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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-058962
Article Type:	Original research
Date Submitted by the Author:	04-Nov-2021
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Keywords:	Tuberculosis < INFECTIOUS DISEASES, HIV & AIDS < INFECTIOUS DISEASES, EPIDEMIOLOGY, Public health < INFECTIOUS DISEASES

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Tuberculosis and HIV/AIDS-attributed Mortalities and Associated Sociodemographic Factors in Papua New Guinea: Evidence from the Comprehensive Health and Epidemiological Surveillance System

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Word count: 3691

Abstract

Objective: Tuberculosis (TB) and HIV/AIDS are public health concerns in Papua New Guinea (PNG). This study examines TB and HIV/AIDS mortalities and associated sociodemographic factors in PNG.

Method: As part of a longitudinal study, verbal autopsy (VA) interviews were conducted using the WHO 2016 VA Instrument to collect data of 926 deaths occurred in the communities within the catchment areas of the Comprehensive Health and Epidemiological Surveillance System from 2018-2020.

InterVA-5 cause of deaths analytic tool was used to assign specific causes of death (COD). Multinomial logistic regression analyses were conducted to identify associated sociodemographic factors, estimate odds ratios (OR), 95% confidential intervals and p-values.

Result: TB and HIV/AIDS were the leading CODs from infectious diseases, attributed to 9% and 8% of the total deaths, respectively.

Young adults (25-34 years) had the highest proportion of deaths from TB (20%) and the risk of dying from TB among this age group was five times more likely than those aged 75+ years (OR: 5.5 [1.4-21.7]). Urban population were 46% less likely to die from this disease compared rural ones (OR: 0.54 [0.3-1.0]). People from middle household wealth quintile were three times more likely to die from TB than those in the richest quintile (OR: 3.0 [1.3-7.4]).

Young adults also had the highest proportion of deaths to HIV/AIDS (18%) and were nearly seven times more likely to die from this disease compared with those aged 75+ years (OR: 6.7 [1.7-25.4]). Males were 48% less likely to die from HIV/AIDS than females (OR: 0.52 [0.3-0.9]). The risk of dying from HIV/AIDS in urban population was 54% less likely than their rural counterparts (OR: 0.46 [0.2-0.9]).

Conclusion: TB and HIV/AIDS interventions are needed to target high-risk and vulnerable populations to reduce premature mortality from these diseases in PNG.

Key words: Tuberculosis; HIV/AIDS; mortality transition; cause of death; verbal autopsy; CHESS; PNG

Article Summary

Strengths and limitations of this study

- This study used TB and HIV/AIDS mortality data extracted from the Comprehensive Health and Epidemiological Surveillance System, providing data of more than 900 deaths recorded in the surveillance population living in the communities across 8 sentinel sites, established in 6 major provinces, representing both urban-rural sectors of four geographical regions of PNG.
- Mortality data were linked with household socioeconomic data, allowing in-depth analyses of sociodemographic factors associated with mortalities from TB and HIV/AIDS.TB and HIV/AIDS mortality data collected via VA interviews with close relatives of the deceased might be biased due the recall process.
- Mortality data did not represent all the TB and HIV/AIDS deaths for the population across the sites during the data collection period because the data did not all deaths occurred in the communities and a part of urbane population could die in hospitals from these diseases.
- This study has provided important understanding and insight that can be used to inform the development of policy and interventions to effectively reduce premature mortality from TB and HIV/AIDS among the PNG population.

Background

The Sustainable Development Goal (SDG) 3.3 states: "By 2030, end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases" (1). Tuberculosis (TB) and HIV/AIDS continue to be major global public health issues, having claimed almost 33 million lives. An estimated 38 million people are living with HIV and approximately 690,000 people died from HIV/AIDS, with an additional 1.7 million people newly infected in 2019 (2). In the Western Pacific Region, TB remains a major public health concern, accounting for nearly 20% of the global burden with an estimated 1.8 million new cases reported in 2019 (3). HIV/AIDS has had a severe impact on the health sector. It is estimated that people living with AIDS occupied 70% of hospital beds in Papua New Guinea (PNG), and 80% of hospital beds in the West Papua region of Indonesia (4).

PNG is the largest nation in the South Pacific region with a total population of approximately 8 million, and annual population growth rate of 2.8% in the decade 2000s-2010s. Life expectancy at birth was at 63 years in 2010 and 40% of the PNG population are under 15 years of age (5, 6). Rural populations account for more than 85% of the entire population and are widely scattered across the four geographical regions: Highlands, Southern, Momase, and Islands. PNG is classified as a lower-middle income country and a signatory to the SDGs (7). PNG has recently undergone an epidemiological transition with premature mortality continuing to decline from 2010 to 2020 (8). Infectious diseases are still the dominant cause of morbidity, accounting for almost half the total burden of diseases and illnesses at the primary health level (9, 10).

TB and HIV/AIDS were reported as major public health concerns in PNG in the 2010s (11, 12). In 2018, it was estimated that 37,000 people contracted TB and around 4,500 of these people died from this disease (3). The prevalence of tuberculosis was high among HIV vulnerable populations such as female sex workers, men who have sex with men, and transgender women (13). Major challenges in the delivery of TB prevention and control programmes include under-detection of new cases, poor treatment outcomes, and the high numbers of TB patients (%) who were lost to follow up (14). PNG had the highest HIV/AIDS incidence and prevalence in the Pacific region accounting for 95% of the reported HIV/AIDS cases (15). As of 2020, approximately 45,000 people living with HIV/AIDS were reported in PNG (2), with this figure likely to be underreported (16).

The national HIV/AIDS and TB programs under the 2016-2020 National Health Plan provide anti-retrovirus therapy (ART) and anti-tuberculosis drugs among other services nationwide (17). At the local level, HIV/AIDS and TB interventions and services are integrated at public health facilities under the administration of Provincial Health Authorities (PHA), established across provinces under the PHA Act 2007. The issue of this Act was part of the government decentralization to increase accountability for the provincial and local level governments to improve the standard of public health practices and the delivery of public health services, including preventive and curative services to communities through provincial health partnerships (18).

In PNG, TB and HIV/AIDS patients can seek health care services at health facilities in urban areas. These patients can be admitted to a tertiary hospital for treatment, but they are often discharged from the hospitals in the late stage of their diseases and die at home in their own villages. Hence the records of TB and HIV/AIDS deaths that occur in the communities are more likely completed than those recorded in health facilities, particularly in the rural areas, where access to TB and HIV/AIDS services are limited.

Social determinants of TB and HIV/AIDS mortality are poorly understood despite of the heavy burden of these diseases on health systems in PNG. Study of social determinants of mortality from TB and HIV/AIDS is important for public health policy and interventions (19). Understanding of social determinants of TB and HIV/AIDS mortalities provides insight into the performance of health systems and healthcare interventions in reducing mortality from these diseases, contributing to achievement of SDGs. The greatest impact of TB and HIV/AIDS on mortality of a population was most likely felt at the individual and household levels. In African countries, higher premature mortality from HIV/AIDS was reported among females compared with males, people living in rural areas, and those from lower household socioeconomic status (20). Sociodemographic factors such as age, sex, education, marital and employment status, housing condition and household socioeconomic status were also associated with HIV/AIDS mortality (21-24). Household socioeconomic demographic factors should be considered when examining social determinants of mortality. No known study has examined sociodemographic factors related to mortality from TB and HIV/AIDS in PNG.

This study examined the proportion of mortality from TB and HIV/AIDS among people in PNG and explored the possible associations of key sociodemographic factors with these mortalities. The study aimed to address the following research questions:

- What are the distributions of mortality from TB and HIV/AIDS by age, sex and household socioeconomic status of the deceased and by urban-rural sectors and provinces?
- What are the sociodemographic factors associated with TB attributed mortality?
- What are the sociodemographic factors associated with mortality attributed to HIV/AIDS?

Materials and methods

Data source

Mortality surveillance data were extracted from the Comprehensive Health and Epidemiological Surveillance System (CHESS), operated since 2018 by Papua New Guinea Institute of Medical Research (PNGIMR). CHESS was based on the integrated Health and Demographic Surveillance System (iHDSS), which was established in PNG in the period 2010-2017. CHESS was designed as a population-based longitudinal follow-up cohort system. The overall purpose of CHESS was to provide a reliable and up-to-date data series for monitoring the implementation of socioeconomic development programmes and healthcare interventions at the sub-national level in PNG. CHESS catchment areas include eight surveillance sites located in six provinces: Eastern Highlands Province (EHP), East New Britain (ENB), East Sepik Province (ESP), Central, Madang, and Port Moresby (POM - the National Capital District). By the end 2022, CHESS will cover a population size of approximately 80,000, equivalent to 1% of the total population of PNG. The system provides population data from rural and urban sectors, with approximately 75% of rural and 25% of urban populations, comparable with the national rural-urban population distribution for the period 2018-2022 (6). The designs and methods of iHDSS and CHESS have been previously published (25, 26). Sociodemographic characteristics of the surveillance population by sites are presented in Table 1. The distance between urban-rural sites in EHP and ENB is about 50 km. This provides a balance between facilitating access and transportation and ensuring differences in socioeconomic development can be observed and captured in the data.

Mortality surveillance data were collected from the population living in the CHESS sites in the period 2018-2020, using the WHO 2016 verbal autopsy (VA) interview instrument. This tool is based on the consolidation of various existing VA tools and programmed for conducting VA interviews using portable electronic devices (27). The WHO 2016 tool does not require interviewers to have a health and medical background to conduct VA interviews (28). The WHO 2016 VA instrument was adapted in 2017 for optimal use in the local context and integrated into CHESS surveillance activities in 2018 (29). An additional data module on identification information of the deceased, including household GPS data and individual ID code was included in the VA instrument for this study, allows linkage between mortality and household socioeconomic demographic data.

The data were collected from March 2018 to September 2020. Mortality data used in this study were collected from the communities. Deaths in the communities were identified by village-based data reporters. VA interviewers were conducted by national scientific officers, who work for CHESS in the demographic team. Among the 1021 deaths identified in the communities, consents were obtained for conducing 1003 VA interviews, resulted in a participation rate of 98%.

Data analyses

The InterVA-5 COD analytic tool was used to analyse cause of death (CODs) of 926 VA interviews. This computer-based programme can assign 64 specific CODs and categories in line with the International Classification of Diseases version 10 (ICD-10) (30). To analyse mortalities from TB and from HIV/AIDS by selected sociodemographic factors, VA data were linked with the household socioeconomic (SES) data from the corresponding period of time using the unique household and individual identification codes. Specifically, the 2018-2020 VA data were linked with the 2018 household SES data. Mortality data from 665 deaths were successfully linked with household SES data and included in the analyses. No household SES data for ESP for 2018 were available as the site was not established until early 2019.

A new variable on household wealth index was constructed for each deceased using the principal component analysis (PCA) method. The application of PCA in the PNGIMR's CHESS has been previously published (31). Household SES and demographic variables were included in PCA models. Significant variable remained in the PCA model including housing characteristics, water and sanitation, and household assets. Non significant variables were excluded from the models including education, employment, and occupation of the deceased. Household wealth indices were then divided into quintiles and categorised as poorest, poor, middle, richer and richest.

Multinomial Logistic Regression (MLR) was used to identify socioeconomic demographic factors associated with mortalities from TB and from HIV/AIDS and to predict the risk of morality from TB and HIV/AIDS across sub-populations. Two binary variables were created: (i) TB attributed death (Yes/No); and (ii) HIV/AIDS attributed death (Yes/No). These variables were included in MLR models as dependent variables, and sociodemographic factors were independent variables. Significant sociodemographic variables that remained in the MLR models included age at death, sex of the deceased, household wealth quintile, and urban-rural sector. The 'province' variable was excluded in the model because of confounding with the urban-rural sector variable. Main effect was selected to produce estimates of odds ratios (OR) for the risks of dying from TB and HIV/AIDS. Statistical likelihood tests were used to provide 95% confidence intervals (CIs) of the estimated ORs. A p-value of less than 0.05 was considered as significant. All analyses were performed using the Statistical Package for Social Sciences (SPSS-version 20).

Patient and public involvement

No patient involved.

Results

TB and HIV/AIDS as top leading infectious disease causes of death

Figure 1 shows mortality from infectious diseases among the surveillance population. A total of 317 deaths were attributed to infectious diseases, in which pulmonary TB was the leading COD and responsible for 84 deaths, followed by acute respiratory tract infections (81 deaths), and HIV/AIDS (75 deaths). Among the 84 deaths attributed to TB, three deaths assigned HIV/AIDS as the second COD,

accounting for 3.6% of TB deaths. Similarly, among the 75 deaths from HIV/AIDS, 6 deaths assigned TB as the second COD, accounting for 0.8% of HIV/AIDS deaths. Hence the co-morbidities of TB and HIV/AIDS could be about 6% of all HIV/AIDS and TB deaths.

Table 2 shows the distribution of TB and HIV/AIDS attributed mortalities by sociodemographic characteristics of the deceased. The mean age of death from TB was 46.3 (± 17.58), which was slightly higher than for HIV/AIDS, 44.21 (± 19.36), but lower than for other CODs, 49.24 (± 24.32) (Eta squared p-value: 0.04). TB accounted for 9% of total deaths in the surveillance population. TB claimed the highest number of deaths in those aged 25-34, comprising 20% of the TB deaths. This was followed by the 35-44 years age group with 18% of deaths. The highest number of TB deaths was observed among people from households in the middle quintile. A slightly higher proportion of deaths occurred in rural areas (10%) compared with urban areas (7%). Central province had the highest numbers of TB deaths, with 41 deaths which accounted for 14% of the death records in this province.

HIV/AIDS attributed to 8% of the total deaths recorded in the surveillance population. The proportion of female deaths attributed to HIV/AIDS was more than twice for males than females, 11% and 5%, respectively. The population aged 25-34 years had the highest number of deaths from HIV/AIDS, accounting for 18% of deaths in this age group. Three HIV/AIDS deaths were identified among children aged 0-4, accounting for 5% of deaths among children in this age group. There were 60 HIV/AIDS deaths identified in rural population, accounting for 9% of deaths in rural areas, compared to 6% reported in urban areas. EHP had the highest number of deaths from HIV/AIDS, with 36 deaths that accounted for 12% of deaths recorded in this province. By contrast, Central province recorded the lowest proportion of deaths from HIV/AIDS (4.5%).

Socioeconomic demographic factors of mortalities from TB and HIV/AIDS

Table 3 shows the odd ratios of mortality from TB by sociodemographic characteristics of the deceased. Those aged 25-34 were over five times more likely to die from TB than those aged 75+ years (OR: 5.48 [1.38-21.75]). Urban population were 45% less likely to die from TB than those in rural areas (OR: 0.54 [0.28-1.0]). Those from the middle household wealth quintile were three times more likely to die from TB than those from the richest quintile (OR: 3.06 [1.27-7.37]). The difference in TB mortality between males and females was not significant (p-value: 0.47).

Table 4 shows the odd ratios of mortality from HIV/AIDS by sociodemographic characteristics of the deceased. Similar to TB, those aged 25-34 were nearly seven times more likely to die from HIV/AIDS than those aged 75+ years (OR: 6.68 [1.75-25.43]). Males were about 50% less likely to die from HIV/AIDS than their female counterparts (OR: 0.52 [0.29-0.9]). Urban population were about 55% less likely to die from HIV/AIDS than rural populations (OR: 0.46 [0.24-0.89]). The differences in HIV/AIDS mortality were not significant among household wealth quintiles (P-values > 0.05).

Discussion

Using the linked dataset between mortality and household SES data from the CHESS database, we have conducted analyses to identify that TB and HIV/AIDS were the leading CODs from infectious diseases in the population in PNG. Analysis of key sociodemographic factors of mortalities from these diseases, we showed that people aged 25-44, particularly females, those living in rural areas, and from households with lower SES were more likely to die from these diseases.

