Author/s:
Livingston, M;Gilmore, W;Taylor, N;Chikritzhs, T;Yuen, WS;Howell, J;Flores, E;Curtis, M;Dietze, P

Title:
Age, period and cohort trends in hospital admissions for alcohol-related liver disease in Australia, 1993–2020

Date:
2025-05-01

Citation:
Livingston, M., Gilmore, W., Taylor, N., Chikritzhs, T., Yuen, W. S., Howell, J., Flores, E., Curtis, M. & Dietze, P. (2025). Age, period and cohort trends in hospital admissions for alcohol-related liver disease in Australia, 1993–2020. Drug and Alcohol Review, 44 (4), pp.1254-1263. https://doi.org/10.1111/dar.14063.

Persistent Link:
https://hdl.handle.net/11343/360763

Received: 4 September 2024 | Revised: 19 March 2025 | Accepted: 3 April 2025

DOI: 10.1111/dar.14063

ORIGINAL PAPER

Drug and Alcohol REVIEW APSAD WILEY

Age, period and cohort trends in hospital admissions for alcohol-related liver disease in Australia, 1993–2020

Michael Livingston[1,2,3] | Will Gilmore[1] | Nic Taylor[1,3] | Tanya Chikritzhs[1] | Wing See Yuen[4] | Jessica Howell[3,5,6,7] | Ericka Flores[5] | Michael Curtis[1,3] | Paul Dietze[1,3]

[1]National Drug Research Institute, enAble Institute, Faculty of Health Sciences, Curtin University, Melbourne, Australia

[2]Centre for Alcohol Policy Research, La Trobe University, Melbourne, Australia

[3]The Burnet Institute, Melbourne, Australia

[4]National Drug and Alcohol Research Centre, UNSW Sydney, Sydney, Australia

[5]St Vincent's Hospital Melbourne, Melbourne, Australia

[6]Department of Medicine, University of Melbourne, Melbourne, Australia

[7]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia

Correspondence
Michael Livingston, National Drug Research Institute, enAble Institute, Faculty of Health Sciences, Curtin University, Melbourne, Australia.
Email: michael.livingston@curtin.edu.au

Funding information
Australian Research Council, Grant/Award Number: FT210100656; Australian Government; Curtin University, Western Australia

Abstract

Introduction: This study examines trends in admissions for alcohol-related liver disease (ALD) for Australian men and women between 1993 and 2020 and disaggregates these trends into age, period and cohort components.

Method: Retrospective age-period-cohort analysis of hospital admissions with a primary diagnosis of ALD. Setting: Australia. Cases: 133,705 hospital admissions – 97,755 men (73%); 35,950 women (27%). Measurements: Hospital admissions for ALD were grouped into five-year age groups (15–19, 20–24 up to 85 and over) for each financial year between 1992/93 and 2020/21.

Results: ALD admission rates were substantially higher for men than women. Rates for men increased up to 2005 and subsequently declined before an uptick in 2020. For women, rates increased steadily over the period. In age-period-cohort models, male admission rates were relatively stable over both period and cohort. For women, period effects increased steadily – compared to the period reference year of 2006, the RR for women's admission rates was 0.69 (0.65, 0.74) in 1993, increasing to 1.23 (1.18, 1.29) in 2020. Recent cohorts had significantly higher rates of hospital admission for ALD than those born earlier (e.g., women born in the 1996 cohort had an RR of 2.2 (1.8, 2.7) relative to those born in the reference year 1956).

Discussion and Conclusions: Increases in hospital admissions for ALD, especially since the COVID-19 pandemic, point to the need for effective identification and interventions for people with alcohol-use disorders at risk of chronic disease outcomes.

KEYWORDS
alcohol, cohort, liver disease, morbidity, trends

1 | INTRODUCTION

Per capita alcohol consumption, as estimated from tax intake, surveys and other data sources by the Australian Bureau of Statistics, declined from a peak of 10.76 litres of pure alcohol per person in 2007 to around 10 litres in 2012 and has been relatively stable since [1]. However, many measures of alcohol-related harms have been increasing [2, 3], raising fundamental questions about the long-established relationship between population-level drinking

and harm. A key potential explanation has been the lack of uniformity in drinking trends, especially by generation. Survey-based estimates suggest that per-capita consumption declines have been driven by sharp falls in drinking among teenagers and young adults, while drinking among middle-aged and older Australians has not declined [4]. In fact, for middle-aged women, there has been some evidence that drinking and risky drinking have *increased* [5]. These findings are not unique to Australia. For example, a meta-analysis of six US surveys found generally increasing trends in drinking for those aged 50 or older, but stability or declines in drinking for younger people [6]. In the UK, declines in drinking since 2004 [7] occurred alongside stable rates of alcohol-induced deaths [8], again potentially reflecting generational divergences in drinking [9].

