling off exponential growth was used to predict the future incidence, as recommended by Moller et al.[10-12] Data were aggregated into three observed 5-year periods (2001–2005, 2006–2010, 2011–2015) and three projected 5-year periods (2016–2020, 2021–2025, and 2026–2030). In order to maintain consistency with the population census data, we categorized the population into five-year age groups from 0–4 years to 70–74 years and 75+ years.

To determine whether cancer incidence changes were attributable to cancer risk changes or population changes, we calculated the percentage change in cancer incidence over the last observed (2011–2015) and last projected periods (2026–2030), as described previously[10 13]. The percentage changes in the corresponding two periods were apportioned to

the contributions of cancer risk and population structure change to help to determine whether changes in incidence are due to changes in cancer risk or due to population change. The "cancer risk change" indicates changes in cancer profiles due to the changes in specific cancer-related risk factors (for example, HPV vaccination and cervical cancer). The change in cancer burden due to "population change" indicates the increase/decrease in cancer cases due to an increase/decrease in the population. [10 13]

Additionally, we performed joinpoint regression, using a segmented regression model in which the regression functions were constrained to be continuous at the joinpoints,[14] and compared results with the results from the age-period-cohort model. The joinpoint model incorporated joinpoints, representing the year in which the most plausible trend changes occurred in cancer incidence. In order to project the future incidence, we extrapolated the ASRs based on the latest trend from the joinpoint regression.

All analyses were conducted using the R software version 3.6.1 (R Foundation for Statistical Computing), with a two-sided type I error and an alpha value of 0.05.

Patient and public involvement

There was no patient or public involvement in this study.

RESULTS

Kaposi sarcoma and non-Hodgkin's lymphoma

During 2016–2030, the number of new KS cases was projected to decrease by 22.6% (19.9% in males, 17.6% in females) (**Table 1**). The decrease in new KS cases was primarily attributable to changes in risk factors (49.8%). Both crude and ASRs were predicted to decrease. The ASR of KS was expected to decline from 29.6 per 100,000 population in 2001–2005 to 10.4 per 100,000 by 2030 (**Figure 1**). The projected KS incidence rate was highest in males aged 35–39 years and females aged 30–34 years (**Figure 2**). Similarly, the incidence rate of NHL was

expected to decrease 2-fold (from 7.6 to 3.2 per 100,000), and the number of new cases was projected to decrease by 37.3% (**Figure 1 and Table 1**). The number of KS and NHL cases showed a decreasing trend in both observed and projected study periods, and the peak age group was 3-40 years in both genders. (**Figure 3**)

Cervical cancer

We found that the burden of cervical cancer will remain high in the next decade in Uganda. The number of new cases was projected to increase to 1,781 by 2030, a 35.3% increase compared to the 2011–2015 period (**Table 1**). The ASR of cervical cancer was projected to increase from 52.6 to 66.1 per 100,000 population by 2030 (**Figure 1**). The incidence rate is expected to increase and peak among females aged 55 to 74 years (**Figure 2**). Cervical cancer cases are expected to increase across all age groups and there were more cases among women aged 30 to 54. (**Figure 3**)

Breast cancer

The incidence of breast cancer was 37.6 per 100,000, with 831 cases in the years 2011-2015. According to our projection, its burden is expected to increase substantially to 48.4 per 100,000 females per year by 2030, with an expected 1,310 new cases between 2026 and 2030 (**Table 1**). In Uganda, female breast cancer was predicted to exceed 48 per 100,000 population per year by 2030 (**Figure 1**). The incidence was predicted to increase by approximately 57.7%, of which 29.7% will be attributable to change in risk factors, and 28.0% will be attributable to the population growth. The incidence rate was predicted to increase in all age groups older than 40 years (**Figure 2**). The number of breast cancer cases are expected to increase across all age groups and more cases are predicted among women aged 30 to 55 years. (**Figure 3**)

Table 1. Observed and projected number of cancer cases, incidence rate, and percentage change of the top five cancers in Kampala, Uganda, 2011–2015 and 2026–2030

