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Impact of COVID-19 mobility restrictions on emergency demand for road traffic injuries in Lima, Peru: an interrupted time series analysis, 2017–2024

Alberto Gonzales Guzmán

agonzalesg@cientifica.edu.pe

Universidad Científica del Sur

Luis Fernando Llanos Zavalaga

Universidad Peruana Cayetano Heredia

Claudia Veralucia Saldaña Díaz

Universidad Privada Norbert Wiener

Research Article

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Impact of COVID-19 mobility restrictions on emergency demand for road traffic injuries in Lima, Peru: an interrupted time series analysis, 2017–2024

Alberto Gonzales Guzmán[1*], Luis Fernando Llanos Zavalaga[2], Claudia Veralucia Saldaña Díaz[3]

[1] Universidad Científica del Sur, Lima, Peru. [2] Universidad Peruana Cayetano Heredia, Lima, Peru. [3] Universidad Privada Norbert Wiener, Lima, Peru.

***Correspondence:** Alberto Gonzales Guzmán. Email: agonzalesg@cientifica.edu.pe. Phone: +51 994729378.

Abstract

Background. Road traffic injuries are a leading cause of morbidity and a public health priority in low- and middle-income countries. The COVID-19 mobility restrictions constituted a natural experiment to evaluate their impact on the demand for emergency care due to road traffic crashes. We assessed the effect of the pandemic restriction and post-restriction periods on the monthly frequency of traffic-crash emergency encounters at a referral hospital in Lima, Peru, overall and by sex and age group.

Methods. Interrupted time series analysis of monthly traffic-crash encounters recorded at the José Casimiro Ulloa Emergency Hospital between January 2017 and December 2024. Three periods were defined: pre-pandemic (January 2017–February 2020), restriction (April 2020–October 2022) and post-restriction (November 2022–December 2024); March 2020 was excluded as a transition month. Because of overdispersion and residual autocorrelation, a segmented negative binomial model with a first-order lag term was selected and compared with Poisson and Fourier specifications using AIC, RMSE, dispersion, Durbin-Watson and Ljung–Box statistics. Interaction models estimated effects by sex and age group. Results are reported as incidence rate ratios (IRR) with 95% confidence intervals (CI).

Results. A total of 20,904 encounters were analyzed (median 230 per month; 95 monthly observations). The pre-pandemic trend was flat (IRR: 1.001; 95%CI: 0.996–1.006). The onset of restrictions was associated with an immediate 36.9% reduction in the level of the series (IRR: 0.631; 95%CI: 0.507–0.785; p<0.001), followed by a significant monthly increase of 2.0% during the restriction period (IRR: 1.020; 95%CI: 1.010–1.030; p<0.001) and stabilization thereafter. The initial reduction was greater in women (IRR: 0.488; 95%CI 0.396-0.602; −51.2%) than in men (IRR 0.714; 95% CI 0.608-0.838; −28.6%) and greatest in adults aged ≥60 years (IRR: 0.294; 95%CI: 0.213-0.407; −70.6%). The negative binomial model with lag had the best fit (AIC: 956.0; dispersion: 0.98).

Conclusions. Mobility restrictions produced an abrupt, heterogeneous drop in traffic-crash emergency demand, disproportionately affecting women and older adults, followed by a progressive recovery. These findings inform emergency-service planning and equity-oriented road-safety policy in middle-income settings.

Keywords: Accidents, traffic; COVID-19; Interrupted time series analysis; Emergency service, hospital; Physical distancing; Peru

Clinical trial number: not applicable.

Background

Road traffic injuries cause approximately 1.35 million deaths annually and a substantial burden of disability, with about 90% of deaths occurring in low- and middle-income countries (LMICs) where motorization is rising and health systems face greater constraints [1–3]. In Peru, road traffic crashes are a persistent public health priority; the Ministry of Health has designated them a national research priority for 2024–2030 [18], and Lima concentrates the largest share of crashes and casualties [10–12].

