Cancer Mortality Projections: A Comparative Analysis of Statistical Models for Evaluating Uncertainty and Improved Mortality Forecasting in Korea

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Introduction Cancer is a leading cause of death globally and in Korea, accounting for over 20% of fatalities. Mortality patterns vary by cancer type and are significantly influenced by the aging population. Since future cancer mortality projections rely on both cancer site-specific trends and demographic shifts, models must accurately capture these complexities. However, in many instances, the robustness of mortality predictions has not been sufficiently evaluated through comprehensive comparisons across multiple models. This study aims to identify by comparing various statistical models and identify the model that shows the most consistent cancer mortality projections.

Materials and Methods Age- and sex-specific cancer incidence and mortality data from the Korea Central Cancer Registry and Statistics Korea were analyzed, focusing on five major cancers. To compare cancer mortality projection models, we considered age-period-cohort (APC) models such as the Age-Drift-Period-Cohort (NordPred) model, Bayesian Age-Period-Cohort (BAPC), and APC derivatives like Age-Cohort(AC), Age-Trend(AT), and 5-year average models. For the APC model with the age variable, Poisson and negative binomial distributions were considered to address the goodness-of-fit issue. Additionally, we included Joinpoint models based on Average Annual Percent Change (AAPC) and time series models (Moving Average, NNETAR, and MLP) to account for year-to-year variations in cancer mortality trends. The analysis utilized cancer mortality data from 1983 to 2002 to project future trends up to the year 2022. To assess the predictive accuracy of each model, we calculated the Average Absolute Relative Deviation (AARD), which measures the absolute difference between the predicted values and the actual observed values over the final five years of the projection period.

Results Performance of 13 statistical and neural-network models for cancer mortality forecasts across five leading cancers, stratified by sex and six age bands, was evaluated using Average Absolute Relative Deviation (AARD). NordPred emerged as the most dependable approach, yielding the lowest mean AARD at the total-age level (35% for males with NP-Poisson; 32% for females with NP-NB) and maintaining errors below 50% in four of six age strata. In stark contrast, Age-Trend models exhibited high variability across age groups; notably, AT-Poisson for males escalated from 83% in 'Younger' groups to 362% in 'Middle-old' cohorts—a four-fold increase—before easing, revealing a pronounced non-linear age-specific error gradient. Joinpoint regression produced the single largest deviations (AARD = 376% in males), while other time-series methods ranged widely (e.g., ~45% for Moving Average to ~180% for ARIMA). Site-specific mean AARDs were lowest for liver (~84-90%) and pancreas (~51-100%) but peaked for prostate (176%) and lung (~150%). Crucially, models fitting the all-age groups well often displayed substantial age-specific errors; AT-Poisson, for instance, showed deviations up to 362% within single cohorts despite reproducing the calibrated total. NordPred led six of twelve sex-by-site combinations, yet no alternative model consistently ranked top across three or more age strata. This illustrates that while a single 'best' model may offer high predictive accuracy for the overall population, its bias can yield substantially larger discrepancies, when disaggregated into specific age groups.

Conclusion Inconsistencies in results from using a single forecasting model can complicate future disease burden projections, preventing effective implementation of health policies and appropriate resource allocation. While the NordPred model demonstrated the most consistent performance, no single model consistently outperformed across age subgroups. Thus, adopting a multi-model approach and ensuring accurate and reliable projection results is essential to support more informed decision-making in public health planning.

Keyword: Mortality and Longevity; Census data; Population projections, forecasts, and estimations; Comparative methods