We found that PNG people were dying from TB and HIV/AIDS at a very young age, with the highest premature mortality among the population in the age group 25-34. Indeed, TB and HIV/AIDS were responsible for 2 in every 5 deaths among young adults aged 15-24. From our observations, young people living in the surveillance sites are highly mobile. Many regularly move from one place to another for education, employment, social and family purposes. They are also sexually active and more likely involved in unprotected sex (32). Lacking access to preventive measure such as condom, young people are more likely to become infected with HIV/AIDS among other sexually transmitted infections. Young people are the main labor force and the most productive in the national and household economies. The loss of young people to TB and HIV/AIDS present a significant economic cost to their families, the communities and society as a whole (32). It was estimated if there were 300,000 adult deaths to HIV/AIDS; the workforce would be reduced by 12.5%; and the annual GDP growth rate would decline by 1.3% by 2025 (4).

Gender inequality was a key factor associated with the increased risk of dying from HIV/AIDS among the female population. In PNG, women are culturally considered as having a lower social status than men. Young women are more likely to engage in high risk sexual activities to satisfy or meet their needs and wants than men. Given the low prevalence of safe sex practices, these women are more likely to be exposed to HIV/AIDS infection (33). In most cases, women are more likely to die younger than men if they are infected with HIV/AIDS. HIV/AIDS also attributed to 5% of deaths among children under five years of age. HIV/AIDS prevention of mother-to-child transmission (PMTCT) programmes have been reportedly integrated into antenatal care services in PNG, but access to these services is limited. Because of social stigma and discrimination, many HIV/AIDS pregnant women did not give correct personal information (33), further hindering the utilisation of antenatal care services. The loss of mothers is likely to leave a large socioeconomic burden to their families, and children are particularly impacted from the loss (14). Infant children died from HIV/AIDS are evidence of the failure of delivery of the PMTCT programme in PNG. Reducing social stigma and discrimination against people living with HIV/AIDS, particularly women is crucial to improving the delivery of HIV/AIDS services. Increasing men's roles in the national response to HIV/AIDS prevention is also important for a successful implementation of HIV/AIDS programme in PNG.

Our study has shown that people who live in the rural areas were twice as likely to die from TB and HIV/AIDS than those in urban areas. Inadequate health promotion and education could be the cause of low public awareness about the diseases and poor knowledge and practices towards prevention of TB

and HIV/AIDS among rural populations. Limited access to basic health care services is often cited as the main reason for the high mortality from TB and HIV/AIDS in PNG (34, 35). The unavailability of skilled health workers, lack of essential drugs and consumables are often reported at primary health facilities in rural areas (11). Access to antiretroviral therapy (ART) has been a key to reducing the risk of dying from HIV/AIDS, but this service is available only at a small number of tertiary health facilities such as hospitals in Port Moresby. Essential laboratory services such as GeneXpert and TB culture for monitoring MDR-TB, and HIV testing are very limited, even unavailable on regular basis at the Eastern Highlands Provincial Hospital. No community-based modality is available for effective detection and management of TB and HIV/AIDS cases (36). Control of the spread of TB and HIV/AIDS infections in the communities has been ineffective due to loss to follow up with the patients (13, 33).

TB-HIV co-infections have increased and are one of the key challenges to the effective implementation of TB and HIV/AIDS programmes in PNG. Our study estimated that the prevalence of TB and HIV/AIDS co-infections could be about 6% of HIV/AIDS and TB patients. This finding is consistent with our morbidity surveillance data (35). The recent emergence of HIV/AIDS co-infections with TB in Western and Eastern Highlands provinces has raised a public health threat of multi-drug resistant tuberculosis (MDR-TB) (17, 36). The resurgence of tropical neglected infectious diseases such as typhoid (37), leprosy (36), recent outbreaks of childhood communicable diseases including polio and measles (38), and the current spread of COVID-19 infection in the communities have imposed threats to the overwhelmed healthcare systems.

The mortality data were collected via VA interviews with close relatives of the deceased. Although the WHO 2016 VA instrument had been pretested with the local people prior to the data collection, the provided information about the deaths may be incomplete and biased due the recall process. InterVA-5 is a standard tool and was used for the first time to collect mortality data in PNG. Although the tool was validated by medical reviews, the ascribed CODs could be also biases due to the death selection process. The mortality data were collected from the population living within the CHESS catchment areas, but the data included only deaths identified by the village-based data reporters. It is challenging to ensure all deaths occurred in the communities were included in the data. Hence, the data used were not representative for all deaths in the surveillance sites across provinces.

Conclusions

Over the past 40 years, HIV/AIDS infections have transitioned to a manageable chronic infection in many LMICs and TB infection has been contained in many parts of the world. The current high mortality from TB and HIV/AIDS in PNG appears in contrast to the global trend of declining infections and deaths from these diseases. TB and HIV/AIDS have recently emerged in PNG and becoming leading causes of death in the population. The high premature mortalities from TB and HIV/AIDS among young people, together with the increased TB-HIV co-infections have raised public concerns about the TB and HIV/AIDS programmes in PNG, threatening the sustainable development of the country (9, 39, 40).

Urgent actions are needed from the PNG Government and health sector to review the current strategies and plans for further improvement in the effectiveness of TB and HIV/AIDS programmes as well as the delivery of healthcare services to the population in PNG in the next decade. More interventions are needed with focus on high-risk and vulnerable populations, particularly those who are young and females in rural areas and from provinces with low socioeconomic development status. The identified sociodemographic factors associated with premature mortality attributed to TB and HIV/AIDS need to be tackled. Further studies on the trend of mortality transition and the change in CODs across different social classes are needed to better inform policy and intervention.

Declarations

Funding

The CHESS was operated with financial supported from the PNG Government through the Department of National Planning and Monitoring (PIP No. 02704). The funder had no role in study design, data collection and analysis, or writing of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Author contributions

BNP designed the CHESS, conceptualized the paper, and analysed and interpreted the data, drafted, revised, finalized and submitted the manuscript. RJ, VDS and NA supervised the fieldwork, collected and analysed the data, and provided inputs. CR, AO reviewed, provided inputs, and commented the manuscript. WP provided oversight the PNGIMR and approved the submission.

Ethics approval

The CHESS was granted ethics approvals from Institutional Review Board of PNG Institute of Medical Research (IRB's Approval no. 18.05) and the Medical Research Advisory Committee of Papua New Guinea (MRAC's Approval no. 18.06). These approvals covered all the data components under the CHESS, including the mortality data which were used in this manuscript. Informed consent was sought from self-identified close relatives of the deceased. They were informed about their right to withdraw from the study at any stage.

Acknowledgement

This study was conducted as part of the PNGIMR's CHESS programme. We appreciate the participants for their time to attend VA interviews and provide information about the deceased. We thank the data reporters and CHESS staff members for their support in field work and data collection. We acknowledge the contributions and supports from our local partners: community members, religion leaders, and Provincial Health Authorities in Central, Eastern Highlands, East New Britain, East Sepik, Madang provinces and Port Moresby for their partnerships and collaborations in this study.

Data statement

The datasets used in this study are available from the corresponding author on reasonable request. The corresponding author has full access to all the data used in this study and had final responsibility for the decision to submit the study for publication.

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Table 1: Socioeconomic characteristics of the surveillance sites, PNGIMR's CHESS, 2018-2020

Province	Port Moresby	Central	Eastern Highlands	Eastern Highlands	Madang	East Sepik	East New Britain	East New Britain
Site	Hohola	Hiri	Goroka	Asaro	Newtown	Maprik	Kokopo	Baining
Sector	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Region	Southern	Southern	Highlands	Highlands	Momase	Momase	Islands	Islands
Location	National Capital District	45 km west of Port Moresby	Township of EHP	50 km northeast of Goroka	Township of Madang	30 km from township	Township of ENB	40 km from the town
Main industry	Shipping, transportation	Fishery, hunting	Coffee, agriculture	Coffee, agriculture	Fishery, services	Vanilla, cocoa	Fishery, tourism	Fishery, tourism
Accessibility	Road and airline	Road	Road and airline	Road and airline	Road and airline	Road and airline	Sea and airline	Sea and airline
Year of establishment	2017	2011	2016	2004	2018	2019	2018	2018
Population	5,000	15,000	5,000	15,000	5,000	5,000	5,000	6,000
Household	1000	3000	1000	3000	1000	3000	1000	3000
Health facility	St. Theresa clinic	Porebada, Papa and Lealea clinics	Provincial Hospital Kwongi, Lopi and Goroka clinics:	Asaro Health Centre	Jomba Clinic	Ilahita clinic, District Hospital	Batuwin Clinic	Vanapalading Aid Post
Laboratory services	POM Lab	N/A	Goroka Lab	N/A	Madang Lab	N/A	N/A	N/A

Table 2: Mortalities from and pulmonary TB, HIV/AIDS and other causes by age group, sex, urban-rural sector, province, and household wealth quintile of the deceased, PNGIMR's CHESS, 2018-2020

		TB	HIV/AIDS	Other CODs	All CODs
Mean age at death (year, SD)	P-value: 0.04	46.32 (17.58)	44.21 (19.36)	49.24 (24.32)	48.56 (23.44)
Age group	0-4	0 (0.0%)	3 (4.5%)	64 (95.5%)	67 (100.0%)
	5-14	1 (3.8%)	0 (0.0%)	25 (96.2%)	26 (100.0%)
	15-24	7 (11.3%)	6 (9.7%)	49 (79.0%)	62 (100.0%)
	25-34	20 (20.2%)	18 (18.2%)	61 (61.6%)	99 (100.0%)
	35-44	17 (18.1%)	11 (11.7%)	66 (70.2%)	94 (100.0%)
	45-54	9 (6.0%)	14 (9.4%)	126 (84.6%)	149 (100.0%)
	55-64	15 (8.8%)	14 (8.2%)	141 (82.9%)	170 (100.0%)
	65-74	12 (8.4%)	4 (2.8%)	127 (88.8%)	143 (100.0%)
	75+	3 (2.7%)	5 (4.4%)	105 (92.9%)	113 (100.0%)
Total		84 (9.1%)	75 (8.1%)	764 (82.8%)	923 (100.0%)
Sex	Male	43 (8.4%)	28 (5.4%)	443 (86.2%)	514 (100.0%)
	Female	41 (10.0%)	47 (11.4%)	324 (78.6%)	412 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)
Sector	Urban	16 (7.0%)	13 (5.7%)	199 (87.3%)	228 (100.0%)
	Rural	67 (9.9%)	60 (8.9%)	550 (81.2%)	677 (100.0%)
Total		83 (9.2%)	73 (8.1%)	749 (82.8%)	905 (100.0%)
Household wealth quintile	Poorest	9 (6.5%)	14 (10.1%)	115 (83.3%)	138 (100.0%)
	Poor	7 (5.1%)	15 (10.9%)	116 (84.1%)	138 (100.0%)
	Middle	21 (15.2%)	14 (10.1%)	103 (74.6%)	138 (100.0%)
	Rich	16 (11.6%)	10 (7.2%)	112 (81.2%)	138 (100.0%)
	Richest	8 (5.8%)	8 (5.8%)	121 (88.3%)	137 (100.0%)
Total		61 (8.9%)	61 (8.9%)	567 (82.3%)	689 (100.0%)
Province	Port Moresby	1 (3.3%)	2 (6.7%)	27 (90.0%)	30 (100.0%)
	Central	41 (14.2%)	13 (4.5%)	234 (81.3%)	288 (100.0%)
	Eastern Highlands	25 (8.3%)	36 (12.0%)	239 (79.7%)	300 (100.0%)
	Madang	8 (10.5%)	8 (10.5%)	60 (78.9%)	76 (100.0%)
	East Sepik	2 (1.7%)	8 (6.9%)	106 (91.4%)	116 (100.0%)
	East New Britain	7 (6.0%)	8 (6.9%)	101 (87.1%)	116 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)

Table 3: Odds ratios of mortality from pulmonary tuberculosis by sociodemographic characteristics of the deceased in PNG, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Odds ratio	Lower Bound	Upper Bound	P-value
Age group	0-4	39	5.9%	NA	NA	NA	NA
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	2.982	0.621	14.317	0.172
	25-34	64	9.6%	5.482	1.382	21.751	0.016
	35-44	62	9.3%	6.428	1.675	24.664	0.007
	45-54	115	17.3%	2.290	0.582	9.009	0.236
	55-64	131	19.7%	3.118	0.856	11.360	0.085
	65-74	102	15.3%	3.438	0.913	12.955	0.068
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	1.227	0.696	2.164	0.479
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.540	0.288	1.000	0.050
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	0.997	0.367	2.708	0.995
	Poor	135	20.3%	0.817	0.283	2.359	0.709
	Middle	130	19.5%	3.067	1.275	7.374	0.012
	Rich	130	19.5%	2.005	0.802	5.010	0.137
	Richest	135	20.3%	Ref.			
Valid total		665	100.0%				

Note: Dependent variable was deaths from tuberculosis. Reference category was deaths from other CODs. Sociodemographic factors remained in MLR models included age, sex, urban-rural sector and household wealth.

Table 4: Odds ratios of mortality from HIV/AIDS by sociodemographic characteristics of the deceased in PNG, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Odds ratio	Lower Bound	Upper Bound	P-value
Age group	0-4	39	5.9%	1.511	0.240	9.531	0.660
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	3.461	0.771	15.548	0.105
	25-34	64	9.6%	6.687	1.758	25.438	0.005
	35-44	62	9.3%	4.872	1.240	19.150	0.023
	45-54	115	17.3%	2.868	0.765	10.758	0.118
	55-64	131	19.7%	2.876	0.783	10.565	0.112
	65-74	102	15.3%	1.108	0.238	5.150	0.896
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	0.517	0.294	0.908	0.022
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.464	0.240	0.899	0.023
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	2.084	0.797	5.452	0.134
	Poor	135	20.3%	2.342	0.901	6.090	0.081
	Middle	130	19.5%	1.999	0.751	5.319	0.165
	Rich	130	19.5%	1.550	0.557	4.311	0.401
	Richest	135	20.3%	Ref.			
Valid		665	100.0%				

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

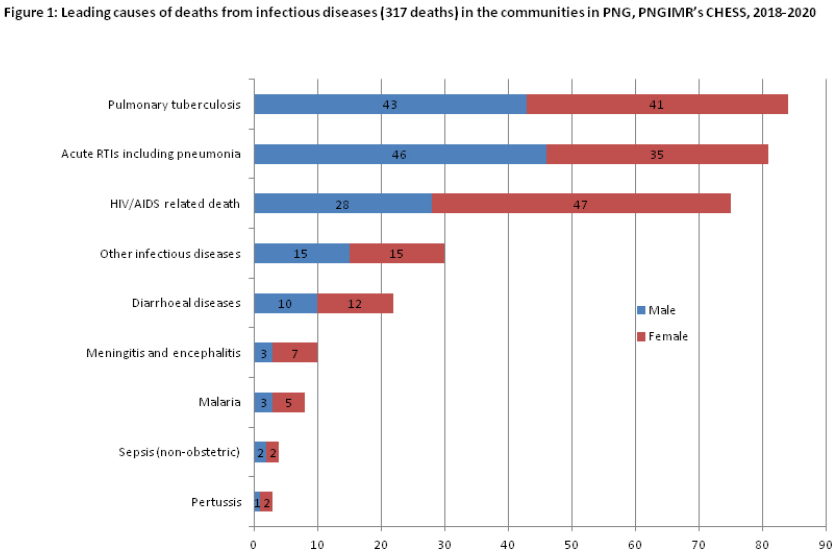

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

254x190mm (96 x 96 DPI)

STROBE Statement—checklist of items that should be included in reports of observational 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	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
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	5
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	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	6
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	6
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*n/a*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*n/a*
		Cross-sectional study—Report numbers of outcome events or summary measures	*n/a*
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	7
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7
Discussion			
Key results	18	Summarise key results with reference to study objectives	7-8
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	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9-10
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	11

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

BMJ Open

Tuberculosis and HIV/AIDS-attributed Mortalities and Associated Sociodemographic Factors in Papua New Guinea: Evidence from the Comprehensive Health and Epidemiological Surveillance System

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-058962.R1
Article Type:	Original research
Date Submitted by the Author:	23-Mar-2022
Complete List of Authors:	Pham, Bang; Papua New Guinea Institute of Medical Research, Population Health and Demography Abori, Norah; Papua New Guinea Institute of Medical Research Silas, Vinson D.; Papua New Guinea Institute of Medical Research, Population Health and Demography Unit Jorry, Ronny; Papua New Guinea Institute of Medical Research Rao, Chalapati; Australian National University Okely, Tony; Illawarra Health and Medical Research Institute Pomat, Willie; Papua New Guinea Institute of Medical Research
Primary Subject Heading:	Global health
Secondary Subject Heading:	HIV/AIDS, Public health, Epidemiology, Infectious diseases
Keywords:	Tuberculosis < INFECTIOUS DISEASES, HIV & AIDS < INFECTIOUS DISEASES, EPIDEMIOLOGY, Public health < INFECTIOUS DISEASES

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Tuberculosis and HIV/AIDS-attributed Mortalities and Associated Sociodemographic Factors in Papua New Guinea: Evidence from the Comprehensive Health and Epidemiological Surveillance System

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Word count: 3683

Abstract

Objective: Tuberculosis (TB) and HIV/AIDS are public health concerns in Papua New Guinea (PNG). This study examines TB and HIV/AIDS mortalities and associated sociodemographic factors in PNG.