The COVID-19 pandemic prompted unprecedented mobility restrictions worldwide. In Peru, a national state of emergency declared on 15 March 2020 imposed mandatory social isolation and movement restrictions that were progressively relaxed and finally lifted on 27 October 2022. These abrupt, externally imposed changes

in population mobility constituted a natural experiment to quantify how mobility shapes the demand for emergency care due to road traffic crashes. International studies reported sharp reductions in crashes and injuries during lockdowns, followed by heterogeneous recovery [4–9]; however, evidence from LMICs, and particularly hospital-based evidence that disaggregates the effect by sex and age, remains scarce.

Quantifying the magnitude, trajectory and distribution of this effect is relevant beyond the pandemic: it clarifies which population groups are most sensitive to changes in mobility and informs the planning of emergency services and equity-oriented road-safety policy. We therefore conducted an interrupted time series (ITS) analysis of traffic-crash emergency encounters at a referral emergency hospital in Lima, Peru, from 2017 to 2024, estimating the effect of the restriction and post-restriction periods overall and by sex and age group, using a modelling strategy that explicitly addressed the count nature of the data, overdispersion and temporal autocorrelation.

Methods

Study design and setting. We conducted an observational, analytical ITS study of monthly counts of emergency encounters for road traffic crashes at the José Casimiro Ulloa Emergency Hospital (HEJCU), a public referral emergency hospital of the Ministry of Health located in Miraflores, Lima, serving a large population of Metropolitan Lima. The study followed the STROBE recommendations for observational studies [16].

Data source and population. We used the administrative database of the HEJCU Statistics and Informatics Office, including all encounters whose reason for care was a road traffic crash between January 2017 and December 2024. Records with incomplete information on sex, age or admission date were excluded (n=4). The unit of analysis was the monthly count of encounters, aggregated overall and by sex and age group (0–17, 18–29, 30–59 and ≥60 years).

Interruption points and periods. Three periods were defined according to the implementation of mobility restrictions in Peru: pre-pandemic (January 2017–February 2020), restriction (April 2020–October 2022) and post-restriction (November 2022–December 2024). March 2020 was excluded as a transition month, yielding 95 monthly observations (94 for models including the lag term).

Statistical analysis. Segmented regression was used to estimate changes in the level and slope of the monthly series at each interruption [13–15]. The model included the underlying pre-pandemic trend and level- and slope-change terms for the restriction and post-restriction periods (each change expressed relative to the projection of the preceding segment). A Poisson model showed marked overdispersion (Pearson chi-square/degrees of freedom = 5.23) and residual autocorrelation (Durbin–Watson = 1.00); we therefore adopted a negative binomial specification and added a first-order lag term (the natural log of the previous month count). Candidate specifications (Poisson and negative binomial, with and without Fourier seasonal terms and the lag term) were compared using the Akaike Information Criterion (AIC), root mean square error (RMSE), the dispersion parameter, and the Durbin–Watson and Ljung–Box statistics. Effect modification by sex and by age group was assessed with interaction models, and group-specific estimates were obtained by linear combination of coefficients. Coefficients were exponentiated and reported as incidence rate ratios (IRR) with 95% confidence intervals (95%CI); a two-sided $p<0.05$ was considered significant. Analyses were performed in Python 3 (statsmodels).

Ethics. The study was approved by the Institutional Research Ethics Committee (CIEI) of Universidad Peruana Cayetano Heredia (approval CIEI-497-39-25). Only anonymized secondary data were used; no data allowing identification of individual patients were accessed.

Results

Series description. A total of 20,904 traffic-crash encounters were analyzed over 95 monthly observations, with a median of 230 encounters per month (interquartile range 204.5–244.5). The lowest annual volume occurred in 2020 (n=1,612) and the highest in 2023 (n=3,074). A seasonal-trend (STL) decomposition showed

a weak seasonal signal (seasonal strength Fs=0.02), indicating that most of the variability was driven by the trend and by the pandemic disruption rather than by seasonality.