Cancer type (ICD-10 Code)	Sex	2011-2015 (Observed)			2026-2030 (Projected)			Percentage changes		
		Cases[a]	Crude[b]	ASR[b]	Cases[a]	Crude[b]	ASR[b]	Overall (%)[c]	Due to risk change (%)[d]	Due to population change (%)[e]
KS (C46)	Both	1,328	10.8	16.4	1,028	6.6	10.4	22.6	−49.8	27.2
	Male	777	13.3	21.4	623	8.4	14.5	19.9	−46.3	26.4
	Female	551	8.5	11.6	454	5.5	7.6	17.6	−45.6	28.0
NHL (C83)	Both	392	3.2	5.4	246	1.6	3.2	37.3	−64.5	27.2
	Male	219	3.8	5.9	144	1.9	3.1	34.4	−60.9	26.4
	Female	173	2.7	5.1	119	1.4	3.7	31.0	−59.0	28.0
Cervical (C53)	Female	1,316	20.2	60.5	1,781	21.4	66.1	35.3	7.4	28.0
Breast (C50)	Female	831	12.8	37.6	1,310	15.7	48.4	57.7	29.7	28.0
Prostate (C61)	Male	600	10.3	54.2	800	10.9	60.5	33.4	7.0	26.4

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardised rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] *Number of cancer cases of the five years*

[b] *Crude rates and ASRs were expressed as per 100,000 (Standardize population: standard world population WHO 2000-2025)*

[c] *Overall percent change in the projected cases of the period 2026–2030 compared to the observed cases of the period 2011–2015.*

[d] *Percentage change in the projected cases due to changes in the risk of each cancer site*

[e] *Percentage change in the projected cases due to the population growth.*

Prostate cancer

Likewise, the projection model predicted that prostate cancer incidence will increase by 33.4% between 2011-2015 and 2026-2030. The number of new prostate cancer cases was reported as 600 in 2011–2015 and is predicted to increase to 800 new cases in 2026–2030 (**Table 1**). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 per year over the study period (**Figure 1**). The increased prostate incidence rate will be concentrated in men aged 50+ years (**Figure 2**). More cases were observed among men aged 60 and above and the number of cases is expected to continually increase in the future across all age groups. (**Figure 3**)

Sensitivity analysis

Additionally, we performed joinpoint regression, and compared results with the findings from the age-period-cohort model. The joinpoint model incorporated joinpoints, representing the year in which the most plausible trend changes occurred in cancer incidence. We extrapolated the ASRs based on the latest trend from the joinpoint regression. Findings from the main analysis and joinpoint regression were consistent with an increase in the incidence rate of prostate, breast, and cervical cancers and a decreased incidence rate of KS and NHL (**Table 2**).

Table 2. The Age Standardized Rates by Nordpred and Joinpoint regression

Cancer type (ICD-10 Code)	Model	Observed/Fitted ASRs			Projected ASRs		
		2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
KS (C46), both male and female	Nordpred[a]	29.6	25.1	16.4	12.3	10.6	10.4
	Joinpoint[b]	28.4	29.0	19.9	12.3	7.6	4.7
KS (C46), male	Nordpred[a]	34.1	32.3	21.4	16.4	14.5	14.5
	Joinpoint[b]	32.1	34.6	26.2	15.7	9.4	5.6
KS (C46), female	Nordpred[a]	25.8	18.6	11.6	8.8	7.8	7.6
	Joinpoint[b]	24.2	23.6	14.1	8.5	5.1	3.1
NHL (C83), both male and female	Nordpred[a]	7.6	8.2	5.4	4.0	3.4	3.2
	Joinpoint[b]	5.1	8.9	6.3	4.5	3.2	2.3
NHL (C83), male	Nordpred[a]	9.1	9.5	5.9	4.2	3.3	3.1
	Joinpoint[b]	7.8	7.0	6.2	5.6	5.0	4.4
NHL (C83), female	Nordpred[a]	6.3	6.9	5.1	4.0	3.8	3.7
	Joinpoint[b]	7.0	9.9	6.9	4.0	2.4	1.4
Cervical (C53)	Nordpred[a]	52.6	56.0	60.5	63.7	65.8	66.1
	Joinpoint[b]	51.7	55.1	58.8	62.7	66.8	71.2
Breast (C50)	Nordpred[a]	33.2	35.2	37.6	40.6	44.1	48.4
	Joinpoint[b]	31.8	34.3	37.0	39.8	42.9	46.2
Prostate (C61)	Nordpred[a]	41.6	52.2	54.2	52.8	55.5	60.5
	Joinpoint[b]	42.8	47.5	52.8	58.7	65.2	72.5

Abbreviations: ICD, International Statistical Classification of Diseases; ASR, Age-standardized rate; KS, Kaposi sarcoma; NHL, Non-Hodgkin lymphoma

[a] Observed ASRs and projected ASRs from Nordpred regression model for each five-year period

[b] Joinpoint regression model was fitted using annual data from 2001-2015 and projected up to 2030. Only fitted and projected ASRs of the first year of each period (2001, 2006, 2011, 2016, 2021, 2026) were presented.