One way to better understand how generational differences in drinking trends play out is via the use of age-period-cohort (APC) modelling, which aims to disaggregate population trends into their component parts: those caused by the age structure of the population (age), those that reflect overall shifts across the whole population (period) and those driven by generational differences (cohort). There are significant methodological challenges in unpicking these different drivers because of their fundamental interdependence [10], but researchers have developed an array of methods to parse out the distinct contributions of age, period, and cohort, which we will discuss in more detail in the methods section. International age-period-cohort analyses of consumption and harm provide some useful context for Australian data. In a recent review of the US literature, Keyes argues that the alcohol APC literature generally shows that baby boom cohorts (born between about 1946 and 1965) drink more heavily across their life course than earlier or later generations and that the large gap between men and women has narrowed over time across generations [11]. In the UK, Meng et al. [12] found steadily increasing drinking by birth cohort from those born in the early 1900s through until 1980, after which drinking sharply fell – they also identified a narrowing of the gender gap over time. Our previous work on Australian drinking produced broadly similar findings [13].

Recent APC models of alcohol-related harms have been less common, although there is a long tradition of comparative European analyses [14–16]. The most recent of these focussed on alcohol-induced disease mortality, which typically results from long periods of heavy drinking, and found markedly different period effects across countries, but a general pattern of higher mortality for earlier cohorts and consistent trends for men and women [17]. A recent analysis of alcohol treatment-seeking behaviour in Berlin found moderate period effects but substantially higher rates for people born between 1951 and 1986 compared to earlier or more recent cohorts [18]. Keyes et al.'s recent study of US alcohol-specific mortality highlighted two concerning patterns: a general increase in mortality across the population over time and an increased cohort effect for people born in the 1980s [19]. An analysis of data from England and Scotland found generally increasing alcohol-caused mortality rates in England, contrasting with sharp declines in Scotland from about 2004 onwards. Cohort mortality was generally higher for earlier cohorts. Period and cohort trends were generally similar for men and women (although male mortality was markedly higher) [20]. In contrast, our recent analysis of alcohol liver disease mortality in Australia found a narrowing of the sex gap, with generally declining rates of mortality for men contrasting with stable period effects for women and some evidence of increased risk for cohorts born during the 1960s who are ageing into the highest risk age groups now [21].

Previous Australian analyses have highlighted marked differences between hospital admission and mortality trends for alcohol-related liver disease (ALD) [22], with especially striking increases in admissions for young people which are unlikely to be reflected in mortality data. These differences may reflect changing patterns of healthcare utilisation or improvements in treatment – the incidence of ALD may have increased even while mortality has not, or they may provide earlier indications of trends given the lag time between onset and mortality can be many years [23]. However, there has been little work examining alcohol-related hospital data in an APC framework. Here, we make use of long-running national data on ALD to examine trends in hospital admissions with primary diagnoses of ALD over a 28-year period (1993/4 to 2020/21), using an APC approach.

2 | METHODS

2.1 | Data

Data are sourced from the Australian Institute for Health and Welfare's Separation Statistics series [24]. These data collate all hospital admissions in Australian hospitals from 1993/4 onwards by primary diagnosis. Australian Institute of Health and Welfare hospital admissions data include all admissions to private and public hospitals in the country and thus provide complete coverage of the relevant population. All admissions where ALD was the primary diagnosis were extracted for analysis – secondary and subsequent diagnoses were not readily available. We focussed on ALD as it has been relatively consistently coded, captures a

key chronic outcome likely to result in hospital admission, and has been the focus of previous analyses of Australian trend work [22]. For the years 1993/4 to 1997/8, diagnoses were coded using the International Classification of Diseases Edition 9, while for the remaining years, diagnoses use the International Classification of Diseases 10th Revision codes. The specific codes included in this study are summarised below in Table 1.

Data are grouped by sex and five-year age group, starting at 15–19 years old and with an upper age category of 85 years or over. Each age group was coded as the midpoint of the category (e.g., 15- to 19-year-olds were coded as 17), with the top age group coded as 87 years. Annual admissions data were provided for the financial years 1993/94 through to 2020/21 – for simplicity, we recoded these to the earlier calendar year (from 1993 to 2020). Birth cohort was then simply calculated as year – age (thus, e.g., a 17-year-old with a hospital separation in 2000/01 would have a birth cohort equal to 2000–17 = 1983). Admission rates per 100,000 population were calculated for each age group and year using population data from the Australian Bureau of Statistics estimated residential populations [25]. Thus, our final data included rates for 15 age groups, 28 periods and 98 birth cohorts (from 1906 up to 2003). It is worth emphasising here that data are only provided at the admission level, and thus likely represent multiple hospital admissions for individual patients. This is a key limitation of these data and means that trends and patterns over time can be unduly influenced by changes in treatment approaches.