Model selection. The negative binomial model with a first-order lag term provided the best fit (AIC: 956.0; RMSE: 27.9; dispersion: 0.98; Durbin–Watson: 1.74; Ljung–Box p=0.127 at lag 12), clearly outperforming the negative binomial without lag (AIC: 984.5) and the Poisson specifications (AIC ≥1,184), which showed severe overdispersion (dispersion ≥5.1) and residual autocorrelation (Table 4).

Overall effect. The pre-pandemic monthly trend was flat (IRR: 1.001; 95%CI: 0.996–1.006; p=0.613). The onset of the restriction period was associated with an immediate reduction of 36.9% in the level of the series (IRR: 0.631; 95%CI: 0.507–0.785; p<0.001). During the restriction period, the series increased significantly by 2.0% per month (IRR: 1.020; 95%CI: 1.010–1.030; p<0.001), indicating a progressive recovery after the initial drop. At the transition to the post-restriction period the level did not change significantly (IRR 0.910; 95%CI: 0.768-1.078; p=0.274), while the recovery slope flattened significantly relative to restriction period (slope-change IRR: 0.974; 95%CI: 0.961-0.987; p<0.001), consistent with stabilization at pre-pandemic levels. The first-order lag term was strongly significant (IRR: 1.499; 95%CI: 1.271-1.767; p<0.001) (Table 1, Fig. 1).

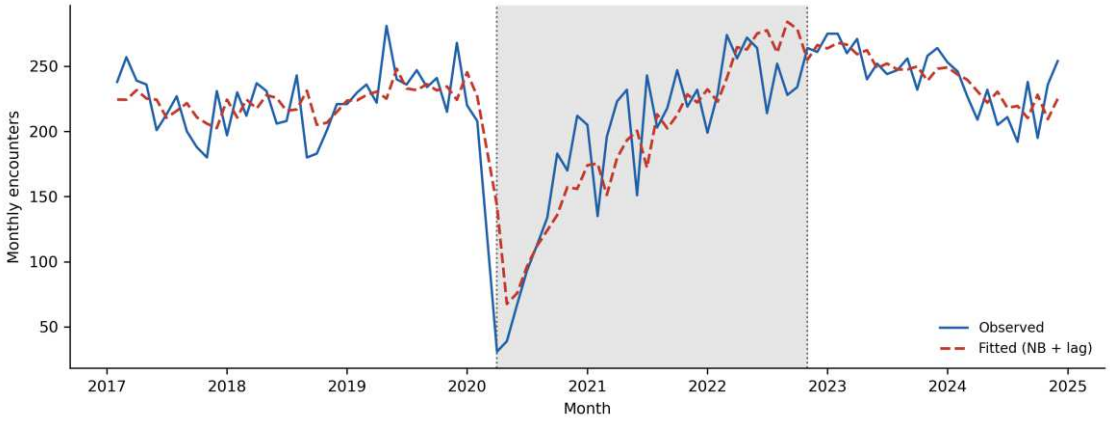

Fig. 1 Observed monthly road traffic-crash encounters (solid line) and fitted segmented negative binomial model with first-order lag (dashed line), HEJCU, 2017–2024. The shaded area marks the restriction period; vertical dotted lines mark its onset (April 2020) and the onset of the post-restriction period (November 2022).

Effect by sex. In the pre-pandemic period, men accounted for 59.8% of encounters and women for 40.2%. The immediate reduction at the onset of restrictions was significantly greater in women (IRR: 0.488; 95%CI: 0.396-0.602; −51.2%) than in men (IRR: 0.714; 95%CI: 0.608-0.838; −28.6%), and the interaction between female sex and the restriction level change was statistically significant. Both sexes recovered significantly during the restriction period (men slope IRR: 1.018; women: 1.026; both p<0.001); in both the recovery slope flattened significantly in the post-restriction period (Table 2, Fig. 2).