DISCUSSION

In this study, we projected incidence of top five cancers in Uganda using the recent data of the Kampala Cancer Registry. The ongoing population growth, the transitions in the living environment, and the extent to which the government's efforts to combat cancer growth will jointly determine future cancer trends in Uganda. Even though the population distribution in Kampala, Uganda, is projected to remain constant (Supplementary Figure 1) in the next decade, the population size is expected to increase. This population growth was reflected in our projection, and thus, our findings suggest that the burden of cancer might be attributable to the growing population, particularly in the young age groups. To our knowledge, this is the first study that predicts the future cancer incidence in Uganda. We predicted that the incidence rate of breast, prostate, and cervical cancers will increase, and KS and NHL incidence rates will decrease. Moreover, we found that the major shift in the incidence of the top five cancers in Uganda is mainly attributable to changes in the incidence rates of cancer-related risk factors.

Decreasing burden in infection-related cancers: Kaposi sarcoma, non-Hodgkin's lymphoma

The decreasing incidence rate of AIDS-related KS and NHL, particularly a substantial decrease in the KS incidence rate, provides indirect evidence of the success of national efforts to control infectious diseases, especially HIV infection.[15] In Uganda, many health interventions, including the early initiation of antiretroviral therapy, have been implemented to lower the risk of infectious diseases, leading to a significant decrease in the HIV incidence[16-18] and the risk of KS and NHL.[19] As a result, Uganda is one of the countries that has managed to curb down the growing burden of HIV infection. There has been a drastic decrease in the prevalence rates of HIV infections from 30% in the 1990s to 6.5% in the 2016.[20 21]

Remaining burden of cervical cancer due to growing population

Cancer of the cervix uteri has been the most common cancer in Ugandan women since the 1950s.[22] A previous study reported that the average increase in Kampala's cervical cancer

incidence rate was 1.5% over 25 years.[3] We found that the burden of cervical cancer will remain high in the next decade. The number of new cervical cancer cases was predicted to increase due to female population growth, indicating that a strategic plan for cervical cancer prevention and screening is needed. A cervical cancer screening programme has been proposed to be implemented, but screening in Uganda has remained erratic or opportunistic. The uptake of cervical screening is low, and some screening modalities, such as Pap smears, are unavailable in some rural areas due to a lack of financial commitment.[3 23]

Emerging burden of lifestyle-related cancers: breast and prostate cancers

Lifestyle changes, such as older age at the first birth, reduced parity, alcohol use, smoking, and increased prevalence of obesity and physical inactivity in Uganda and other African countries, are likely to drive significant changes in future cancer statistics.[24 25] Currently, more than 80% of females with breast cancer in Uganda present with advanced disease, which accounts for the poor prognosis and low survival rate.[26] Given the substantial burden of breast cancer projected and the late presentation, the national cancer control plan should focus on prevention and early detection of breast cancer, making greater use of clinical breast examination and screening programmes.

The incidence of prostate cancer has been the most prevalent cancer type in Ugandan males since 1996[3 27], and the study results predict that the burden of this cancer will continue to increase. The projection model predicted that prostate cancer incidence would increase by 33.4% by 2030. The number of new prostate cancer cases was expected to increase to 800 in 2026–2030 (Table 1). The ASR was estimated to increase 1.5-fold from 41.6 per 100,000 per year to 60.5 per 100,000 over the study period (Figure 1). The increased prostate incidence rate will be concentrated in males aged 50+ years (Figure 2). A previous study suggested that the increase in prostate cancer incidence might be attributable to increased awareness, readiness to perform prostatectomy for urinary symptoms in older males, and histological examination of

operative biopsies.[3] [28] Thus, the implementation of prostate-specific antigen screening in Uganda could have also contributed to the increased detection of new cases in recent years.[28]