Method: As part of a longitudinal study, verbal autopsy (VA) interviews were conducted using the WHO 2016 VA Instrument to collect data of 926 deaths occurred in the communities within the catchment areas of the Comprehensive Health and Epidemiological Surveillance System from 2018-2020.

InterVA-5 cause of deaths analytic tool was used to assign specific causes of death (COD). Multinomial logistic regression analyses were conducted to identify associated sociodemographic factors, estimate odds ratios (OR), 95% confidential intervals and p-values.

Result: TB and HIV/AIDS were the leading CODs from infectious diseases, attributed to 9% and 8% of the total deaths, respectively.

Young adults (25-34 years) had the highest proportion of deaths from TB (20%) and the risk of dying from TB among this age group was five times more likely than those aged 75+ years (OR: 5.5 [1.4-21.7]). Urban population were 46% less likely to die from this disease compared rural ones (OR: 0.54 [0.3-1.0]). People from middle household wealth quintile were three times more likely to die from TB than those in the richest quintile (OR: 3.0 [1.3-7.4]).

Young adults also had the highest proportion of deaths to HIV/AIDS (18%) and were nearly seven times more likely to die from this disease compared with those aged 75+ years (OR: 6.7 [1.7-25.4]). Males were 48% less likely to die from HIV/AIDS than females (OR: 0.52 [0.3-0.9]). The risk of dying from HIV/AIDS in urban population was 54% less likely than their rural counterparts (OR: 0.46 [0.2-0.9]).

Conclusion: TB and HIV/AIDS interventions are needed to target high-risk and vulnerable populations to reduce premature mortality from these diseases in PNG.

Key words: Tuberculosis; HIV/AIDS; mortality transition; cause of death; verbal autopsy; CHESS; PNG

Article Summary

Strengths and limitations of this study

- This study used TB and HIV/AIDS mortality data extracted from the Comprehensive Health and Epidemiological Surveillance System, providing data of more than 900 deaths recorded in the surveillance population living in the communities across 8 sentinel sites, established in 6 major provinces, representing both urban-rural sectors of four geographical regions of PNG.
- Mortality data were linked with household socioeconomic data, allowing in-depth analyses of sociodemographic factors associated with mortalities from TB and HIV/AIDS.TB and HIV/AIDS mortality data collected via VA interviews with close relatives of the deceased might be biased due the recall process.
- Mortality data did not represent all the TB and HIV/AIDS deaths for the population across the sites during the data collection period because the data did not all deaths occurred in the communities and a part of urbane population could die in hospitals from these diseases.
- This study has provided important understanding and insight that can be used to inform the development of policy and interventions to effectively reduce premature mortality from TB and HIV/AIDS among the PNG population.

Background

The Sustainable Development Goal (SDG) 3.3 states: "By 2030, end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases" [1](2). Tuberculosis (TB) and HIV/AIDS continue to be major global public health issues, having claimed almost 33 million lives. An estimated 38 million people are living with HIV and approximately 690,000 people died from HIV/AIDS, with an additional 1.7 million people newly infected in 2019 [2]. In the Western Pacific Region, TB remains a major public health concern, accounting for nearly 20% of the global burden with an estimated 1.8 million new cases reported in 2019 [3].

Papua New Guinea ((5)(6)PNG) is the largest nation in the South Pacific region with a total population of approximately 8 million, and annual population growth rate of 2.8% in the decade 2000s-2010s. Life expectancy at birth was at 63 years in 2010 and 40% of the PNG population are under 15 years of age [4 5]. Rural populations account for more than 85% of the entire population and are widely scattered across the four geographical regions: Highlands, Southern, Momase, and Islands. PNG is classified as a lower-middle income country and a signatory to the SDGs [6]. PNG has recently undergone an epidemiological transition with premature mortality continuing to decline from 2010 to 2020 [7]. Infectious diseases are still the dominant cause of morbidity, accounting for almost half the total burden of diseases and illnesses at the primary health level [8 9].

TB and HIV/AIDS were reported as major public health concerns in PNG in the 2010s [10 11]. PNG had the highest HIV/AIDS incidence and prevalence in the Pacific region accounting for 95% of the reported HIV/AIDS cases in the region [12]. This disease has had severe impacts on the health sector and it was estimated that people living with AIDS occupied 70% of hospital beds in 2015 [13]. With TB prevalence infection rate of approximately 333 cases per 100,000 population, PNG was classified among 14 countries with the highest burden of TB in the world in 2016. TB prevalence was particularly high among vulnerable populations such as female sex workers and men who have sex with men in Port Moresby, about 1200 and 1000 per 100,000 in 2017, respectively [14]. It was estimated in 2018 that 37,000 people contracted TB and around 4,500 of these people died from this disease [3]. (6)(16)As of 2020, approximately 45,000 people living with HIV/AIDS were reported in PNG [2], with this figure likely to be underreported [15].

In PNG, HIV/AIDS and TB interventions and services are integrated into public health services at the local level and under the administration of Provincial Health Authorities (PHA), which were established across provinces under the PHA Act 2007. The issue of this Act was part of the government decentralization to increase accountability for the provincial and local level governments to improve the standard of public health practices and the delivery of public health services, including preventive and curative services to communities through provincial health partnerships [16]. The national HIV/AIDS and TB programs provide anti-retrovirus therapy (ART) and anti-tuberculosis drugs among other services under the 2016-2020 National Health Plan [17].

Major challenges in the delivery of TB and HIV/AIDS prevention and control programmes include under-detection of new cases, poor treatment outcomes, and the high numbers of TB and HIV/AIDS patients who were lost to follow up [18]. TB and HIV/AIDS patients can seek health care services at health facilities in urban areas. These patients can be admitted to a tertiary hospital for treatment, but they are often discharged from the hospitals in the late stage of their diseases and die at home in their own villages. Hence the records of TB and HIV/AIDS deaths that occur in the communities are more likely completed than those recorded in health facilities, particularly in the rural areas, where access to TB and HIV/AIDS services are limited.

Social determinants of TB and HIV/AIDS mortality are poorly understood despite of the heavy burden of these diseases on health systems in PNG. Study of social determinants of mortality from TB and HIV/AIDS is important for public health policy and interventions [19]. Understanding of social determinants of TB and HIV/AIDS mortalities provides insight into the performance of health systems and healthcare interventions in reducing mortality from these diseases, contributing to achievement of SDGs. In African countries, higher premature mortality from HIV/AIDS was reported among females compared with males, people living in rural areas, and those from lower household socioeconomic status [20]. Sociodemographic factors such as age, sex, education, marital and employment status, housing condition and household socioeconomic status were also associated with HIV/AIDS mortality [21-24]. The impact of TB and HIV/AIDS on mortality of a population could be likely detected and identified at the individual and household levels. Household socioeconomic demographic factors should be considered when examining social determinants of mortality. However, few studies on household and individual sociodemographic factors associated with mortalities attributed to TB and HIV have been conducted in countries in the Western Pacific region. No known study has examined sociodemographic factors related to mortality from TB and HIV/AIDS in PNG.

This study examined the proportion of mortality from TB and HIV/AIDS among people in PNG and explored the possible associations of key sociodemographic factors with these mortalities. The study aimed to address the following research questions:

- What are the distributions of mortality from TB and HIV/AIDS by age, sex and household socioeconomic status of the deceased and by urban-rural sectors and provinces?
- What are the sociodemographic factors associated with TB attributed mortality?
- What are the sociodemographic factors associated with mortality attributed to HIV/AIDS?

Materials and methods

Data source

Mortality surveillance data were extracted from the Comprehensive Health and Epidemiological Surveillance System (CHESS), operated since 2018 by Papua New Guinea Institute of Medical Research (PNGIMR). CHESS was based on the integrated Health and Demographic Surveillance System (iHDSS), which was established in PNG in the period 2010-2017. CHESS was designed as a population-based longitudinal follow-up cohort system. The overall purpose of CHESS was to provide a reliable and up-to-date data series for monitoring the implementation of socioeconomic development programmes and healthcare interventions at the sub-national level in PNG. CHESS catchment areas include eight surveillance sites located in six provinces: Eastern Highlands Province (EHP), East New Britain (ENB), East Sepik Province (ESP), Central, Madang, and Port Moresby (POM - the National Capital District). By the end 2022, CHESS will cover a population size of approximately 80,000, equivalent to 1% of the total population of PNG. The system provides population data from rural and urban sectors, with approximately 75% of rural and 25% of urban populations, comparable with the national rural-urban population distribution for the period 2018-2022 [5]. The designs and methods of iHDSS and CHESS have been previously published [25 26]. The distance between urban-rural sites in EHP and ENB is about 50 km. This provides a balance between facilitating access and transportation and ensuring differences in socioeconomic development can be observed and captured in the data. Sociodemographic characteristics of the surveillance population by sites are presented in Table 1.

Data collection

Mortality surveillance data were collected from the population living in the CHESS sites in the period 2018-2020, using the WHO 2016 verbal autopsy (VA) interview instrument. This tool is based on the consolidation of various existing VA tools and programmed for conducting VA interviews using portable electronic devices [27]. The WHO 2016 tool does not require interviewers to have a health and medical background to conduct VA interviews [28]. The WHO 2016 VA instrument was adapted in 2017 for optimal use in the local context and integrated into CHESS surveillance activities in 2018 [29]. An additional data module on identification information of the deceased, including household GPS data and individual ID code was included in the VA instrument for this study, allows linkage between mortality and household socioeconomic demographic data.

The field work and data collection were integrated into the on-going routine surveillance activities of the CHESS in PNG. The mortality data were collected from the surveillance population, who live in eight surveillance sites established across six provinces: Central, Port Moresby (POM - the National Capital District), Eastern Highlands, Madang, East Sepik, and East New Britain. Data used in this study focused on deaths from the communities and no death records from health facilities were included.

Deaths in the communities were identified by data reporters, who are local people living in their villages, recruited to work for CHESS, and based in their villages. They collected information on birth, death, and migration through regular visits to households for collecting information on demographic changes. Given the social network, data reporters were easily aware of deaths that occurred in their villages and had access to the households at a convenient time to collect further information about the deceased, including the date of death. Data reporters pre-arranged VA interviews at a time and location that convenient for both interviewer and interviewee to attend.

The mortality data and information were collected from March 2018 to September 2020. VA interviews were conducted by national scientific officers of the CHESS's demographic team in *Tok-Pisin,* the most common local language in PNG and *Motu* language was used in Central Province. VA interviews were usually scheduled in the two weeks after mourning period [30]. However, the organisation of VA interviews could take several weeks due to logistical arrangements and the availability of interviewees and transportation means. Some VA interviews required more than one visit to complete. The completion of VA interviews was also prolonged because of lockdowns for several periods and CHESS staff members being infected with COVID-19 during the COVID-19 outbreaks in 2020.

Household relatives, who participated in VA interviews, were often household heads for adults who were deceased and parents/ caregivers for child who were deceased. These participants should have spent a considerable period of time to directly take care of the deceased prior to the deaths, who were able to recognise and remember important clinical signs the deceased demonstrated in their last stage prior to deaths, who were capacitate, willing to cooperate in VA interview, and respond to the interview questions.

Data linkage

An additional data module on the deceased identification information was included in the questionnaire, including household location (GPS data) and individual identification information. This information allows identifying the deceased in the communities and linkages their mortality data and other existing data components available from the CHESS database, including morbidity data and household socioeconomic data.

The household and individual ID coding systems used in CHESS were created in 2014-2015, aligned with the national coding system, published by the National Statistics Office [5]. Household codes consist of 17 digits representing for province/ city (2 digits), district/ town (2 digits), Local Level Government (2 digits), commune/ ward (2 digits), village/ street (3 digits), dwelling/ compound (3 digits), and household number (3 digits). The three last code identifiers were established by the CHESS. Individual ID codes were constructed based on the household ID code by adding two digits (household individual line number) to the end of their respective household ID codes. Individual ID codes are updated on regular basis, using the household demographic change data on birth, death and migration in and out of the households. In addition, households can be also identified, using household GPS data on latitude (Degree South with 8 digits), longitude (Degree East with 8 digits), and elevation (meter with 6 digits).

These coding systems are applied consistently across the surveillance sites and studies conducted using the CHESS research platform that allows identifying households and individuals participating in different studies. Mortality data and household socioeconomic demographic data were linked together by using the household and individual ID codes of the deceased. The linked mortality-household SES data set was for use in the analyses of sociodemographic factors in this study.

The CHESS database is updated with household socioeconomic status (SES) data on every 2 years. The SES data used in this study were also collected from January-June 2018 by village-based data reporters under supervision of demographic team leaders and site managers. Household interviews were conducted with household members, most often with household heads, using the household SES questionnaire, which was comprised of nine data modules: (i) Household identification information, including global positioning system (GPS); (ii) List of household members and their relationship to household head; (iii) Education level of household members aged 5 or above; (iv) Employment status of household members of working age 15-64; (v) Access, availability and utilisation of bed-nets; (vi) Water and sanitation; (vii) Hand washing; (viii) Housing characteristics and household assets; and (ix) Access and utilisation of health services. These data were used to construct the household wealth index.

Data analyses

The InterVA-5 COD analytic tool was used to analyse cause of death (CODs) using VA interview data. This computer-based programme can assign 64 specific CODs and categories in line with the International Classification of Diseases version 10 (ICD-10) [31]. Among the 1021 deaths identified in the communities, consents were obtained for conducing 1003 VA interviews, resulted in a participation rate of 98%. InterVA-5 COD analytic tool successfully assigned specific CODs for 926 VA interviews. InterVA-5 program can assign more than one specific COD for a death with respective likelihoods. However, in this study, only the first ascribed CODs with the highest likelihoods were analysed. For instance of deaths when TB was assigned as the first COD and HIV was the second COD, only TB was included in the TB-attributed mortality analysis. Similarly, in the case when HIV was assigned as the first COD and TB was the second COD, then only HIV attributed deaths were included in the HIV mortality analysis

To analyse mortalities from TB and from HIV/AIDS by selected sociodemographic factors, VA data were linked with the household socioeconomic (SES) data from the corresponding period of time using the unique household and individual identification codes. Specifically, the 2018-2020 VA data were linked with the 2018 household SES data. Mortality data from 665 deaths were successfully linked with household SES data and included in the analyses. No household SES data for ESP for 2018 were available as the site was not established until early 2019.