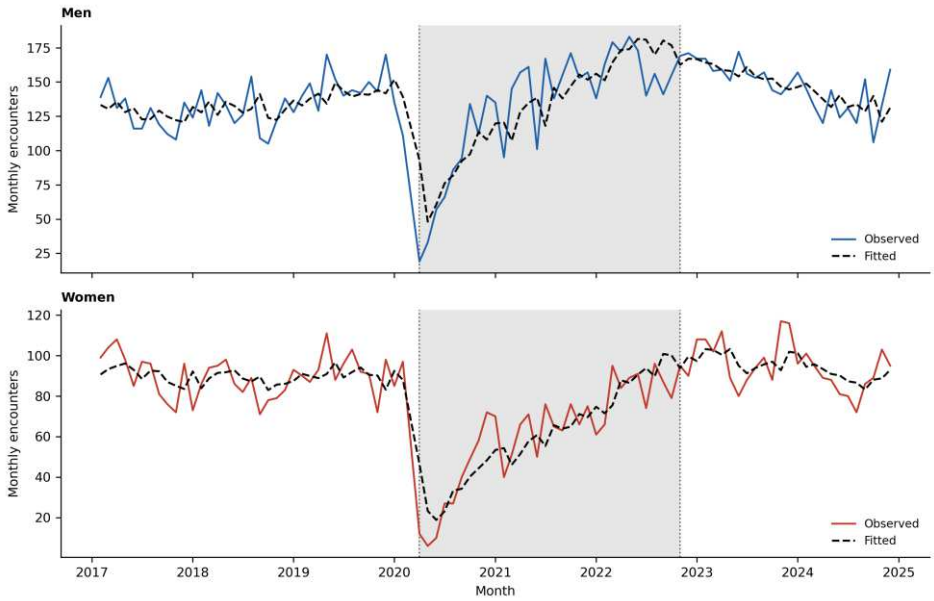

Fig. 2 Observed (coloured) and fitted (dashed) monthly encounters by sex (upper panel, men; lower panel, women), segmented negative binomial model with first-order lag and sex interaction, HEJCU, 2017–2024.

Effect by age group. All age groups showed a significant immediate reduction. The decline was largest among adults aged ≥60 years (IRR: 0.294; 95%CI: 0.213-0.407; −70.6%), followed by children and adolescents aged 0–17 years (IRR: 0.452; 95%CI: 0.334-0.611; −54.8%), and adults aged 18–29 (IRR: 0.621; 95%CI: 0.523-0.738; −37.9%) and 30–59 years (IRR: 0.618; 95%CI: 0.520–0.734; −38.2%). All groups recovered progressively during the restriction period (slope IRR: 1.020-1.040; p<0.001) and stabilized thereafter (Table 3, Fig. 3).