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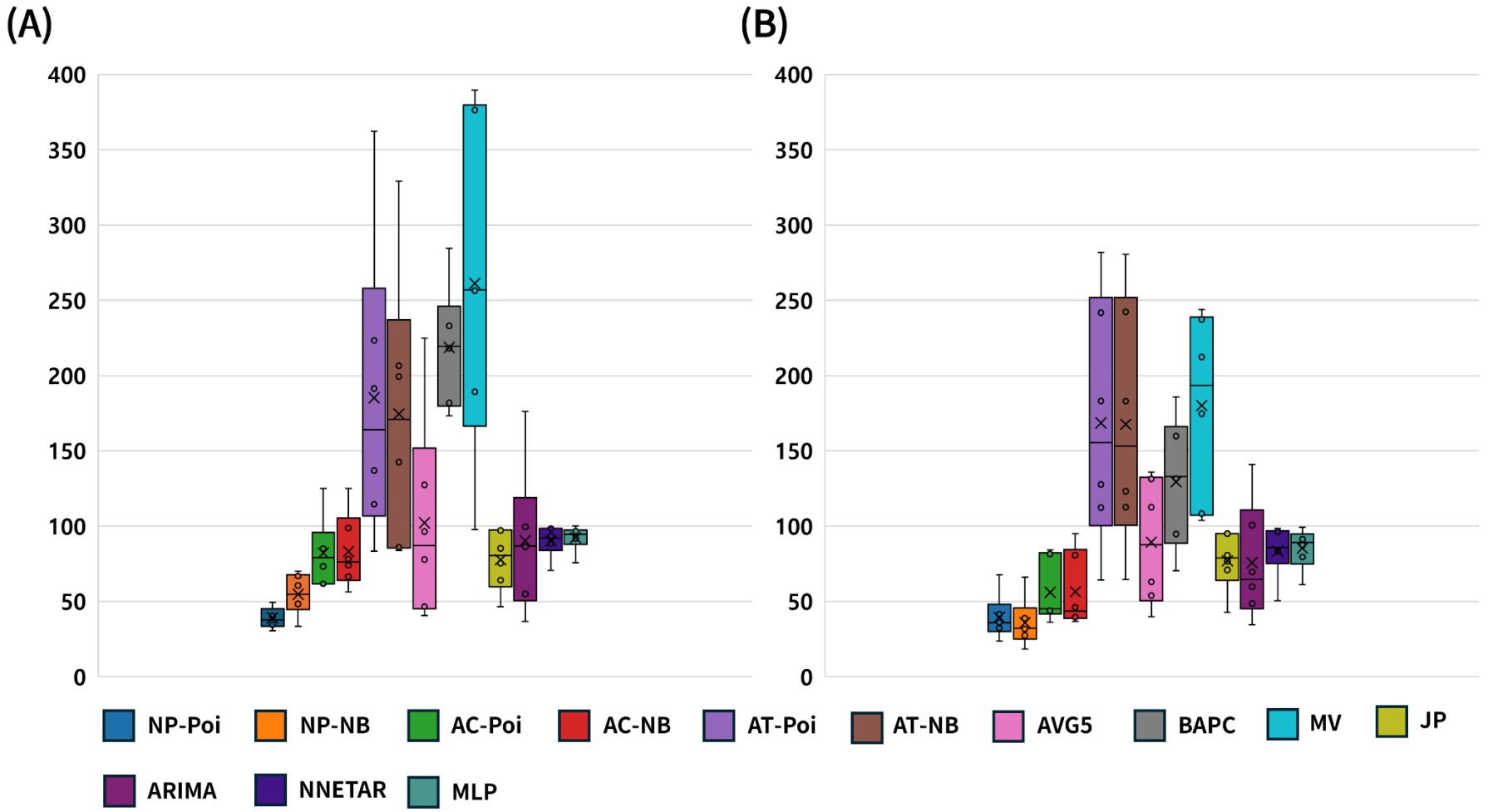

Figure1. Average Absolute Relative Deviation (AARD) of Cancer Mortality Projections Across Predictive Models and Age Groups, Averaged by Cancer Type (Last 5-Year Projection) (A) Male, (B) Female

***Notes : Poi: Poisson; NB: Negative Binomial; NP: NordPred (Age-Drift-Period-Cohort); AC: Age-Cohort; AT: Age-Trend; AVG5 : Average 5-year BAPC: Bayesian Age-Period-Cohort; JP: Joinpoint. MV: Moving Average; ARIMA: Autoregressive Integrated Moving Average Model, NNETAR: Neural Network Time Series Forecasts**