A new variable on household wealth index was constructed for each deceased using the principal component analysis (PCA) method. The application of PCA in the PNGIMR's CHESS has been previously published [32]. Household SES and demographic variables were included in PCA models. Significant variables remained in the PCA model including housing characteristics, water and sanitation, and household assets. Non significant variables were excluded from the models including education,

employment, and occupation of the deceased. Household wealth indices were then divided into quintiles and categorised as poorest, poor, middle, richer and richest.

Two binary variables were created: (i) TB attributed death ('Yes' was for deaths from TB and 'No' was deaths from any other causes of death (infectious or non-communicable diseases); and (ii) HIV/AIDS attributed death ('Yes' was deaths from HIV/AIDS and 'No' was deaths from any other causes of death (infectious or non-communicable diseases). These variables were included in logistic regression analyses as dependent variables, and sociodemographic factors were independent variables [33].

Unadjusted and adjusted ORs of mortalities from TB and HIV were first produced by using the binary logistic regression analysis. All significant variables identified in these analyses were then included in Multinomial Logistic Regression (MLR) to predict the increased risk of mortalities from TB and from HIV/AIDS across sub-populations. The significant variables remained in the MLR models including age at death, sex of the deceased, household wealth quintile, and urban-rural sector, except for the 'province' variable, which was excluded in the model because of confounding with the urban-rural sector variable (The surveillance site in Port Moresby is located urban area while the site in Central Province in rural area). Main effect was selected to produce estimates of ORs for the risks of dying from TB and HIV/AIDS. Statistical likelihood tests were used to provide 95% confidence intervals (CIs) of the estimated ORs. A p-value of less than 0.05 was considered as significant. All analyses were performed using the Statistical Package for Social Sciences (SPSS-version 20).

Patient and public involvement

No patient involved.

Results

TB and HIV/AIDS as top leading infectious disease causes of death

Figure 1 shows mortality from infectious diseases among the surveillance population. A total of 317 deaths were attributed to infectious diseases, in which pulmonary TB was the leading COD and responsible for 84 deaths, followed by acute respiratory tract infections (81 deaths), and HIV/AIDS (75 deaths). Among the 84 deaths attributed to TB, three deaths assigned HIV/AIDS as the second COD, accounting for 3.6% of TB deaths. Similarly, among the 75 deaths from HIV/AIDS, 6 deaths assigned TB as the second COD, accounting for 0.8% of HIV/AIDS deaths. Hence the co-morbidities of TB and HIV/AIDS could be about 6% of all HIV/AIDS and TB deaths.

Table 2 shows the distribution of TB and HIV/AIDS attributed mortalities by sociodemographic characteristics of the deceased. The mean age of death from TB was 46.3 (± 17.58), which was slightly higher than for HIV/AIDS, 44.21 (± 19.36), but lower than for other CODs, 49.24 (± 24.32) (Eta squared p-value: 0.04). TB accounted for 9% of total deaths in the surveillance population. TB claimed the highest number of deaths in those aged 25-34, comprising 20% of the TB deaths. This was followed by the 35-44

years age group with 18% of deaths. The highest number of TB deaths was observed among people from households in the middle quintile. A slightly higher proportion of deaths occurred in rural areas (10%) compared with urban areas (7%). Central province had the highest numbers of TB deaths, with 41 deaths which accounted for 14% of the death records in this province.

HIV/AIDS attributed to 8% of the total deaths recorded in the surveillance population. The proportion of female deaths attributed to HIV/AIDS was more than twice for males than females, 11% and 5%, respectively. The population aged 25-34 years had the highest number of deaths from HIV/AIDS, accounting for 18% of deaths in this age group. Three HIV/AIDS deaths were identified among children aged 0-4, accounting for 5% of deaths among children in this age group. There were 60 HIV/AIDS deaths identified in rural population, accounting for 9% of deaths in rural areas, compared to 6% reported in urban areas. EHP had the highest number of deaths from HIV/AIDS, with 36 deaths that accounted for 12% of deaths recorded in this province. By contrast, Central province recorded the lowest proportion of deaths from HIV/AIDS (4.5%).

Socioeconomic demographic factors of mortalities from TB and HIV/AIDS

Table 3 shows the adjusted odd ratios of mortality from TB by sociodemographic characteristics of the deceased (Only adjusted ORs are presented because the unadjusted and adjusted ORs were similar). Those aged 25-34 were over five times more likely to die from TB than those aged 75+ years (OR: 5.48 [1.38-21.75]). Urban population were 45% less likely to die from TB than those in rural areas (OR: 0.54 [0.28-1.0]). Those from the middle household wealth quintile were three times more likely to die from TB than those from the richest quintile (OR: 3.06 [1.27-7.37]). The difference in TB mortality between males and females was not significant (p-value: 0.47).

Table 4 shows the adjusted odd ratios of mortality from HIV/AIDS by sociodemographic characteristics of the deceased (Only adjusted ORs are presented because the unadjusted and adjusted ORs were similar). Similar to TB, those aged 25-34 were nearly seven times more likely to die from HIV/AIDS than those aged 75+ years (OR: 6.68 [1.75-25.43]). Males were about 50% less likely to die from HIV/AIDS than their female counterparts (OR: 0.52 [0.29-0.9]). Urban population were about 55% less likely to die from HIV/AIDS than rural populations (OR: 0.46 [0.24-0.89]). The differences in HIV/AIDS mortality were not significant among household wealth quintiles (P-values > 0.05).

Discussion

Using the linked dataset between mortality and household SES data from the CHESS database, we have conducted analyses to identify that TB and HIV/AIDS were the leading CODs from infectious diseases in the population in PNG. Analysis of key sociodemographic factors of mortalities from these diseases, we showed that people aged 25-44, particularly females, those living in rural areas, and from households with lower SES were more likely to die from these diseases.

We found that PNG people were dying from TB and HIV/AIDS at a very young age, with the highest premature mortality among the population in the age group 25-34. Indeed, TB and HIV/AIDS were responsible for 2 in every 5 deaths among young adults aged 15-24. From our observations, young people living in the surveillance sites are highly mobile. Many regularly move from one place to another for education, employment, social and family purposes. They are also sexually active and more likely involved in unprotected sex [34]. Lacking access to preventive measure such as condom, young people are more likely to become infected with HIV/AIDS among other sexually transmitted infections. Young people are the main labor force and the most productive in the national and household economies. The loss of young people to TB and HIV/AIDS present a significant economic cost to their families, the communities and society as a whole [34]. It was estimated if there were 300,000 adult deaths to HIV/AIDS; the workforce would be reduced by 12.5%; and the annual GDP growth rate would decline by 1.3% by 2025 [13].

Gender inequality was a key factor associated with the increased risk of dying from HIV/AIDS among the female population. In PNG, women are culturally considered as having a lower social status than men. Young women are more likely to engage in high risk sexual activities to satisfy or meet their needs and wants than men. Given the low prevalence of safe sex practices, these women are more likely to be exposed to HIV/AIDS infection [35]. In most cases, women are more likely to die younger than men if they are infected with HIV/AIDS. HIV/AIDS also attributed to 5% of deaths among children under five years of age. HIV/AIDS prevention of mother-to-child transmission (PMTCT) programmes have been reportedly integrated into antenatal care services in PNG, but access to these services is limited. Because of social stigma and discrimination, many HIV/AIDS pregnant women did not give correct personal information [35], further hindering the utilisation of antenatal care services. The loss of mothers is likely to leave a large socioeconomic burden to their families, and children are particularly impacted from the loss [18]. Infant children died from HIV/AIDS are evidence of the failure of delivery of the PMTCT programme in PNG. Reducing social stigma and discrimination against people living with HIV/AIDS, particularly women is crucial to improving the delivery of HIV/AIDS services. Increasing men's roles in the national response to HIV/AIDS prevention is also important for a successful implementation of HIV/AIDS programme in PNG.

Our study has shown that people who live in the rural areas were twice as likely to die from TB and HIV/AIDS as those in urban areas. Inadequate health promotion and education could be the cause of low public awareness about the diseases and poor knowledge and practices towards prevention of TB and HIV/AIDS among rural populations. Limited access to basic health care services is often cited as the main reason for the high mortality from TB and HIV/AIDS in PNG [36 37]. The unavailability of skilled health workers, lack of essential drugs and consumables are often reported at primary health facilities in rural areas [10]. Access to antiretroviral therapy (ART) has been a key to reducing the risk of dying from HIV/AIDS, but this service is available only at a small number of tertiary health facilities such as hospitals in Port Moresby. Essential laboratory services such as GeneXpert and TB culture for monitoring MDR-TB, and HIV testing are very limited, even unavailable on regular basis at the Eastern Highlands Provincial Hospital. No community-based modality is available for effective detection and management of TB and

HIV/AIDS cases [38]. Control of the spread of TB and HIV/AIDS infections in the communities has been ineffective due to loss to follow up with the patients [14 35].

The high mobility among young populations between urban and rural areas and particularly the increased number of young migrants moving from rural to urban areas for employment would further complicate the spread of HIV and TB, elevating the higher risks of dying from these diseases, particularly in rural areas, where the access to HIV/AIDS services were even more limited. Health education on preventive measures of HIV/AIDS, including safe sex practice and equitable access to youth-friendly HIV and TB services are needed to reduce the premature mortalities among young people

TB-HIV co-infections have increased and are one of the key challenges to the effective implementation of TB and HIV/AIDS programmes in PNG. Our study estimated that the prevalence of TB and HIV/AIDS co-infections could be about 6% of HIV/AIDS and TB patients. This finding is consistent with our morbidity surveillance data [37]. The recent emergence of HIV/AIDS co-infections with TB in Western and Eastern Highlands provinces has raised a public health threat of multi-drug resistant tuberculosis (MDR-TB) [17 38]. The resurgence of tropical neglected infectious diseases such as typhoid [39], leprosy [38], recent outbreaks of childhood communicable diseases including polio and measles [40], and the current spread of COVID-19 infection in the communities have imposed threats to the overwhelmed healthcare systems.

Using the update-to-date data extracted from the CHESS database, we were able to link the mortality data and the household SES data to enhance the scope of mortality analyses, especially in analysing the sociodemographic factors associated with the increased risk of dying from TB and HIV among the population (The list of significant variables retained in the CPA model component 1 for constructing household wealth index is shown in supplementary Table 1). The use of WHO 2016 VA tool to collect mortality data from the communities are more likely to reflect a real and complete picture of mortality in the population than health facility death records. The InterVA-5 analytic program was used for the first time in this study in PNG to ascertain CODs from TB and HIV in the population that can be scaled up in PNG and replicated in similar settings

The mortality data were collected via VA interviews with close relatives of the deceased. Although the WHO 2016 VA instrument had been pretested with the local people prior to the data collection, the provided information about the deaths may be incomplete and biased due the recall process. InterVA-5 is a standard tool, but the ascribed CODs could be also biases due to the death selection process. The mortality data were collected from the population living within the CHESS catchment areas, but the data included only deaths identified by the village-based data reporters. It is challenging to ensure all deaths occurred in the communities were included in the data. Hence, the data used were not representative for all deaths in the surveillance sites across provinces.

Given the high level of social stigma around TB and discrimination against people living with HIV/AIDS in PNG, deaths from these diseases might have been under reported in this study. The relatively small numbers of deaths, 84 from TB and 75 from HIV compared to all other CODs might have hindered the identification of sociodemographic factors of TB and HIV attributed mortalities. The limited numbers of

observations could have also led to important associations being non-significant when TB and HIV deaths were compared to deaths from all other causes (Unadjusted and adjusted ORs of mortalities from TB and HIV/AIDS in binary logistic regression models are presented in supplementary Table 2). This limits the interpretation of risk factors associated TB and HIV mortalities in this study. An assessment of the accuracy and reliability of specific CODs assigned by InterVA-5 is beyond the scope of this study and will be addressed in a separate study.

Conclusions

Over the past 40 years, HIV/AIDS infections have transitioned to a manageable chronic infection in many LMICs and TB infection has been contained in many parts of the world. The current high mortality from TB and HIV/AIDS in PNG appears in contrast to the global trend of declining infections and deaths from these diseases. TB and HIV/AIDS have recently emerged in PNG and becoming leading causes of death in the population. The high premature mortalities from TB and HIV/AIDS among young people, together with the increased TB-HIV co-infections have raised public concerns about the TB and HIV/AIDS programmes in PNG, threatening the sustainable development of the country [8 41 42].

Urgent actions are needed from the PNG Government and health sector to review the current strategies and plans for further improvement in the effectiveness of TB and HIV/AIDS programmes as well as the delivery of healthcare services to the population in PNG in the next decade. More interventions are needed with focus on high-risk and vulnerable populations, particularly those who are young and females in rural areas and from provinces with low socioeconomic development status. The identified sociodemographic factors associated with premature mortality attributed to TB and HIV/AIDS need to be tackled. Further studies on the trend of mortality transition and the change in CODs across different social classes are needed to better inform policy and intervention.

Declarations

Funding

The CHESS was operated with financial supported from the PNG Government through the Department of National Planning and Monitoring (PIP No. 02704). The funder had no role in study design, data collection and analysis, or writing of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Author contributions

BNP designed the CHESS, conceptualized the paper, and analysed and interpreted the data, drafted, revised, finalized and submitted the manuscript. RJ, VDS and NA supervised the fieldwork, collected and analysed the data, and provided inputs. CR and TO reviewed, provided inputs, and commented the manuscript. WP provided oversight the PNGIMR and approved the submission.

Ethics approval

The CHESS was granted ethics approvals from Institutional Review Board of PNG Institute of Medical Research (IRB's Approval no. 18.05) and the Medical Research Advisory Committee of Papua New Guinea (MRAC's Approval no. 18.06). These approvals covered all the data components under the CHESS, including the mortality data which were used in this manuscript. Informed consent was sought from self-identified close relatives of the deceased. They were informed about their right to withdraw from the study at any stage.

Acknowledgement

This study was conducted as part of the PNGIMR's CHESS programme. We appreciate the participants for their time to attend VA interviews and provide information about the deceased. We thank the data reporters and CHESS staff members for their support in field work and data collection. We acknowledge the contributions and supports from our local partners: community members, religion leaders, and Provincial Health Authorities in Central, Eastern Highlands, East New Britain, East Sepik, Madang provinces and Port Moresby for their partnerships and collaborations in this study.

Data statement

The datasets used in this study are available from the corresponding author on reasonable request. The corresponding author has full access to all the data used in this study and had final responsibility for the decision to submit the study for publication.