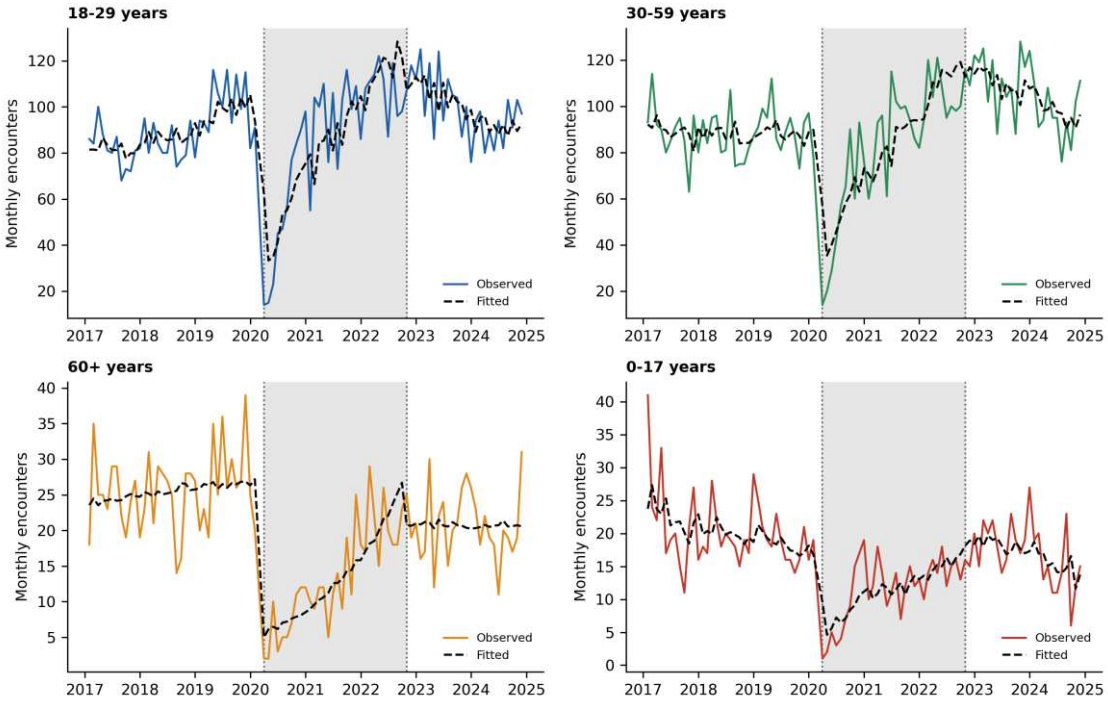

Fig. 3 Observed (coloured) and fitted (dashed) monthly encounters by age group, segmented negative binomial model with first-order lag and age interaction, HEJCU, 2017–2024.

Differential immediate impact. Figure 4 summarizes the level-change IRRs with their 95% confidence intervals. The confidence intervals for women versus men, and for adults aged ≥60 years versus every other age group, did not overlap, supporting a genuinely heterogeneous immediate impact of the restrictions across population subgroups.

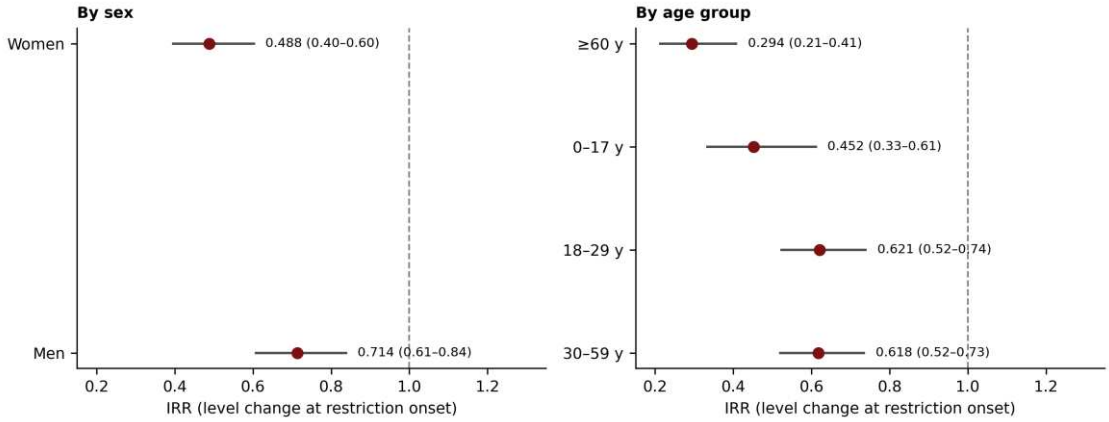

Fig. 4 Immediate level change at the onset of restrictions (incidence rate ratio and 95% confidence interval) by sex and by age group, from segmented negative binomial models with first-order lag and interaction terms. The dashed line indicates no effect (IRR=1).

Discussion

In this eight-year hospital-based ITS analysis, the COVID-19 mobility restrictions were associated with an abrupt 36.9% reduction in the demand for emergency care due to road traffic crashes, followed by a progressive monthly recovery of 2.0% and eventual stabilization at pre-pandemic levels once restrictions were lifted. The magnitude of the initial drop was markedly heterogeneous across population groups, being greatest among women and older adults.