Strengths and Limitations

This study was, to our knowledge, the first study to predict the future cancer burden in Uganda. Data quality of the Kampala Cancer Registry has been qualified by the International Agency for Research on Cancer. Therefore, its data has been published in all Cancer Incidence in Five Continents recent volumes [29]. However, it should be noted that despite the increase in the annual number of cases, data quality indicators, including percentage of morphologically verified and death certificate only cases, have remained relatively low over time. Despite these drawbacks in data quality, data from Kampala Cancer Registry still has its strong point as the longest standing registry in Africa. Thus, projection of cancer burden from this cancer registry might help provide evidence on the cancer burden of Uganda and other African countries. Another strong point of this study is that we performed join point regression [14], and compared results with the results from the age-period-cohort model as a sensitivity analysis. Findings from both approaches were consistent with an increase in the incidence rate of prostate, breast, and cervical cancers and a decreased incidence rate of KS and NHL.

There are several limitations of this study. First, it should be noticed that in our projection, both the age-period-cohort model and joint point regression assume that past trends will continue in the future, which may not be accurate in some cases. Another drawback of our projection is that the projection model did not incorporate changes in risk factors due to the limited information available in Uganda and other African countries. Hence, future studies in this regard are warranted. A modelling approach to explicitly assess cancer risk factors changes and the impact of cancer prevention efforts would be a valuable complement to this study. In

addition, the most recent cancer statistics of Uganda[30] indicates that oesophagus and liver cancers have surpassed Non-Hodgkin lymphoma cancer and were among the most commonly diagnosed cancers. Thus, trends in these cancer sites are needed in future research to provide a more comprehensive cancer burden prediction of Uganda.

Directions For Future Cancer Surveillance Towards Cancer Control Program

Our findings might be helpful for cancer surveillance and planning the allocation of resources for future cancer control. Results from our projection suggest that the risk of cancer in Uganda is driven by increases in the incidence of cancers associated with westernized lifestyle changes. The rising burden of prostate and breast cancer emphasizes the primary prevention to focus on behaviours, health awareness, and the importance of healthy lifestyle-related modification, such as physical activities, diet, and reducing adiposity. While infectious-related cancers, including KS and NHL have gradually decreased, cancer of the cervix is expected to increase in both new cases and rates. Thus, prevention of cervical cancer through vaccination programs and an effective screening program to detect preinvasive cases might be needed in future cancer surveillance and control program in Uganda.

Secondary prevention on early detection, with focusing on detect early-stage breast cancer cases, is likewise required. In Uganda, secondary prevention for breast cancer has been enhanced through increased awareness and increased screening and early detection efforts. However, screening is opportunistic, mainly in nature. The Uganda cancer institute has put in more effort by sending health workers to different regions for outreaches so that all people get a chance of being screened. Screening methods have improved from self-exam to ultrasound and then mammography. Increase of activism of survivorship where survivors willingly teach other women and increased funding from various cancer societies and organizations have also boosted early detection and good outcomes.[4] Prostate cancer has exhibited increasing trends in incidence in Uganda over the years, and many strategies have been put in place to prevent its

rampant escalation. There has been an increase in prostate cancer awareness and screening. Uganda has adopted the use of prostate-specific antigens in screening, which detects cases that may not otherwise have been seen in one's lifetime.[4 31]

To reduce the growing burden of cancer the government of Uganda has put in place some cancer control programs at a national level. One example is establishing a Community Program, also called the Comprehensive Cancer Program, that takes the lead in primary cancer prevention and early detection in Uganda. The program aims to reduce cancer risk by increasing access to cancer prevention services through mass media for cancer awareness, outreach. In addition, hospital-based health education on cancer risk factors, prevention, early detection measures, and screening for the leading cancers, including cervical, breast, and prostate cancer, were also conducted.[32] However, there is limited funding for this program, so some remote and hard-to-reach areas are not outreached.

CONCLUSION

In summary, the study found that substantial changes in the burden of cancers are likely to occur during the next decade due to a transition from infection-related to lifestyle-related cancers. Our results suggest a rapid shift in the profile of common cancers in Uganda, reflecting a new trend emerging in low- and middle-income countries. This change in the cancer spectrum, from infection-related to lifestyle-related, yields another challenge for both cancer surveillance to capture the burden as well as cancer control programmes in resource-limited countries.