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Table 1: Socioeconomic characteristics of the surveillance sites, PNGIMR's CHESS, 2018-2020

Province	Port Moresby	Central	Eastern Highlands	Eastern Highlands	Madang	East Sepik	East New Britain	East New Britain
Surveillance site	Hohola	Hiri	Goroka	Asaro	Newtown	Maprik	Kokopo	Baining
Sector	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Region	Southern	Southern	Highlands	Highlands	Momase	Momase	Islands	Islands
Location	National Capital District	45 km west of Port Moresby	Township of EHP	50 km northeast of Goroka	Township of Madang	30 km from township	Township of ENB	40 km from the town
Main industry	Shipping, transportation	Fishery, hunting	Coffee, agriculture	Coffee, agriculture	Fishery, services	Vanilla, cocoa	Fishery, tourism	Fishery, tourism
Accessibility	Road and airline	Road	Road and airline	Road and airline	Road and airline	Road and airline	Sea and airline	Sea and airline
Year of site established	2017	2011	2016	2004	2018	2019	2018	2018
Population	5,000	15,000	5,000	15,000	5,000	5,000	5,000	6,000
Household	1000	3000	1000	3000	1000	3000	1000	3000
Health facility	St. Theresa clinic	Porebada, Papa and Lealea clinics	Provincial Hospital Kwongi, Lopi and Goroka clinics:	Asaro Health Centre	Jomba Clinic	Ilahita clinic, District Hospital	Batuwin Clinic	Vanapalading Aid Post
Laboratory services	POM Lab	N/A	Goroka Lab	N/A	Madang Lab	N/A	N/A	N/A

Table 2: Distribution of deaths from pulmonary TB, HIV/AIDS, and other causes of death (number and percents) by age group, sex, urban-rural sector, province, and household wealth quintile of the deceased, PNGIMR's CHESS, 2018-2020

		TB	HIV/AIDS	Other CODs	All CODs
Mean age at death (year, SD)	P-value: 0.04	46.32 (17.58)	44.21 (19.36)	49.24 (24.32)	48.56 (23.44)
Age group	0-4	0 (0.0%)	3 (4.5%)	64 (95.5%)	67 (100.0%)
	5-14	1 (3.8%)	0 (0.0%)	25 (96.2%)	26 (100.0%)
	15-24	7 (11.3%)	6 (9.7%)	49 (79.0%)	62 (100.0%)
	25-34	20 (20.2%)	18 (18.2%)	61 (61.6%)	99 (100.0%)
	35-44	17 (18.1%)	11 (11.7%)	66 (70.2%)	94 (100.0%)
	45-54	9 (6.0%)	14 (9.4%)	126 (84.6%)	149 (100.0%)
	55-64	15 (8.8%)	14 (8.2%)	141 (82.9%)	170 (100.0%)
	65-74	12 (8.4%)	4 (2.8%)	127 (88.8%)	143 (100.0%)
	75+	3 (2.7%)	5 (4.4%)	105 (92.9%)	113 (100.0%)
Total		84 (9.1%)	75 (8.1%)	764 (82.8%)	923 (100.0%)
Sex	Male	43 (8.4%)	28 (5.4%)	443 (86.2%)	514 (100.0%)
	Female	41 (10.0%)	47 (11.4%)	324 (78.6%)	412 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)
Sector	Urban	16 (7.0%)	13 (5.7%)	199 (87.3%)	228 (100.0%)
	Rural	67 (9.9%)	60 (8.9%)	550 (81.2%)	677 (100.0%)
Total		83 (9.2%)	73 (8.1%)	749 (82.8%)	905 (100.0%)
Household wealth quintile	Poorest	9 (6.5%)	14 (10.1%)	115 (83.3%)	138 (100.0%)
	Poor	7 (5.1%)	15 (10.9%)	116 (84.1%)	138 (100.0%)
	Middle	21 (15.2%)	14 (10.1%)	103 (74.6%)	138 (100.0%)
	Rich	16 (11.6%)	10 (7.2%)	112 (81.2%)	138 (100.0%)
	Richest	8 (5.8%)	8 (5.8%)	121 (88.3%)	137 (100.0%)
Total		61 (8.9%)	61 (8.9%)	567 (82.3%)	689 (100.0%)
Province	Port Moresby	1 (3.3%)	2 (6.7%)	27 (90.0%)	30 (100.0%)
	Central	41 (14.2%)	13 (4.5%)	234 (81.3%)	288 (100.0%)
	Eastern Highlands	25 (8.3%)	36 (12.0%)	239 (79.7%)	300 (100.0%)
	Madang	8 (10.5%)	8 (10.5%)	60 (78.9%)	76 (100.0%)
	East Sepik	2 (1.7%)	8 (6.9%)	106 (91.4%)	116 (100.0%)
	East New Britain	7 (6.0%)	8 (6.9%)	101 (87.1%)	116 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)

Table 3: Distribution of deaths and adjusted odds ratios of mortality from pulmonary tuberculosis versus all other causes of death, by sociodemographic characteristics of the deceased, multinomial logistic regression analysis, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Adjusted Odds ratio	Lower Bound	Upper Bound	P-value
Age group (in year)	0-4	39	5.9%	NA	NA	NA	NA
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	2.982	0.621	14.317	0.172
	25-34	64	9.6%	5.482	1.382	21.751	0.016
	35-44	62	9.3%	6.428	1.675	24.664	0.007
	45-54	115	17.3%	2.290	0.582	9.009	0.236
	55-64	131	19.7%	3.118	0.856	11.360	0.085
	65-74	102	15.3%	3.438	0.913	12.955	0.068
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	1.227	0.696	2.164	0.479
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.540	0.288	1.000	0.050
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	0.997	0.367	2.708	0.995
	Poor	135	20.3%	0.817	0.283	2.359	0.709
	Middle	130	19.5%	3.067	1.275	7.374	0.012
	Rich	130	19.5%	2.005	0.802	5.010	0.137
	Richest	135	20.3%	Ref.			
Valid total		665	100.0%				

Note: Dependent variable was deaths from tuberculosis. Reference category was deaths from other CODs. Sociodemographic factors remained in MLR models included age, sex, urban-rural sector and household wealth.

Table 4: Distribution of deaths and adjusted odds ratios of mortality from HIV/AIDS versus all other causes of death, by sociodemographic characteristics of the deceased, multinomial logistic regression analysis, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Adjusted Odds ratio	Lower Bound	Upper Bound	P-value
Age group	0-4	39	5.9%	1.511	0.240	9.531	0.660
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	3.461	0.771	15.548	0.105
	25-34	64	9.6%	6.687	1.758	25.438	0.005
	35-44	62	9.3%	4.872	1.240	19.150	0.023
	45-54	115	17.3%	2.868	0.765	10.758	0.118
	55-64	131	19.7%	2.876	0.783	10.565	0.112
	65-74	102	15.3%	1.108	0.238	5.150	0.896
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	0.517	0.294	0.908	0.022
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.464	0.240	0.899	0.023
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	2.084	0.797	5.452	0.134
	Poor	135	20.3%	2.342	0.901	6.090	0.081
	Middle	130	19.5%	1.999	0.751	5.319	0.165
	Rich	130	19.5%	1.550	0.557	4.311	0.401
	Richest	135	20.3%	Ref.			
Valid		665	100.0%				

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

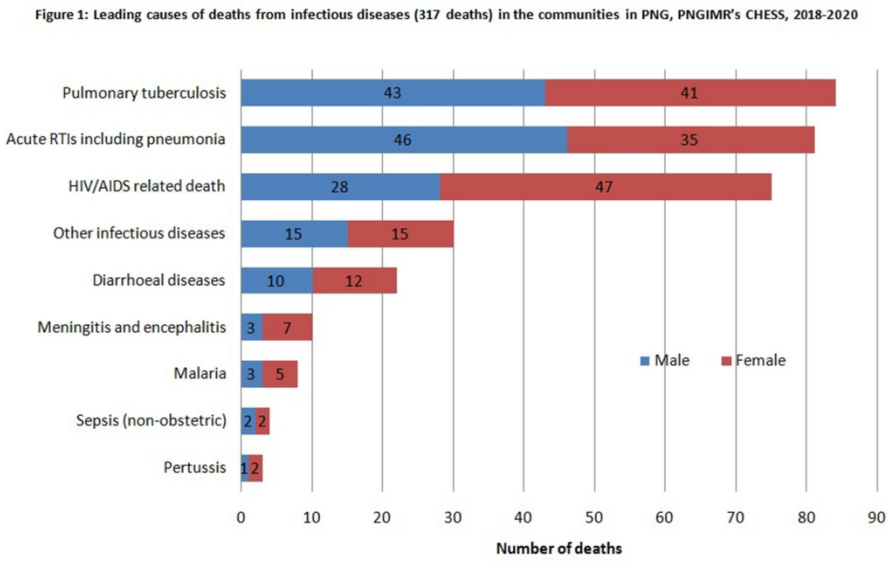

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

176x132mm (300 x 300 DPI)

Supplementary file

Supplementary Table 1: List of significant variables retained in principal component analysis (PCA) for constructing household wealth index, PNGIMR's CHESS 2018-2020

Number	Variable name	Extraction	Component 1
	Water and sanitation		
1	Main source of water for drinking	0.827	0.315
2	Main source of water for cooking	0.887	0.333
3	Water source location	0.739	-0.176
4	Kind of toilet facility	0.834	0.13
5	Shared/ non shared toilet facility	0.744	-0.01
6	Public / household shared toilet facilities	0.661	0.047
	Hand washing		
7	Facility for washing hands	0.713	-0.055
8	Available water for hand washing	0.737	-0.029
9	Available soap or detergent for washing hands	0.852	-0.383
10	Bar soap available	0.844	0.404
11	Detergent (Powder / Liquid / Paste) available	0.751	0.015
12	Liquid soap Available	0.756	0.282
13	Ash / Mud / Sand available	0.852	0.303
14	None above available	0.591	-0.086
	Housing characteristics		
15	Type of house	0.955	0.206
16	Number of room in house	0.848	-0.095
17	Number of sleeping room	0.835	-0.109
18	Wall materials	0.846	0.117
19	Floor materials	0.766	-0.166
20	Roof amterials	0.889	0.234
21	Source of fuel for cooking	0.618	-0.015
22	Separate room for cooking	0.79	-0.126
	Household assets		
23	Owned/ Not owned car/Truck	0.751	0.083
24	Owned/ Not owned Cupboard	0.777	0.245
25	Owned/ Not owned Motorcycle	0.768	0.035
26	Owned/ Not owned Bicycle	0.775	0.28
27	Owned/ Not owned Generator	0.722	0.227
28	Owned/ Not owned Computer	0.796	0.213
29	Owned/ Not owned Refrigerator	0.85	0.075
30	Owned/ Not owned Freezer	0.811	0.053
31	Owned/ Not owned Clock/Watch	0.702	0.233
32	Owned/ Not owned Radio	0.721	0.465
33	Owned/ Not owned TV	0.743	0.334
34	Owned/ Not owned Fan	0.834	0.195
35	Owned/ Not owned Landline phone	0.822	0.035

36	Owned/ Not owned Table/chairs	0.641	0.294
37	Owned/ Not owned Canoe/boat	0.746	-0.109
38	Owned/ Not owned Air-conditioner	0.702	-0.039
39	Owned/ Not owned Gas/elect cooker	0.847	0.075
40	Owned/ Not owned Washing machine	0.666	0.095
41	Owned/ Not owned Mobile phone	0.776	0.267
42	Owned/ Not owned Beds (framed)	0.831	0.267
43	Owned/ Not owned Internet connection	0.641	-0.004
44	Owned or rent house	0.719	-0.029
45	Owned agriculture land	0.917	-0.005
46	Ownership of water surface for aquaculture	0.906	-0.015
47	Owned livestock, farm animals	0.773	-0.277
48	Ownership of BUFFALO	0.607	-0.026
49	Ownership of HORSES	0.737	0.086
50	Ownership of GOATS	0.675	0.012
51	Ownership of SHEEP	0.686	-0.03
52	Ownership of CHICKENS	0.768	0.039
53	Ownership of PIGS	0.777	0.355
54	Ownership of DUCKS	0.753	-0.038
55	Ownership of bank account	0.876	-0.037
56	English spoken in the household	0.726	0.203
57	Tok-Pisin spoken in the household	0.795	-0.102
58	Motu spoken in the household	0.867	0.109
59	Tokples spoken in the household	0.742	-0.205
	Health services		
60	Close to health facility	0.794	0.306
61	Transportation means commonly used	0.758	0.195
62	Last time used the health service	0.801	-0.032
63	Out-patient consultation service	0.8	-0.134
64	In-patient clinical, care and treatment service	0.841	0.146
65	Laboratory investigation services	0.777	0.102
66	Cost for health service	0.611	-0.19
67	Satisfaction of health service provided	0.681	-0.284
	Household size		
68	Urban-rural sector	0.815	-0.074
69	Total number of ALL household members	0.907	-0.011
70	Total number of WOMEN aged 15-49	0.754	0.02
71	Total number of CHILDREN under 5	0.752	0.02
72	Total number of MEN aged 15-65	0.738	-0.037
	Education		
73	Household members aged 5-24 attended class in school year 2018	0.596	-0.013
74	Educational level attended by household members aged 5-24 years	0.912	0.06
75	School grades attended by household members in school year 2018	0.918	0.039

Supplementary Table 2: Unadjusted and adjusted odds ratios of mortalities from TB and HIV/AIDS versus other causes of death by household sociodemographic characteristics of the deceased, binary logistic regression analysis, PNGIMR's CHESS, 2018-2020

Socioeconomic determinant	Category	N	%	Unadjusted Odds Ratio [b]				Adjusted Odds Ratio			
				uOR	Lower	Upper	P-value	aOR	Lower	Upper	P-value
Sector	Urban	226	34.0%	0.317	0.166	0.606	0.001	0.149	0.102	0.356	0.001
	Rural	439	66.0%	Ref.				Ref.			
Province [a]	POM	30	4.5%	1.013	0.250	4.107	0.985	1.013	0.396	2.313	0.961
	Central	167	25.1%	0.698	0.324	1.505	0.359	0.641	0.152	1.447	0.366
	EHP	277	41.7%	1.255	0.637	2.473	0.512	1.227	0.540	2.033	0.488
	Madang	75	11.3%	2.658	1.116	6.331	0.027	1.977	1.078	3.070	0.032
	ENB	116	17.4%	Ref.				Ref.			
Sex	Male	387	58.2%	0.736	0.479	1.129	0.160	0.693	0.220	1.125	0.165
	Female	278	41.8%	Ref.				Ref.			
Age group (in year)	0-4	39	5.9%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	5-14	20	3.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	15-24	45	6.8%	3.713	1.190	11.581	0.024	2.312	1.000	3.790	0.020
	25-34	64	9.6%	7.820	2.842	21.518	0.000	3.057	2.161	4.514	0.003
	35-44	62	9.3%	7.059	2.566	19.421	0.000	2.954	2.022	4.485	0.003
	45-54	115	17.3%	3.230	1.203	8.671	0.020	2.173	1.221	3.574	0.013
	55-64	131	19.7%	3.363	1.297	8.718	0.013	2.213	1.251	3.457	0.015
	65-74	102	15.3%	2.257	0.822	6.200	0.114	1.814	0.771	3.175	0.101
	75-102	87	13.1%	Ref.				Ref.			
Household wealth	Poorest	135	20.3%	1.618	0.779	3.363	0.197	1.481	0.750	2.363	0.195
	Poor	135	20.3%	1.539	0.736	3.216	0.252	1.431	0.615	2.258	0.251
	Middle	130	19.5%	3.232	1.598	6.536	0.001	2.173	1.506	2.985	0.002
	Rich	130	19.5%	1.950	0.940	4.043	0.073	1.668	0.916	2.488	0.079
	Richest	135	20.3%	Ref.				Ref.			
Valid		665	100.0%	[a] No data of ESP was included in the Multivariate Logistic Regress Model.							
Missing		261		[b] Dependent variable was deaths from HIV/AIDS and tuberculosis. The reference category was deaths from other COD rather than tese two diseases. Socioeconomic and demographic factors included in the model were urban-rural sector, province, sex and age group of the deceased and household wealth group.							
Total		926		[c] Results were based on 1000 bootstrap samples.							
Subpopulation		341[d]		[d] The dependent variable had only one value observed in 271 (79.5%) subpopulations.							

STROBE Statement—checklist of items that should be included in reports of observational 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	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
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	*6*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	N/A
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
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	10
		(*b*) Report category boundaries when continuous variables were categorized	10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
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	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
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 cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

BMJ Open

Tuberculosis and HIV/AIDS-attributed Mortalities and Associated Sociodemographic Factors in Papua New Guinea: Evidence from the Comprehensive Health and Epidemiological Surveillance System

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-058962.R2
Article Type:	Original research
Date Submitted by the Author:	02-May-2022
Complete List of Authors:	Pham, Bang; Papua New Guinea Institute of Medical Research, Population Health and Demography Abori, Norah; Papua New Guinea Institute of Medical Research Silas, Vinson D.; Papua New Guinea Institute of Medical Research, Population Health and Demography Unit Jorry, Ronny; Papua New Guinea Institute of Medical Research Rao, Chalapati; Australian National University Okely, Tony; Illawarra Health and Medical Research Institute Pomat, Willie; Papua New Guinea Institute of Medical Research
Primary Subject Heading:	Global health
Secondary Subject Heading:	HIV/AIDS, Public health, Epidemiology, Infectious diseases
Keywords:	Tuberculosis < INFECTIOUS DISEASES, HIV & AIDS < INFECTIOUS DISEASES, EPIDEMIOLOGY, Public health < INFECTIOUS DISEASES

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Tuberculosis and HIV/AIDS-attributed Mortalities and Associated Sociodemographic Factors in Papua New Guinea: Evidence from the Comprehensive Health and Epidemiological Surveillance System

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Word count: 5240

Abstract

Objective: Tuberculosis (TB) and HIV/AIDS are public health concerns in Papua New Guinea (PNG). This study examines TB and HIV/AIDS mortalities and associated sociodemographic factors in PNG.