The overall pattern—an immediate fall followed by gradual recovery—is consistent with international reports that documented sharp reductions in crashes and injuries during lockdowns and heterogeneous rebounds thereafter [4–9]. Our study adds hospital-based evidence from an LMIC and quantifies the trajectory with a model that accounts for the count nature, overdispersion and autocorrelation of the data, which are frequently overlooked in ITS studies of this kind [13–15]. The strong lag term underscores the month-to-month dependence of emergency demand, and the significant flattening of the recovery slope in the post-restriction period—together with a non-significant level change—indicates that, once mobility was restored, traffic-crash demand returned to its structural baseline rather than overshooting it.

The disproportionate reduction among women (−51.2% vs −28.6% in men) and older adults (−70.6%) is the most novel finding, and the non-overlapping confidence intervals (Fig. 4) support its robustness. It is compatible with differential mobility responses: groups whose travel was more discretionary or more sensitive to infection risk—plausibly women and older adults—reduced their exposure more sharply during restrictions. This heterogeneity has an equity dimension, as it identifies which groups' exposure, and therefore risk, is most responsive to mobility policy [17,19]. The predominance of young men among encounters throughout the period is consistent with national and international evidence on the epidemiology of road traffic injuries [10,17,20].

These results have practical implications. The close coupling between mobility and emergency demand supports the use of mobility indicators for short-term forecasting and surge planning in emergency services, and the differential effects argue for road-safety interventions and communication tailored to specific groups, including older pedestrians and, as mobility patterns shift, other vulnerable road users. Integrating hospital-based series with police and surveillance data could strengthen the monitoring of road traffic injuries in Peru and comparable settings.

This study has limitations. First, it is a single-center analysis based on administrative records, so results may not be generalizable to other hospitals or to the general population, and selection related to the hospital's catchment area and complexity level cannot be excluded. Second, as an uncontrolled ITS without a concurrent control series, the estimated effects may be influenced by co-occurring events during the pandemic (for example, changes in health-seeking behavior or hospital operations) rather than by mobility restrictions alone [15]. Third, the counts may be affected by under-registration and misclassification, and we did not have

information on injury severity or on causal factors such as alcohol, speed or protective-device use. Despite these limitations, the consistency of the effect across sexes and age groups, and the rigorous handling of overdispersion and autocorrelation, support the robustness of the findings.

Conclusions

The COVID-19 mobility restrictions were associated with an abrupt reduction in the demand for emergency care due to road traffic crashes at a referral hospital in Lima, followed by a progressive recovery and stabilization after restrictions were lifted. The initial impact was heterogeneous, disproportionately affecting women and older adults. Beyond the pandemic, these findings illustrate the tight link between population mobility and traffic-crash emergency demand and support equity-oriented, group-specific road-safety planning in middle-income settings. Multicenter studies incorporating severity measures and control series are warranted.

Declarations

Ethics approval and consent to participate. The study was approved by the Institutional Research Ethics Committee (CIEI) of Universidad Peruana Cayetano Heredia (approval CIEI-497-39-25). It used anonymized secondary administrative data; the requirement for individual informed consent was waived by the committee. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication. Not applicable.

Clinical trial number: not applicable.

Availability of data and materials. The aggregated monthly dataset supporting the conclusions of this article is included as Additional file 1. Further data are available from the corresponding author on reasonable request, subject to institutional permission from the José Casimiro Ulloa Emergency Hospital.

Competing interests. Alberto Gonzales Guzmán served as a public official at the José Casimiro Ulloa Emergency Hospital at the time the data were obtained. The other authors declare that they have no competing interests.

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Authors' contributions. AGG conceived and designed the study, collected, analysed and interpreted the data, and drafted the manuscript. LFLZ contributed to the design and critically revised the manuscript for important intellectual content. CVSD contributed to data analysis and interpretation and to drafting. All authors read and approved the final manuscript.

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Additional files. Additional file 1: Monthly aggregated counts of road traffic-crash encounters, HEJCU, 2017–2024 (XLSX). Anonymised monthly counts overall and by sex and age group, with the interrupted time series period assigned to each month.