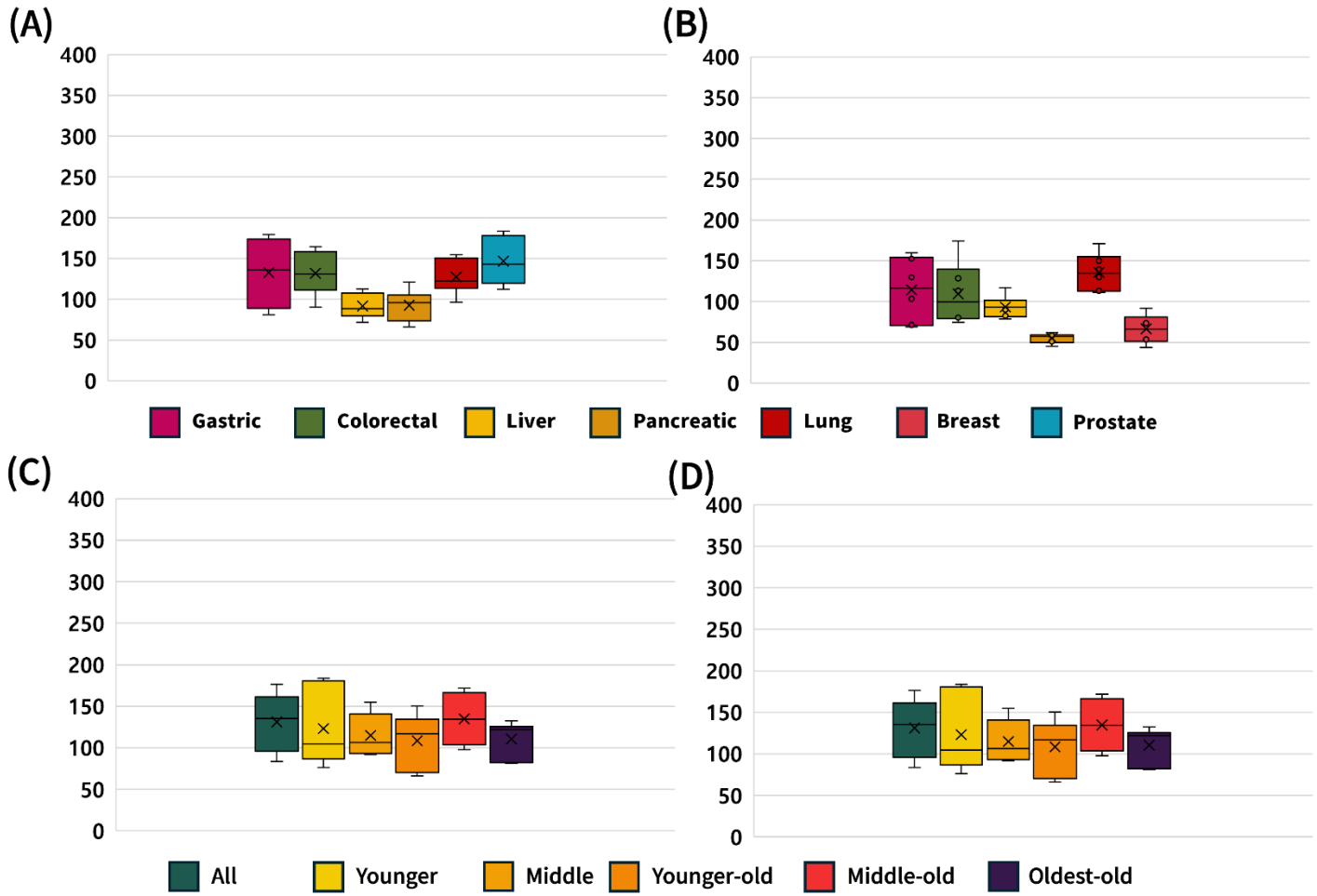

Figure2. Average AARD of Projection Models by Cancer Site and Age Group (A–B: cancer site, males / females; C–D: age group, males / females)

Note: Younger Age groups: 00-39; Middle Age groups: 40-64; Younger Old Age groups: 65-74; Middle Old Age groups: 75-84; Oldest Old Age groups: 85+.

Table1. Comparative performance of top prediction models for age, sex, and cancer type based on Average absolute relative deviation (AARD) evaluation

Sex	Cancer	All		Younger (00-39)		Middle (40-64)		Younger Old (65-74)		Middle Old (75-84)		Oldest Old (85+)	
		Model	AARD	Model	AARD	Model	AARD	Model	AARD	Model	AARD	Model	AARD
Male	Gastric	NNETAR	42%	AT-Poi/NB	38.6%	MV	29.2%	JP	13.9%	ARIMA	20.6%	AC-Poi	36.3%
	Colorectal	AVG5	5%	AC-Poi	1.4%	NP-Poi	8.1%	AVG5	18.8%	AVG5	1.1%	NP-NB	41.2%
	Liver	MV	11.9%	NP-Poi	2.2%	ARIMA	25.7%	AT-Poi/NB	26%	AC-NB	1.7%	NP-Poi	11.4%
	Pancreatic	NP-Poi	1.8%	NP-Poi	5.7%	NP-NB	4.9%	NP-Poi	4.2%	NP-Poi	6.8%	AVG5	42.5%
	Lung	NP-NB	30.9%	AC-Poi	3.9%	NP-Poi	48.5%	ARIMA	23%	AVG5	2.7%	AVG5	36.9%
	Prostate	NNETAR	5.3%	ARIMA	99%	NP-NB	4.5%	NP-Poi	2.4%	NP-NB	7.1%	NP-NB	9.3%
Female	Gastric	NP-NB	25.5%	BAPC	51.1%	AT-Poi/NB	1.3%	ARIMA	18.7%	AC-NB	4.6%	NP-NB	0.7%
	Colorectal	AVG5	1.7%	AC-NB	0.6%	NP-Poi	18.4%	JP	20%	AVG5	0.5%	NP-NB	3.2%
	Liver	AC-Poi	2.1%	BAPC	4.5%	ARIMA	7.4%	ARIMA	10.2%	NP-Poi/NB	0.3%	AC-NB	8.1%
	Pancreatic	JP	4.8%	JP	1.9%	AC-Poi	2.6%	NP-NB	0.1%	NP-NB	14.3%	NP-Poi	11.5%
	Lung	AVG5	26.5%	AC-Poi	12%	NP-Poi	27.3%	ARIMA	10.2%	AVG5	16.6%	AVG5	34.8%
	Breast	AC-NB	3.5%	BAPC	6.2%	AC-NB	3.4%	NP-NB	6.3%	NP-Poi	11.3%	NP-Poi	3.1%

Note: C16: Gastric Cancer; C18-C21: Colorectal-Anus Cancer; C22: Liver Cancer; C25: Pancreatic Cancer; C33-C34: Lung and Trachea Cancer; C50: Breast Cancer; C61: Prostate Cancer.
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