Method: As part of a longitudinal study, verbal autopsy (VA) interviews were conducted using the WHO 2016 VA Instrument to collect data of 926 deaths occurred in the communities within the catchment areas of the Comprehensive Health and Epidemiological Surveillance System from 2018-2020.

InterVA-5 cause of deaths analytic tool was used to assign specific causes of death (COD). Multinomial logistic regression analyses were conducted to identify associated sociodemographic factors, estimate adjusted odds ratios (AOR), 95% confidential intervals (CIs) and p-values.

Result: TB and HIV/AIDS were the leading CODs from infectious diseases, attributed to 9% and 8% of the total deaths, respectively.

Young adults (25-34 years) had the highest proportion of deaths from TB (20%) and the risk of dying from TB among this age group was five times more likely than those aged 75+ years (AOR: 5.5 [1.4-21.7]). Urban populations were 46% less likely to die from this disease compared rural ones although the difference was not significant (AOR: 0.54 [0.3-1.0]). People from middle household wealth quintile were three times more likely to die from TB than those in the richest quintile (AOR: 3.0 [1.3-7.4]).

Young adults also had the highest proportion of deaths to HIV/AIDS (18%) and were nearly seven times more likely to die from this disease compared with those aged 75+ years (AOR: 6.7 [1.7-25.4]). Males were 48% less likely to die from HIV/AIDS than females (AOR: 0.52 [0.3-0.9]). The risk of dying from HIV/AIDS in urban population was 54% less likely than their rural counterparts (AOR: 0.46 [0.2-0.9]).

Conclusion: TB and HIV/AIDS interventions are needed to target vulnerable populations to reduce premature mortality from these diseases in PNG.

Key words: Tuberculosis; HIV/AIDS; mortality transition; cause of death; verbal autopsy; CHESS; PNG

Article Summary

Strengths and limitations of the study method

- This study used TB and HIV/AIDS mortality data extracted from the Comprehensive Health and Epidemiological Surveillance System, providing data of more than 900 deaths recorded in the surveillance population, representing both urban-rural sectors of four geographical regions of PNG.
- Mortality data were collected in the period 2018-2020 via verbal autopsy (VA) interviews with close relatives of the deceased, who died in the communities, using the WHO 2016 VA interview instrument.
- The InterVA-5 analytic tool was used to assign specific causes of death (CODs) and categories in line with the International Classification of Diseases version 10 (ICD-10).
- TB and HIV/AIDS mortality data were linked with household socioeconomic data and household wealth index was constructed, allowing in-depth analyses of sociodemographic factors associated with mortalities from TB and HIV/AIDS.
- Mortality data did not represent all the TB and HIV/AIDS deaths in the communities across the surveillance sites during the data collection period and might be biased due the recall process.

Background

The Sustainable Development Goal (SDG) 3.3 states: "By 2030, end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases" [1](2). Tuberculosis (TB) and HIV/AIDS continue to be major global public health issues, having claimed almost 33 million lives. An estimated 38 million people are living with HIV and approximately 690,000 people died from HIV/AIDS, with an additional 1.7 million people newly infected in 2019 [2]. In the Western Pacific Region, TB remains a major public health concern, accounting for nearly 20% of the global burden with an estimated 1.8 million new cases reported in 2019 [3].

Papua New Guinea ((5)(6)PNG) is the largest nation in the South Pacific region with a total population of approximately 8 million, and annual population growth rate of 2.8% in the decade 2000s-2010s. Life expectancy at birth was at 63 years in 2010 and 40% of the PNG population are under 15 years of age [4 5]. Rural populations account for more than 85% of the entire population and are widely scattered across the four geographical regions: Highlands, Southern, Momase, and Islands. PNG is classified as a lower-middle income country and a signatory to the SDGs [6]. PNG has recently undergone an epidemiological transition with premature mortality continuing to decline from 2010 to 2020 [7]. Infectious diseases are still the dominant cause of morbidity, accounting for almost half the total burden of diseases and illnesses at the primary health level [8 9].

TB and HIV/AIDS were reported as major public health concerns in PNG in the 2010s [10 11]. PNG had the highest HIV/AIDS incidence and prevalence in the Pacific region accounting for 95% of the reported HIV/AIDS cases in the region [12]. This disease has had severe impacts on the health sector and it was estimated that people living with AIDS occupied 70% of hospital beds in 2015 [13]. With TB prevalence infection rate of approximately 333 cases per 100,000 population, PNG was classified among 14 countries with the highest burden of TB in the world in 2016. TB prevalence was particularly high among vulnerable populations such as female sex workers and men who have sex with men in Port Moresby, about 1200 and 1000 per 100,000 in 2017, respectively [14]. It was estimated in 2018 that 37,000 people contracted TB and around 4,500 of these people died from this disease [3]. (6)(16)As of 2020, approximately 45,000 people living with HIV/AIDS were reported in PNG [2], with this figure likely to be underreported [15].

In PNG, HIV/AIDS and TB interventions and services are integrated into public health services at the local level and under the administration of Provincial Health Authorities (PHA), which were established across provinces under the PHA Act 2007. The issue of this Act was part of the government decentralization to increase accountability for the provincial and local level governments to improve the standard of public health practices and the delivery of public health services, including preventive and curative services to communities through provincial health partnerships [16]. The national HIV/AIDS and TB programs provide anti-retrovirus therapy (ART) and anti-tuberculosis drugs among other services under the 2016-2020 National Health Plan [17].

Major challenges in the delivery of TB and HIV/AIDS prevention and control programmes include under-detection of new cases, poor treatment outcomes, and the high numbers of TB and HIV/AIDS patients who were lost to follow up [18]. TB and HIV/AIDS patients can seek health care services at health facilities in urban areas. These patients can be admitted to a tertiary hospital for treatment, but they are often discharged from the hospitals in the late stage of their diseases and die at home in their own villages. Hence the records of TB and HIV/AIDS deaths that occur in the communities are more likely completed than those recorded in health facilities, particularly in the rural areas, where access to TB and HIV/AIDS services are limited.

Social determinants of TB and HIV/AIDS mortality are poorly understood despite of the heavy burden of these diseases on health systems in PNG. Study of social determinants of mortality from TB and HIV/AIDS is important for public health policy and interventions [19]. Understanding of social determinants of TB and HIV/AIDS mortalities provides insight into the performance of health systems and healthcare interventions in reducing mortality from these diseases, contributing to achievement of SDGs. In African countries, higher premature mortality from HIV/AIDS was reported among females compared with males, people living in rural areas, and those from lower household socioeconomic status [20]. Sociodemographic factors such as age, sex, education, marital and employment status, housing condition and household socioeconomic status were also associated with HIV/AIDS mortality [21-24]. The impact of TB and HIV/AIDS on mortality of a population could be likely detected and identified at the individual and household levels. Household socioeconomic demographic factors should be considered when examining social determinants of mortality. However, few studies on household and individual sociodemographic factors associated with mortalities attributed to TB and HIV have been conducted in countries in the Western Pacific region. No known study has examined sociodemographic factors related to mortality from TB and HIV/AIDS in PNG.

This study examined the proportion of mortality from TB and HIV/AIDS among people in PNG and explored the possible associations of key sociodemographic factors with these mortalities. The study aimed to address the following research questions:

- What are the distributions of mortality from TB and HIV/AIDS by age, sex and household socioeconomic status of the deceased and by urban-rural sectors and provinces?
- What are the sociodemographic factors associated with TB attributed mortality?
- What are the sociodemographic factors associated with mortality attributed to HIV/AIDS?

Materials and methods

Data source

Mortality surveillance data were extracted from the Comprehensive Health and Epidemiological Surveillance System (CHESS), operated since 2018 by Papua New Guinea Institute of Medical Research (PNGIMR). CHESS was based on the integrated Health and Demographic Surveillance System (iHDSS), which was established in PNG in the period 2010-2017. CHESS was designed as a population-based longitudinal follow-up cohort system. The overall purpose of CHESS was to provide a reliable and up-to-date data series for monitoring the implementation of socioeconomic development programmes and healthcare interventions at the sub-national level in PNG. CHESS catchment areas include eight surveillance sites located in six provinces: Eastern Highlands Province (EHP), East New Britain (ENB), East Sepik Province (ESP), Central, Madang, and Port Moresby (POM - the National Capital District). By the end 2022, CHESS will cover a population size of approximately 80,000, equivalent to 1% of the total population of PNG. The system provides population data from rural and urban sectors, with approximately 75% of rural and 25% of urban populations, comparable with the national rural-urban population distribution for the period 2018-2022 [5]. The designs and methods of iHDSS and CHESS have been previously published [25 26]. The distance between urban-rural sites in EHP and ENB is about 50 km. This provides a balance between facilitating access and transportation and ensuring differences in socioeconomic development can be observed and captured in the data. Sociodemographic characteristics of the surveillance population by sites are presented in Table 1.

Data collection

Mortality surveillance data were collected from the population living in the CHESS sites in the period 2018-2020, using the WHO 2016 verbal autopsy (VA) interview instrument. This tool is based on the consolidation of various existing VA tools and programmed for conducting VA interviews using portable electronic devices [27]. The WHO 2016 tool does not require interviewers to have a health and medical background to conduct VA interviews [28]. The WHO 2016 VA instrument was adapted in 2017 for optimal use in the local context and integrated into CHESS surveillance activities in 2018 [29]. An additional data module on identification information of the deceased, including household GPS data and individual ID code was included in the VA instrument for this study, allows linkage between mortality and household socioeconomic demographic data.

The field work and data collection were integrated into the on-going routine surveillance activities of the CHESS in PNG. The mortality data were collected from the surveillance population, who live in eight surveillance sites established across six provinces: Central, Port Moresby (POM - the National Capital District), Eastern Highlands, Madang, East Sepik, and East New Britain. Data used in this study focused on deaths from the communities and no death records from health facilities were included.

Deaths in the communities were identified by data reporters, who are local people living in their villages, recruited to work for CHESS, and based in their villages. They collected information on birth, death, and migration through regular visits to households for collecting information on demographic changes. Given the social network, data reporters were easily aware of deaths that occurred in their villages and had access to the households at a convenient time to collect further information about the deceased, including the date of death. Data reporters pre-arranged VA interviews at a time and location that convenient for both interviewer and interviewee to attend.

The mortality data and information were collected from March 2018 to September 2020. VA interviews were conducted by national scientific officers of the CHESS's demographic team in *Tok-Pisin,* the most common local language in PNG and *Motu* language was used in Central Province. VA interviews were usually scheduled in the two weeks after mourning period [30]. However, the organisation of VA interviews could take several weeks due to logistical arrangements and the availability of interviewees and transportation means. Some VA interviews required more than one visit to complete. The completion of VA interviews was also prolonged because of lockdowns for several periods and CHESS staff members being infected with COVID-19 during the COVID-19 outbreaks in 2020.

Household relatives, who participated in VA interviews, were often household heads for adults who were deceased and parents/ caregivers for child who were deceased. These participants should have spent a considerable period of time to directly take care of the deceased prior to the deaths, who were able to recognise and remember important clinical signs the deceased demonstrated in their last stage prior to deaths, who were capacitate, willing to cooperate in VA interview, and respond to the interview questions.

Data linkage

An additional data module on the deceased identification information was included in the questionnaire, including household location (GPS data) and individual identification information. This information allows identifying the deceased in the communities and linkages their mortality data and other existing data components available from the CHESS database, including morbidity data and household socioeconomic data.

The household and individual ID coding systems used in CHESS were created in 2014-2015, aligned with the national coding system, published by the National Statistics Office [5]. Household codes consist of 17 digits representing for province/ city (2 digits), district/ town (2 digits), Local Level Government (2 digits), commune/ ward (2 digits), village/ street (3 digits), dwelling/ compound (3 digits), and household number (3 digits). The three last code identifiers were established by the CHESS. Individual ID codes were constructed based on the household ID code by adding two digits (household individual line number) to the end of their respective household ID codes. Individual ID codes are updated on regular basis, using the household demographic change data on birth, death and migration in and out of the households. In addition, households can be also identified, using household GPS data on latitude (Degree South with 8 digits), longitude (Degree East with 8 digits), and elevation (meter with 6 digits).

These coding systems are applied consistently across the surveillance sites and studies conducted using the CHESS research platform that allows identifying households and individuals participating in different studies. Mortality data and household socioeconomic demographic data were linked together by using the household and individual ID codes of the deceased. The linked mortality-household SES data set was for use in the analyses of sociodemographic factors in this study.

The CHESS database is updated with household socioeconomic status (SES) data on every 2 years. The SES data used in this study were also collected from January-June 2018 by village-based data reporters under supervision of demographic team leaders and site managers. Household interviews were conducted with household members, most often with household heads, using the household SES questionnaire, which was comprised of nine data modules: (i) Household identification information, including global positioning system (GPS); (ii) List of household members and their relationship to household head; (iii) Education level of household members aged 5 or above; (iv) Employment status of household members of working age 15-64; (v) Access, availability and utilisation of bed-nets; (vi) Water and sanitation; (vii) Hand washing; (viii) Housing characteristics and household assets; and (ix) Access and utilisation of health services. These data were used to construct the household wealth index.

Data analyses

The InterVA-5 COD analytic tool was used to analyse causes of death (CODs) using VA interview data. This computer-based programme can assign 64 specific CODs and categories in line with the International Classification of Diseases version 10 (ICD-10) [31]. Among the 1021 deaths identified in the communities, consents were obtained for conducing 1003 VA interviews, resulted in a participation rate of 98%. InterVA-5 COD analytic tool successfully assigned specific CODs for 926 VA interviews. InterVA-5 program can assign more than one specific COD for a death with respective likelihoods. However, in this study, only the first ascribed CODs with the highest likelihoods were analysed. For instance of deaths when TB was assigned as the first COD and HIV was the second COD, only TB was included in the TB-attributed mortality analysis. Similarly, in the case when HIV was assigned as the first COD and TB was the second COD, then only HIV attributed deaths were included in the HIV mortality analysis

To analyse mortalities from TB and from HIV/AIDS by selected sociodemographic factors, VA data were linked with the household socioeconomic (SES) data from the corresponding period of time using the unique household and individual identification codes. Specifically, the 2018-2020 VA data were linked with the 2018 household SES data. Mortality data from 665 deaths were successfully linked with household SES data and included in the analyses. No household SES data for ESP for 2018 were available as the site was not established until early 2019.

A new variable on household wealth index was constructed for each deceased using the principal component analysis (PCA) method. The application of PCA in the PNGIMR's CHESS has been previously published [32]. Household SES and demographic variables were included in PCA models. Significant variables remained in the PCA model including housing characteristics, water and sanitation, and household assets. Non significant variables were excluded from the models including education,

employment, and occupation of the deceased. Household wealth indices were then divided into quintiles and categorised as poorest, poor, middle, richer and richest.

Two binary variables were created: (i) TB attributed death ('Yes' was for deaths from TB and 'No' was deaths from any other causes of death (infectious or non-communicable diseases); and (ii) HIV/AIDS attributed death ('Yes' was deaths from HIV/AIDS and 'No' was deaths from any other causes of death (infectious or non-communicable diseases). These variables were included in logistic regression analyses as dependent variables, and sociodemographic factors were independent variables [33].