Use of large language models. During the preparation of this manuscript the authors used Claude (Anthropic) to assist with drafting and language editing of the text and with writing the analysis code used to produce the statistical models, tables and data figures. All quantitative results were generated from the authors' own dataset; the authors reviewed, verified and edited all outputs, and take full responsibility for the content and integrity of the work. The large language model is not listed as an author and did not make any editorial or scientific decisions.

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Table 1 Segmented negative binomial model with first-order lag for the monthly frequency of road traffic-crash encounters, HEJCU, 2017–2024

Parameter	IRR (95% CI)	p
Pre-pandemic trend (per month)	1.001 (0.996–1.006)	0.613
Level change, restriction	0.631 (0.507–0.785)	<0.001
Slope change, restriction	1.020 (1.010–1.030)	<0.001
Level change, post-restriction	0.910 (0.768–1.078)	0.274
Slope change, post-restriction	0.974 (0.961–0.987)	<0.001
First-order lag, log(Y t−1)	1.499 (1.271–1.767)	<0.001

IRR: incidence rate ratio; CI: confidence interval. Dispersion parameter α=0.021 (p<0.001); AIC 956.0. Each level/slope change is expressed relative to the projection of the preceding segment.

Table 2 Effect by sex: segmented negative binomial model with first-order lag and sex interaction

Effect	IRR (95% CI)	p
Men – level, restriction	0.714 (0.608–0.838)	<0.001
Women – level, restriction	0.488 (0.396–0.602)	<0.001
Men – slope, restriction	1.018 (1.010–1.026)	<0.001
Women – slope, restriction	1.026 (1.016–1.035)	<0.001
Men – level, post-restriction	0.893 (0.764–1.044)	0.155

Effect	IRR (95% CI)	p
Women – level, post-restriction	0.966 (0.813–1.148)	0.694
Men – slope, post-restriction	0.975 (0.964–0.986)	<0.001
Women – slope, post-restriction	0.970 (0.958–0.982)	<0.001

Reference category: men. Model diagnostics: 188 observations; AIC 1641.1; Durbin–Watson 1.75.

Table 3 Effect by age group (IRR with 95% CI): segmented negative binomial model with first-order lag and age interaction

Age group	Level, restriction	Slope, restriction	Level, post-restr.	Slope, post-restr.
0–17 y	0.452 (0.33–0.61)	1.020 (1.01–1.03)	1.143 (0.85–1.55)	0.969 (0.95–0.99)
18–29 y	0.621 (0.52–0.74)	1.025 (1.02–1.03)	0.864 (0.72–1.03)	0.968 (0.96–0.98)
30–59 y	0.618 (0.52–0.73)	1.024 (1.02–1.03)	0.941 (0.79–1.12)	0.969 (0.96–0.98)
≥60 y	0.294 (0.21–0.41)	1.040 (1.03–1.06)	0.814 (0.62–1.07)	0.961 (0.94–0.98)

IRR: incidence rate ratio. Reference age group: 18–29 years. Model diagnostics: 376 observations; AIC 2750.8; Durbin–Watson 1.91.

Table 4 Comparison of candidate models for the monthly series

Model	AIC	RMSE	Dispersion	Durbin–Watson	Ljung–Box p (lag 12)
Negative binomial + lag-1	956.01	27.92	0.98	1.74	0.127
NB + Fourier + lag-1	958.08	27.71	1.02	1.73	0.054
NB + Fourier	984.27	30.23	1.05	0.93	<0.001
Negative binomial (base)	984.47	30.74	1.02	0.90	<0.001
Poisson + Fourier	1184.21	28.66	5.11	1.03	<0.001
Poisson	1201.95	29.44	5.23	1.00	<0.001

Lower AIC and RMSE, dispersion close to 1, Durbin–Watson near 2 and a non-significant Ljung–Box test indicate better fit. The negative binomial model with first-order lag was selected.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1monthlyaggregates.xlsx
- STROBEchecklistBMCITS.docx