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Data Availability Statement: The data used in this study was obtained from the Kampala Cancer Registry with permission. Data that support the findings of this study can be available upon reasonable request to the Kampala Cancer Registry (E-mail: kampalacancerregistry@gmail.com).

Ethics approval: This study was approved by the Institutional Review Board of the National Cancer Centre (approval number: NCC2019-0189). The requirement for informed consent is not applicable because this study used de-identified secondary data.

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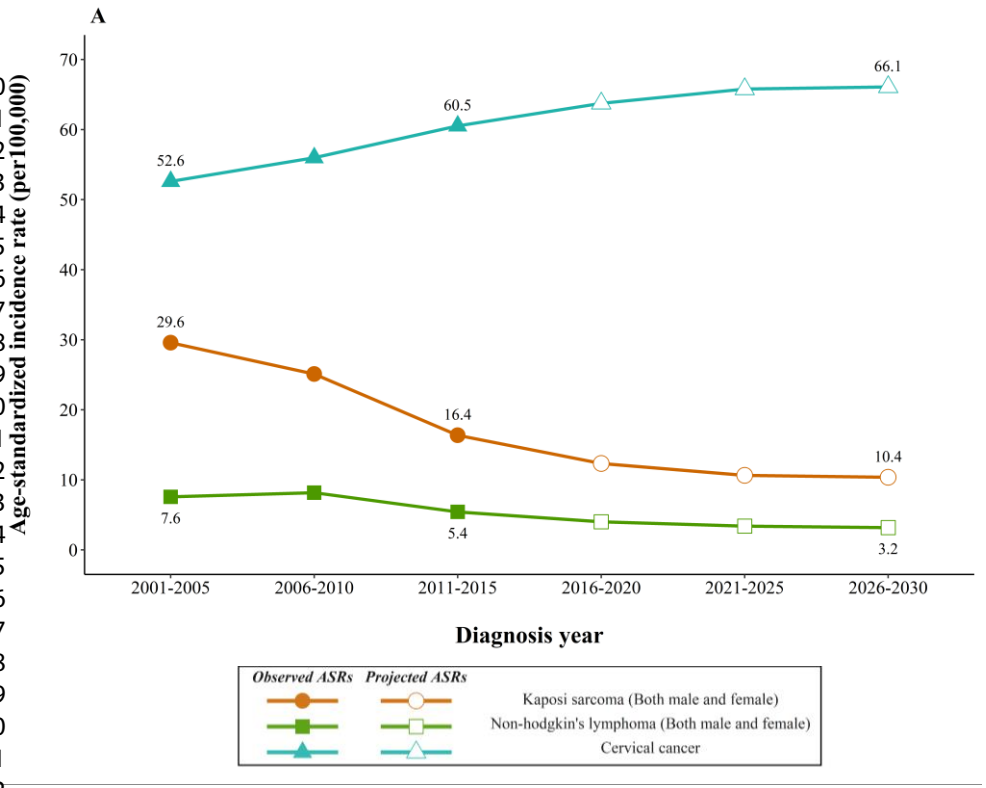
Figure legends