Unadjusted and adjusted ORs of mortalities from TB and HIV were first produced by using the binary logistic regression analysis. All significant variables identified in these analyses were then included in Multinomial Logistic Regression (MLR) to predict the increased risk of mortalities from TB and from HIV/AIDS across sub-populations. The significant variables remained in the MLR models including age at death, sex of the deceased, household wealth quintile, and urban-rural sector, except for the 'province' variable, which was excluded in the model because of confounding with the urban-rural sector variable (The surveillance site in Port Moresby is located urban area while the site in Central Province in rural area). Main effect was selected to produce estimates of ORs for the risks of dying from TB and HIV/AIDS. Statistical likelihood tests were used to provide 95% confidence intervals (CIs) of the estimated ORs. A p-value of less than 0.05 was considered as significant. All analyses were performed using the Statistical Package for Social Sciences (SPSS-version 20).

Patient and public involvement

No patient involved.

Results

TB and HIV/AIDS as top leading infectious disease causes of death

Figure 1 shows mortality from infectious diseases among the surveillance population. A total of 317 deaths were attributed to infectious diseases, in which pulmonary TB was the leading COD and responsible for 84 deaths, followed by acute respiratory tract infections (81 deaths), and HIV/AIDS (75 deaths). Among the 84 deaths attributed to TB, three deaths assigned HIV/AIDS as the second COD, accounting for 3.6% of TB deaths. Similarly, among the 75 deaths from HIV/AIDS, 6 deaths assigned TB as the second COD, accounting for 0.8% of HIV/AIDS deaths. Hence the co-morbidities of TB and HIV/AIDS could be about 6% of all HIV/AIDS and TB deaths.

Table 2 shows the distribution of TB and HIV/AIDS attributed mortalities by sociodemographic characteristics of the deceased. The mean age of death from TB was 46.3 (± 17.58), which was slightly higher than for HIV/AIDS, 44.21 (± 19.36), but lower than for other CODs, 49.24 (± 24.32) (Eta squared p-value: 0.04). TB accounted for 9% of total deaths in the surveillance population. TB claimed the highest number of deaths in those aged 25-34, comprising 20% of all CODs recorded in this age group. This was

followed by the 35-44 years age group with 18% of deaths. The highest number of TB deaths was observed among people from households in the middle quintile. A slightly higher proportion of deaths occurred in rural areas (10%) compared with urban areas (7%). Central province had the highest numbers of TB deaths, with 41 deaths which accounted for 14% of the death records in this province.

HIV/AIDS attributed to 8% of the total deaths recorded in the surveillance population. The proportion of deaths attributed to HIV/AIDS was more than twice for females than males, 11% and 5%, respectively. The population aged 25-34 years had the highest number of deaths from HIV/AIDS, accounting for 18% of deaths in this age group. Three HIV/AIDS deaths were identified among children aged 0-4, accounting for 5% of deaths among children in this age group. There were 60 HIV/AIDS deaths identified in rural population, accounting for 9% of deaths in rural areas, compared to 6% reported in urban areas. EHP had the highest number of deaths from HIV/AIDS, with 36 deaths that accounted for 12% of deaths recorded in this province. By contrast, Central province recorded the lowest proportion of deaths from HIV/AIDS (4.5%).

Socioeconomic demographic factors of mortalities from TB and HIV/AIDS

Table 3 shows the adjusted odd ratios of mortality from TB by sociodemographic characteristics of the deceased (Only adjusted ORs are presented because the unadjusted and adjusted ORs were similar). Those aged 25-34 were over five times more likely to die from TB than those aged 75+ years (AOR: 5.48 [1.38-21.75]). Urban populations were 46% less likely to die from TB than those in rural areas (AOR: 0.54 [0.28-1.0]) although the difference was not significant (p-value: 0.05). People from the middle household wealth quintile were three times more likely to die from TB than those from the richest quintile (AOR: 3.06 [1.27-7.37]). The difference in TB mortality between males and females was not significant (p-value: 0.47).

Table 4 shows the adjusted odd ratios of mortality from HIV/AIDS by sociodemographic characteristics of the deceased (Only adjusted ORs are presented because the unadjusted and adjusted ORs were similar). Similar to TB, those aged 25-34 were nearly seven times more likely to die from HIV/AIDS than those aged 75+ years (AOR: 6.68 [1.75-25.43]). Males were about 50% less likely to die from HIV/AIDS than their female counterparts (AOR: 0.52 [0.29-0.9]). Urban population were about 55% less likely to die from HIV/AIDS than rural populations (AOR: 0.46 [0.24-0.89]). The differences in HIV/AIDS mortality were not significant among household wealth quintiles (P-values > 0.05).

Discussion

Using the linked dataset between mortality and household SES data from the CHESS database, we have conducted analyses to identify that TB and HIV/AIDS were the leading CODs from infectious diseases in the population in PNG. Analysis of key sociodemographic factors of mortalities from these diseases, we found that age, sex, urban-rural residence and household wealth had significant associations, but the effects of these factors on TB and HIV/AIDS mortalities were varied. People in the age groups 25-34 and 35-44 years were at the highest risk to die from both TB (p-values of 0.016 and 0.007, respectively) and

HIV/AIDS (p-values of 0.005 and 0.023, respectively) (see Tables 3 and 4). Females and those living in rural areas were more at risk to die from HIV/AIDS than males and urban population (p-value of 0.023, see Table 4). People from households in middle wealth quintile were more likely to die from TB than those from the highest quintile (p-value of 0.012, see Table 3), but there was no significant association between HIV/AIDS mortality and household SES (p-value above 0.05 across the wealth quintiles, see Table 4).

We found that PNG people were dying from TB and HIV/AIDS at a very young age, with the highest premature mortality among the young adults. Specifically, TB and HIV/AIDS were responsible for nearly 2 in every 5 deaths (or 38% of all deaths) in the population aged 25-34 years. From our observations, young people living in the surveillance sites are highly mobile. Many regularly move from one place to another for education, employment, social and family purposes. They are also sexually active and more likely involved in unprotected sex [34]. Lacking access to preventive measure such as condom, young people are more likely to become infected with HIV/AIDS among other sexually transmitted infections. Young people are the main labor force and the most productive in the national and household economies. The loss of young people to TB and HIV/AIDS present a significant economic cost to their families, the communities and society as a whole [34]. It was estimated if there were 300,000 adult deaths to HIV/AIDS; the workforce would be reduced by 12.5%; and the annual GDP growth rate would decline by 1.3% by 2025 [13].

Gender inequality was a key factor associated with the increased risk of dying from HIV/AIDS among the female population. In PNG, women are culturally considered as having a lower social status than men. Young women are more likely to engage in high risk sexual activities to satisfy or meet their needs and wants than men. Given the low prevalence of safe sex practices, these women are more likely to be exposed to HIV/AIDS infection [35]. In most cases, women are more likely to die younger than men if they are infected with HIV/AIDS. HIV/AIDS also attributed to 5% of deaths among children under five years of age. HIV/AIDS prevention of mother-to-child transmission (PMTCT) programmes have been reportedly integrated into antenatal care services in PNG, but access to these services is limited. Because of social stigma and discrimination, many HIV/AIDS pregnant women did not give correct personal information [35], further hindering the utilisation of antenatal care services. The loss of mothers is likely to leave a large socioeconomic burden to their families, and children are particularly impacted from the loss [18]. Infant children died from HIV/AIDS are evidence of the failure of delivery of the PMTCT programme in PNG. Reducing social stigma and discrimination against people living with HIV/AIDS, particularly women is crucial to improving the delivery of HIV/AIDS services. Increasing men's roles in the national response to HIV/AIDS prevention is also important for a successful implementation of HIV/AIDS programme in PNG.

Our study has shown that people who live in the rural areas were twice as likely to die from TB and HIV/AIDS as those in urban areas. Inadequate health promotion and education could be the cause of low public awareness about the diseases and poor knowledge and practices towards prevention of TB and HIV/AIDS among rural populations. Limited access to basic health care services is often cited as the main reason for the high mortality from TB and HIV/AIDS in PNG [36 37]. The unavailability of skilled health

workers, lack of essential drugs and consumables are often reported at primary health facilities in rural areas [10]. Access to antiretroviral therapy (ART) has been a key to reducing the risk of dying from HIV/AIDS, but this service is available only at a small number of tertiary health facilities such as hospitals in Port Moresby. Essential laboratory services such as GeneXpert and TB culture for monitoring MDR-TB, and HIV testing are very limited, even unavailable on regular basis at the Eastern Highlands Provincial Hospital. No community-based modality is available for effective detection and management of TB and HIV/AIDS cases [38]. Control of the spread of TB and HIV/AIDS infections in the communities has been ineffective due to loss to follow up with the patients [14 35].

The high mobility among young populations between urban and rural areas and particularly the increased number of young migrants moving from rural to urban areas for employment would further complicate the spread of HIV and TB, elevating the higher risks of dying from these diseases, particularly in rural areas, where the access to HIV/AIDS services were even more limited. Health education on preventive measures of HIV/AIDS, including safe sex practice and equitable access to youth-friendly HIV and TB services are needed to reduce the premature mortalities among young people

TB-HIV co-infections have increased and are one of the key challenges to the effective implementation of TB and HIV/AIDS programmes in PNG. Our study estimated that the prevalence of TB and HIV/AIDS co-infections could be about 6% of HIV/AIDS and TB patients. This finding is consistent with our morbidity surveillance data [37]. The recent emergence of HIV/AIDS co-infections with TB in Western and Eastern Highlands provinces has raised a public health threat of multi-drug resistant tuberculosis (MDR-TB) [17 38]. The resurgence of tropical neglected infectious diseases such as typhoid [39], leprosy [38], recent outbreaks of childhood communicable diseases including polio and measles [40], and the current spread of COVID-19 infection in the communities have imposed threats to the overwhelmed healthcare systems.

Using the update-to-date data extracted from the CHESS database, we were able to link the mortality data and the household SES data to enhance the scope of mortality analyses, especially in analysing the sociodemographic factors associated with the increased risk of dying from TB and HIV among the population (The list of significant variables retained in the CPA model component 1 for constructing household wealth index is shown in supplementary Table 1). The use of WHO 2016 VA tool to collect mortality data from the communities are more likely to reflect a real and complete picture of mortality in the population than health facility death records. The InterVA-5 analytic program was used for the first time in this study in PNG to ascertain CODs from TB and HIV in the population that can be scaled up in PNG and replicated in similar settings

The mortality data were collected via VA interviews with close relatives of the deceased. Although the WHO 2016 VA instrument had been pretested with the local people prior to the data collection, the provided information about the deaths may be incomplete and biased due the recall process. InterVA-5 is a standard tool, but the ascribed CODs could be also biases due to the death selection process. The mortality data were collected from the population living within the CHESS catchment areas, but the data included only deaths identified by the village-based data reporters. It is challenging to ensure all deaths

occurred in the communities were included in the data. Hence, the data used were not representative for all deaths in the surveillance sites across provinces.

Given the high level of social stigma around TB and discrimination against people living with HIV/AIDS in PNG, deaths from these diseases might have been under reported in this study. The relatively small numbers of deaths, 84 from TB and 75 from HIV compared to all other CODs might have hindered the identification of sociodemographic factors of TB and HIV attributed mortalities. The limited numbers of observations could have also led to important associations being non-significant when TB and HIV deaths were compared to deaths from all other causes (Unadjusted and AORs of TB and HIV/AIDS combined mortalities in binary logistic regression models are presented in supplementary Table 2, which are different from those presented in Tables 3 and 4, where AORs of TB mortality and HIV mortality were estimated separately). The small sample size may have limited ability to draw concrete conclusions based on adjusted ORs that were estimated with large CIs covering node value of 1 and non-significant p-values of 0.05 or above. This limits the interpretation of risk factors associated TB and HIV mortalities in this study. An assessment of the accuracy and reliability of specific CODs assigned by InterVA-5 is beyond the scope of this study and will be addressed in a separate study.

Conclusions

Over the past 40 years, HIV/AIDS infections have transitioned to a manageable chronic infection in many LMICs and TB infection has been contained in many parts of the world. The current high mortality from TB and HIV/AIDS in PNG appears in contrast to the global trend of declining infections and deaths from these diseases. TB and HIV/AIDS have recently emerged in PNG and becoming leading causes of death in the population. The high premature mortalities from TB and HIV/AIDS among young people, together with the increased TB-HIV co-infections have raised public concerns about the TB and HIV/AIDS programmes in PNG, threatening the sustainable development of the country [8 41 42].

Urgent actions are needed from the PNG Government and health sector to review the current strategies and plans for further improvement in the effectiveness of TB and HIV/AIDS programmes as well as the delivery of healthcare services to the population in PNG in the next decade. More interventions are needed with focus on high-risk and vulnerable populations, particularly those who are young and females in rural areas and from provinces with low socioeconomic development status. The identified sociodemographic factors associated with premature mortality attributed to TB and HIV/AIDS need to be tackled. Further studies on the trend of mortality transition and the change in CODs across different social classes are needed to better inform policy and intervention.

Declarations

Funding

The CHESS was operated with financial supported from the PNG Government through the Department of National Planning and Monitoring (PIP No. 02704). The funder had no role in study design, data collection and analysis, or writing of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Author contributions

BNP designed the CHESS, conceptualized the paper, and analysed and interpreted the data, drafted, revised, finalized and submitted the manuscript. RJ, VDS and NA supervised the fieldwork, collected and analysed the data, and provided inputs. CR and TO reviewed, provided inputs, and commented the manuscript. WP provided oversight the PNGIMR and approved the submission.

Ethics approval

The CHESS was granted ethics approvals from Institutional Review Board of PNG Institute of Medical Research (IRB's Approval no. 18.05) and the Medical Research Advisory Committee of Papua New Guinea (MRAC's Approval no. 18.06). These approvals covered all the data components under the CHESS, including the mortality data which were used in this manuscript. Informed consent was sought from self-identified close relatives of the deceased. They were informed about their right to withdraw from the study at any stage.

Acknowledgement

This study was conducted as part of the PNGIMR's CHESS programme. We appreciate the participants for their time to attend VA interviews and provide information about the deceased. We thank the data reporters and CHESS staff members for their support in field work and data collection. We acknowledge the contributions and supports from our local partners: community members, religion leaders, and Provincial Health Authorities in Central, Eastern Highlands, East New Britain, East Sepik, Madang provinces and Port Moresby for their partnerships and collaborations in this study.

Data statement

No data are available

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Table 1: Socioeconomic characteristics of the surveillance sites, PNGIMR's CHESS, 2018-2020

Province	Port Moresby	Central	Eastern Highlands	Eastern Highlands	Madang	East Sepik	East New Britain	East New Britain
Surveillance site	Hohola	Hiri	Goroka	Asaro	Newtown	Maprik	Kokopo	Baining
Sector	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Region	Southern	Southern	Highlands	Highlands	Momase	Momase	Islands	Islands
Location	National Capital District	45 km west of Port Moresby	Township of EHP	50 km northeast of Goroka	Township of Madang	30 km from township	Township of ENB	40 km from the town
Main industry	Shipping, transportation	Fishery, hunting	Coffee, agriculture	Coffee, agriculture	Fishery, services	Vanilla, cocoa	Fishery, tourism	Fishery, tourism
Accessibility	Road and airline	Road	Road and airline	Road and airline	Road and airline	Road and airline	Sea and airline	Sea and airline
Year of site established	2017	2011	2016	2004	2018	2019	2018	2018
Population	5,000	15,000	5,000	15,000	5,000	5,000	5,000	6,000
Household	1000	3000	1000	3000	1000	3000	1000	3000
Health facility	St. Theresa clinic	Porebada, Papa and Lealea clinics	Provincial Hospital Kwongi, Lopi and Goroka clinics:	Asaro Health Centre	Jomba Clinic	Ilahita clinic, District Hospital	Batuwin Clinic	Vanapalading Aid Post
Laboratory services	POM Lab	N/A	Goroka Lab	N/A	Madang Lab	N/A	N/A	N/A

Table 2: Distribution of deaths from pulmonary TB, HIV/AIDS, and other causes of death (number and percents) by age group, sex, urban-rural sector, province, and household wealth quintile of the deceased, PNGIMR's CHESS, 2018-2020

		TB	HIV/AIDS	Other CODs	All CODs
Mean age at death (year, SD)	P-value: 0.04	46.32 (17.58)	44.21 (19.36)	49.24 (24.32)	48.56 (23.44)
Age group	0-4	0 (0.0%)	3 (4.5%)	64 (95.5%)	67 (100.0%)
	5-14	1 (3.8%)	0 (0.0%)	25 (96.2%)	26 (100.0%)
	15-24	7 (11.3%)	6 (9.7%)	49 (79.0%)	62 (100.0%)
	25-34	20 (20.2%)	18 (18.2%)	61 (61.6%)	99 (100.0%)
	35-44	17 (18.1%)	11 (11.7%)	66 (70.2%)	94 (100.0%)
	45-54	9 (6.0%)	14 (9.4%)	126 (84.6%)	149 (100.0%)
	55-64	15 (8.8%)	14 (8.2%)	141 (82.9%)	170 (100.0%)
	65-74	12 (8.4%)	4 (2.8%)	127 (88.8%)	143 (100.0%)
	75+	3 (2.7%)	5 (4.4%)	105 (92.9%)	113 (100.0%)
Total		84 (9.1%)	75 (8.1%)	764 (82.8%)	923 (100.0%)
Sex	Male	43 (8.4%)	28 (5.4%)	443 (86.2%)	514 (100.0%)
	Female	41 (10.0%)	47 (11.4%)	324 (78.6%)	412 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)
Sector	Urban	16 (7.0%)	13 (5.7%)	199 (87.3%)	228 (100.0%)
	Rural	67 (9.9%)	60 (8.9%)	550 (81.2%)	677 (100.0%)
Total		83 (9.2%)	73 (8.1%)	749 (82.8%)	905 (100.0%)
Household wealth quintile	Poorest	9 (6.5%)	14 (10.1%)	115 (83.3%)	138 (100.0%)
	Poor	7 (5.1%)	15 (10.9%)	116 (84.1%)	138 (100.0%)
	Middle	21 (15.2%)	14 (10.1%)	103 (74.6%)	138 (100.0%)
	Rich	16 (11.6%)	10 (7.2%)	112 (81.2%)	138 (100.0%)
	Richest	8 (5.8%)	8 (5.8%)	121 (88.3%)	137 (100.0%)
Total		61 (8.9%)	61 (8.9%)	567 (82.3%)	689 (100.0%)
Province	Port Moresby	1 (3.3%)	2 (6.7%)	27 (90.0%)	30 (100.0%)
	Central	41 (14.2%)	13 (4.5%)	234 (81.3%)	288 (100.0%)
	Eastern Highlands	25 (8.3%)	36 (12.0%)	239 (79.7%)	300 (100.0%)
	Madang	8 (10.5%)	8 (10.5%)	60 (78.9%)	76 (100.0%)
	East Sepik	2 (1.7%)	8 (6.9%)	106 (91.4%)	116 (100.0%)
	East New Britain	7 (6.0%)	8 (6.9%)	101 (87.1%)	116 (100.0%)
Total		84 (9.1%)	75 (8.1%)	767 (82.8%)	926 (100.0%)

Table 3: Distribution of deaths and adjusted odds ratios of mortality from pulmonary tuberculosis versus all other causes of death, by sociodemographic characteristics of the deceased, multinomial logistic regression analysis, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Adjusted Odds ratio	Lower Bound	Upper Bound	P-value
Age group (in year)	0-4	39	5.9%	NA	NA	NA	NA
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	2.982	0.621	14.317	0.172
	25-34	64	9.6%	5.482	1.382	21.751	0.016
	35-44	62	9.3%	6.428	1.675	24.664	0.007
	45-54	115	17.3%	2.290	0.582	9.009	0.236
	55-64	131	19.7%	3.118	0.856	11.360	0.085
	65-74	102	15.3%	3.438	0.913	12.955	0.068
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	1.227	0.696	2.164	0.479
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.540	0.288	1.000	0.050
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	0.997	0.367	2.708	0.995
	Poor	135	20.3%	0.817	0.283	2.359	0.709
	Middle	130	19.5%	3.067	1.275	7.374	0.012
	Rich	130	19.5%	2.005	0.802	5.010	0.137
	Richest	135	20.3%	Ref.			
Valid total		665	100.0%				

Note: Dependent variable was deaths from tuberculosis. Reference category was deaths from other CODs. Sociodemographic factors remained in MLR models included age, sex, urban-rural sector and household wealth.

Table 4: Distribution of deaths and adjusted odds ratios of mortality from HIV/AIDS versus all other causes of death, by sociodemographic characteristics of the deceased, multinomial logistic regression analysis, PNGIMR's CHESS, 2018-2020

Sociodemographic characteristics	Category	N	%	Adjusted Odds ratio	Lower Bound	Upper Bound	P-value
Age group	0-4	39	5.9%	1.511	0.240	9.531	0.660
	5-14	20	3.0%	NA	NA	NA	NA
	15-24	45	6.8%	3.461	0.771	15.548	0.105
	25-34	64	9.6%	6.687	1.758	25.438	0.005
	35-44	62	9.3%	4.872	1.240	19.150	0.023
	45-54	115	17.3%	2.868	0.765	10.758	0.118
	55-64	131	19.7%	2.876	0.783	10.565	0.112
	65-74	102	15.3%	1.108	0.238	5.150	0.896
	75-102	87	13.1%	Ref.			
Sex	Male	387	58.2%	0.517	0.294	0.908	0.022
	Female	278	41.8%	Ref.			
Sector	Urban	226	34.0%	0.464	0.240	0.899	0.023
	Rural	439	66.0%	Ref.			
Household wealth	Poorest	135	20.3%	2.084	0.797	5.452	0.134
	Poor	135	20.3%	2.342	0.901	6.090	0.081
	Middle	130	19.5%	1.999	0.751	5.319	0.165
	Rich	130	19.5%	1.550	0.557	4.311	0.401
	Richest	135	20.3%	Ref.			
Valid		665	100.0%				

Note: Dependent variable was deaths from HIV/AIDS. Reference category was deaths from other CODs. Sociodemographic factors remained in MLR models included age, sex, urban-rural sector and household wealth.

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

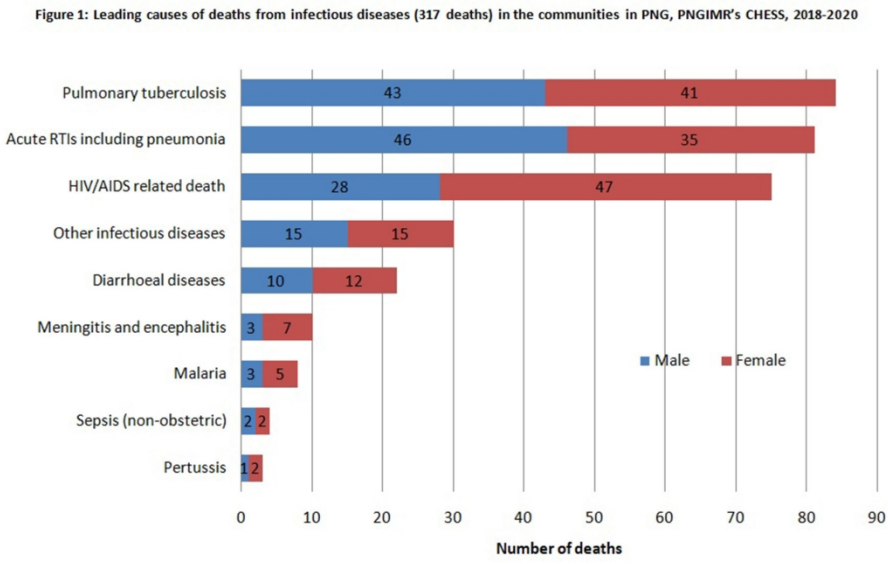

Figure 1: Leading causes of deaths from infectious diseases (317 deaths) in the communities in PNG, PNGIMR's CHESS, 2018-2020

176x132mm (300 x 300 DPI)

Supplementary file

Supplementary Table 1: List of significant variables retained in principal component analysis (PCA) for constructing household wealth index, PNGIMR's CHESS 2018-2020

Number	Variable name	Extraction	Component 1
	Water and sanitation		
1	Main source of water for drinking	0.827	0.315
2	Main source of water for cooking	0.887	0.333
3	Water source location	0.739	-0.176
4	Kind of toilet facility	0.834	0.13
5	Shared/ non shared toilet facility	0.744	-0.01
6	Public / household shared toilet facilities	0.661	0.047
	Hand washing		
7	Facility for washing hands	0.713	-0.055
8	Available water for hand washing	0.737	-0.029
9	Available soap or detergent for washing hands	0.852	-0.383
10	Bar soap available	0.844	0.404
11	Detergent (Powder / Liquid / Paste) available	0.751	0.015
12	Liquid soap Available	0.756	0.282
13	Ash / Mud / Sand available	0.852	0.303
14	None above available	0.591	-0.086
	Housing characteristics		
15	Type of house	0.955	0.206
16	Number of room in house	0.848	-0.095
17	Number of sleeping room	0.835	-0.109
18	Wall materials	0.846	0.117
19	Floor materials	0.766	-0.166
20	Roof amterials	0.889	0.234
21	Source of fuel for cooking	0.618	-0.015
22	Separate room for cooking	0.79	-0.126
	Household assets		
23	Owned/ Not owned car/Truck	0.751	0.083
24	Owned/ Not owned Cupboard	0.777	0.245
25	Owned/ Not owned Motorcycle	0.768	0.035
26	Owned/ Not owned Bicycle	0.775	0.28
27	Owned/ Not owned Generator	0.722	0.227
28	Owned/ Not owned Computer	0.796	0.213
29	Owned/ Not owned Refrigerator	0.85	0.075
30	Owned/ Not owned Freezer	0.811	0.053
31	Owned/ Not owned Clock/Watch	0.702	0.233
32	Owned/ Not owned Radio	0.721	0.465
33	Owned/ Not owned TV	0.743	0.334
34	Owned/ Not owned Fan	0.834	0.195
35	Owned/ Not owned Landline phone	0.822	0.035

36	Owned/ Not owned Table/chairs	0.641	0.294
37	Owned/ Not owned Canoe/boat	0.746	-0.109
38	Owned/ Not owned Air-conditioner	0.702	-0.039
39	Owned/ Not owned Gas/elect cooker	0.847	0.075
40	Owned/ Not owned Washing machine	0.666	0.095
41	Owned/ Not owned Mobile phone	0.776	0.267
42	Owned/ Not owned Beds (framed)	0.831	0.267
43	Owned/ Not owned Internet connection	0.641	-0.004
44	Owned or rent house	0.719	-0.029
45	Owned agriculture land	0.917	-0.005
46	Ownership of water surface for aquaculture	0.906	-0.015
47	Owned livestock, farm animals	0.773	-0.277
48	Ownership of BUFFALO	0.607	-0.026
49	Ownership of HORSES	0.737	0.086
50	Ownership of GOATS	0.675	0.012
51	Ownership of SHEEP	0.686	-0.03
52	Ownership of CHICKENS	0.768	0.039
53	Ownership of PIGS	0.777	0.355
54	Ownership of DUCKS	0.753	-0.038
55	Ownership of bank account	0.876	-0.037
56	English spoken in the household	0.726	0.203
57	Tok-Pisin spoken in the household	0.795	-0.102
58	Motu spoken in the household	0.867	0.109
59	Tokples spoken in the household	0.742	-0.205
	Health services		
60	Close to health facility	0.794	0.306
61	Transportation means commonly used	0.758	0.195
62	Last time used the health service	0.801	-0.032
63	Out-patient consultation service	0.8	-0.134
64	In-patient clinical, care and treatment service	0.841	0.146
65	Laboratory investigation services	0.777	0.102
66	Cost for health service	0.611	-0.19
67	Satisfaction of health service provided	0.681	-0.284
	Household size		
68	Urban-rural sector	0.815	-0.074
69	Total number of ALL household members	0.907	-0.011
70	Total number of WOMEN aged 15-49	0.754	0.02
71	Total number of CHILDREN under 5	0.752	0.02
72	Total number of MEN aged 15-65	0.738	-0.037
	Education		
73	Household members aged 5-24 attended class in school year 2018	0.596	-0.013
74	Educational level attended by household members aged 5-24 years	0.912	0.06
75	School grades attended by household members in school year 2018	0.918	0.039

Supplementary Table 2: Unadjusted and adjusted odds ratios of mortalities from TB and HIV/AIDS versus other causes of death by household sociodemographic characteristics of the deceased, binary logistic regression analysis, PNGIMR's CHESS, 2018-2020

Socioeconomic determinant	Category	N	%	Unadjusted Odds Ratio [b] uOR	Lower	Upper	P-value	Adjusted Odds Ratio aOR	Lower	Upper	P-value
Sector	Urban	226	34.0%	0.317	0.166	0.606	0.001	0.149	0.102	0.356	0.001
	Rural	439	66.0%	Ref.				Ref.			
Province [a]	POM	30	4.5%	1.013	0.250	4.107	0.985	1.013	0.396	2.313	0.961
	Central	167	25.1%	0.698	0.324	1.505	0.359	0.641	0.152	1.447	0.366
	EHP	277	41.7%	1.255	0.637	2.473	0.512	1.227	0.540	2.033	0.488
	Madang	75	11.3%	2.658	1.116	6.331	0.027	1.977	1.078	3.070	0.032
	ENB	116	17.4%	Ref.				Ref.			
Sex	Male	387	58.2%	0.736	0.479	1.129	0.160	0.693	0.220	1.125	0.165
	Female	278	41.8%	Ref.				Ref.			
Age group (in year)	0-4	39	5.9%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	5-14	20	3.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	15-24	45	6.8%	3.713	1.190	11.581	0.024	2.312	1.000	3.790	0.020
	25-34	64	9.6%	7.820	2.842	21.518	0.000	3.057	2.161	4.514	0.003
	35-44	62	9.3%	7.059	2.566	19.421	0.000	2.954	2.022	4.485	0.003
	45-54	115	17.3%	3.230	1.203	8.671	0.020	2.173	1.221	3.574	0.013
	55-64	131	19.7%	3.363	1.297	8.718	0.013	2.213	1.251	3.457	0.015
	65-74	102	15.3%	2.257	0.822	6.200	0.114	1.814	0.771	3.175	0.101
	75-102	87	13.1%	Ref.				Ref.			
Household wealth	Poorest	135	20.3%	1.618	0.779	3.363	0.197	1.481	0.750	2.363	0.195
	Poor	135	20.3%	1.539	0.736	3.216	0.252	1.431	0.615	2.258	0.251
	Middle	130	19.5%	3.232	1.598	6.536	0.001	2.173	1.506	2.985	0.002
	Rich	130	19.5%	1.950	0.940	4.043	0.073	1.668	0.916	2.488	0.079
	Richest	135	20.3%	Ref.				Ref.			
Valid		665	100.0%	[a] No data of ESP was included in the Multivariate Logistic Regress Model.							
Missing		261		[b] Dependent variable was deaths from HIV/AIDS and tuberculosis. The reference category was deaths from other COD rather than tese two diseases. Socioeconomic and demographic factors included in the model were urban-rural sector, province, sex and age group of the deceased and household wealth group.							
Total		926		[c] Results were based on 1000 bootstrap samples.							
Subpopulation		341[d]		[d] The dependent variable had only one value observed in 271 (79.5%) subpopulations.							

STROBE Statement—checklist of items that should be included in reports of observational 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	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
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	*6*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	N/A
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	n/a

Continued on next page

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	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
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	10
		(*b*) Report category boundaries when continuous variables were categorized	10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
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	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
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 cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.