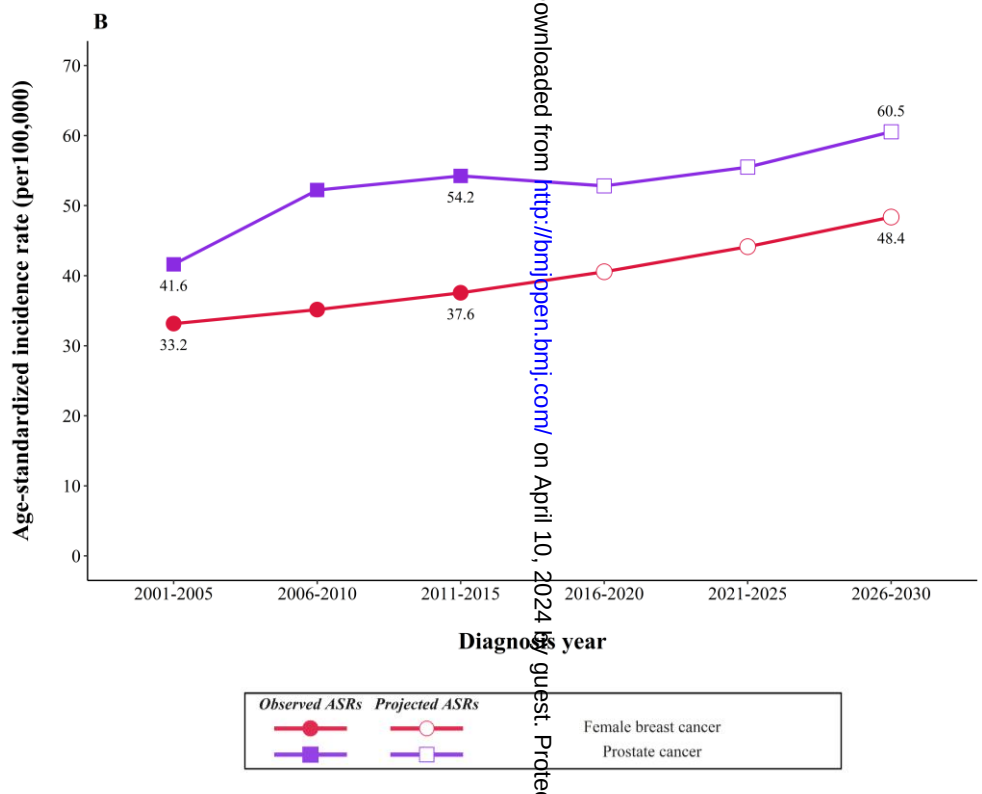
Figure 1. Current and future age-standardised rates of the five most common cancers in Uganda

(A) Observed and predicted trends in the Kaposi sarcoma, non-Hodgkin's lymphoma, and cervical cancer; (B) Observed and predicted trends in breast and prostate cancer.

Figure 2. Current and future age-specific incidence rates of the five most common cancers in Uganda

Figure 3. Current and future age-specific number of cases of the five most common cancers in Uganda





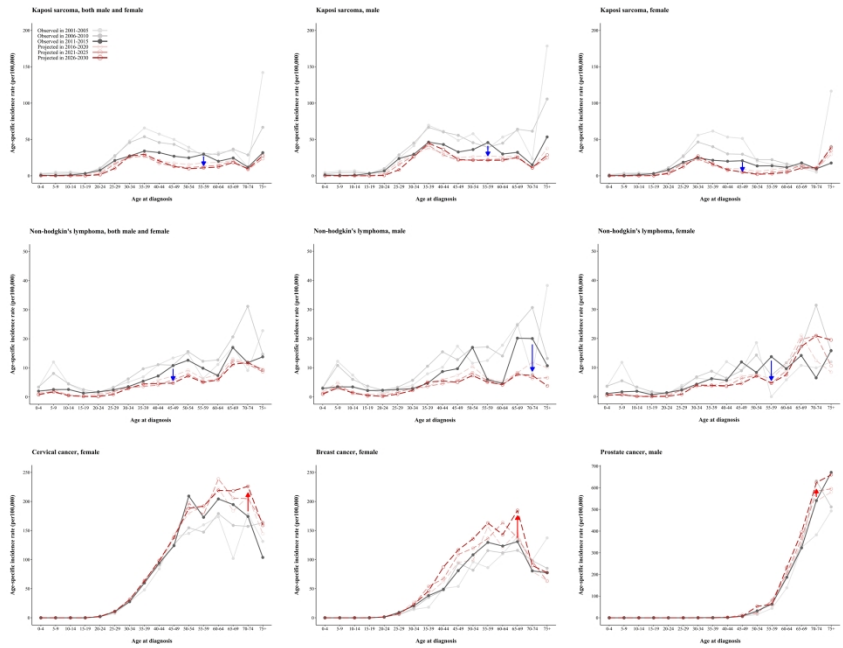
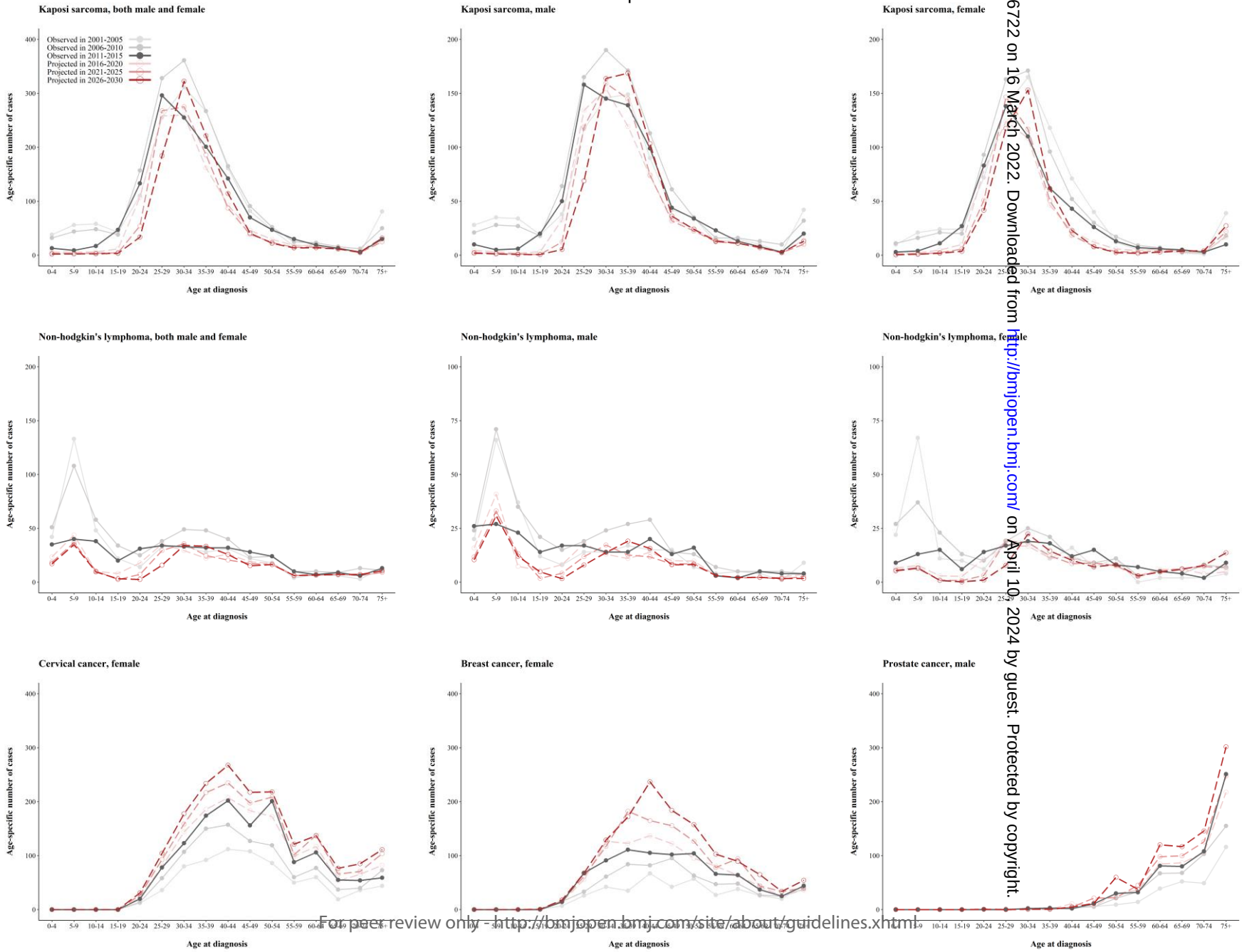
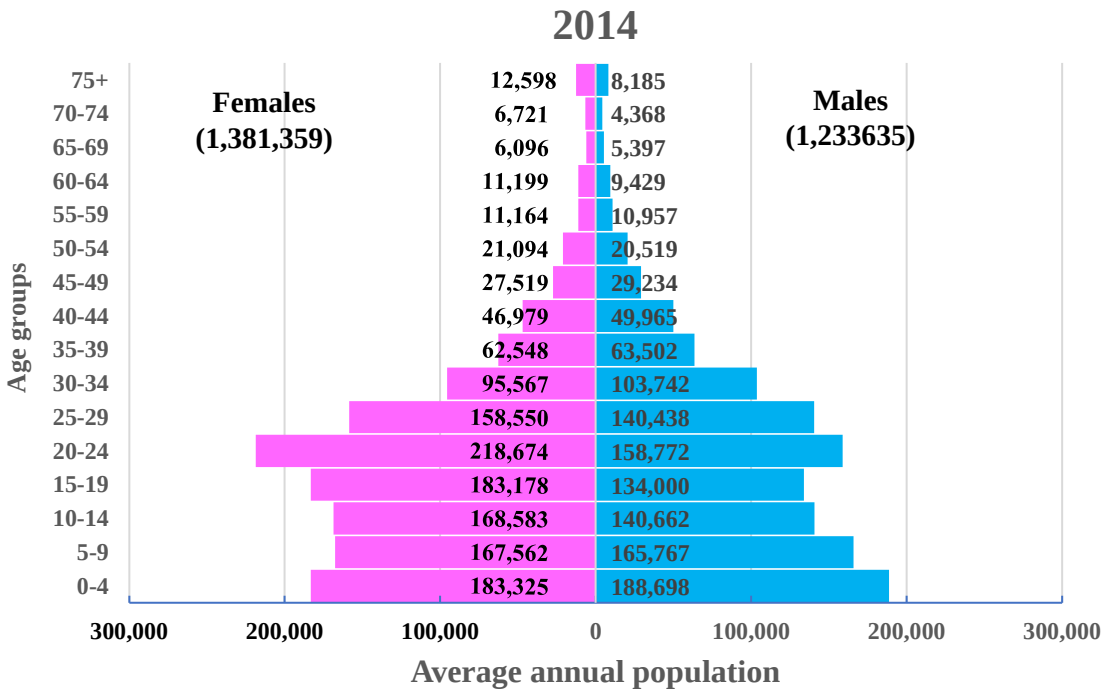
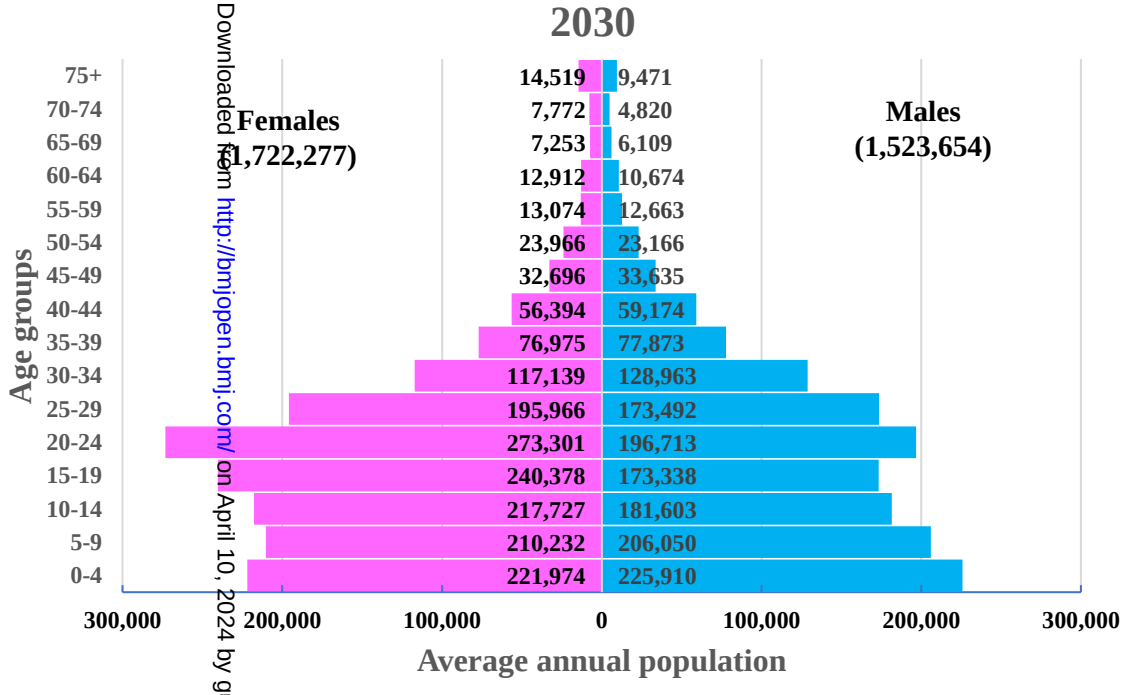


Figure 2. Current and future age-specific incidence rates of the five most common cancers in Uganda

275x190mm (300 x 300 DPI)







STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	Not applicable
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Not applicable
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-8
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.