TABLE 1 Diagnosis codes included in analyses.

Years	Classification	Specific codes
1993/94 to 1997/98	ICD9	571.0 – Alcoholic fatty liver 571.1 – Acute alcoholic hepatitis 571.2 – Alcoholic cirrhosis of the liver 571.3 – Alcoholic liver damage, unspecified
1998/99 to 2020/21	ICD10	K70.0 – Alcoholic fatty liver K70.1 – Alcoholic hepatitis K70.2 – Alcoholic fibrosis and sclerosis of the liver K70.3 – Alcoholic cirrhosis of the liver K70.4 – Alcoholic hepatic failure K70.9 – Alcoholic liver disease, unspecified

Abbreviations: ICD9, International Classification of Diseases, Ninth Revision; ICD10, International Classification of Diseases, Tenth Revision.

2.2 | Analyses

Descriptive plots of annual total admission rates, as well as plots of age-specific admissions by year, were constructed for men and women. Age, period and cohort patterns of admission rates were demonstrated via Hexamaps, as developed and described by Jalal and Burke [26]. As has been widely noted, models estimating age, period and cohort effects are challenged by the fundamental dependence of the three measures (cohort = period – age) [10, 27]. This is known as the identification problem, and numerous strategies have been outlined to attempt to overcome it, although all rely on important assumptions, and there remains a lack of consensus in the literature on modelling processes. We follow Keyes et al., who, in their recent work, showed that various approaches to the statistical modelling of age, period and cohort effects on US alcohol mortality produced similar results [19]. They broadly argue that Carstensen's first-derivative approach [28] provided the most robust results. In previous work we used this method in our main analysis for alcohol-related liver disease mortality [21], and thus we used it again here for our estimates here. Models were estimated using the Stata modules developed by Rutherford et al. [29]. Separate models were estimated for men and women given the well-established sex differences in alcoholic liver disease rates and trends [30].

The modelling approach is described in detail elsewhere [28, 29, 31]. In summary, the first-derivative approach models age, period, and cohort as non-linear, continuous effects via the use of restricted cubic splines. Separate models are used to fit age and period effects (with cohort constrained to an average linear drift of 0, AP-C models) and age and cohort effects (with period constrained, AC-P models). The number of knots fitted for each spline is pre-specified – we fitted 4 knots for each spline, based on exploratory modelling that found 4 knots minimised the Bayesian Information Criterion. We fit both A-PC and A-CP models and present Age and Period effects from AP-C models and Age and Cohort effects from AC-P models. Period and cohort effects are presented as risk ratios relative to reference categories (chosen as the middle data points: 2006 for period, 1954 for cohort), while age effects are presented as predicted admission rates.

Due to the concerns about the robustness of APC models, we also conduct a sensitivity analysis, fitting APC models using Yang et al.'s intrinsic estimator (IE) approach [31] as implemented in Stata by Schulhofer-Wohl and Yang [32]. The IE models required periods to be combined into five-year groups

(1993–1997 through to 2013–2017, with a three-year top category of 2018–2020). Cohorts were thus similarly combined to ensure that the key requirement (age + cohort = period) held. Results for the IE models are included in the Supporting Information and briefly summarised below.

3 | RESULTS

The crude overall admission rate trends for men and women are presented in Figure 1. Male rates of ALD admissions are more than twice as high as female rates for most of the study period, although the gap narrows after 2015.

Admission rates for men and women grew steadily between the late 1990s and 2007, after which male rates plateaued until a sharp decline in 2012. Female rates were relatively stable between 2007 and 2013 but subsequently increased steadily. Hospital admissions for men and women increased sharply in 2019 and 2020. Figure 2a,b shows how trends across the life course have changed over time.

Figure 2a shows an increase in morbidity over time for women and generally younger peaks in morbidity than seen for males in Figure 2b. Male morbidity rates showed relatively stable age patterns, but clear differences overall by year, with 2007 morbidity well higher than earlier and later years. Hexamap figures showing admission rates by age, period and cohort for women and men are presented in Figures S1 and S2, Supporting Information.

Results of the formal age-period-cohort modelling are presented in graphical form below, with full model outputs provided in the Supporting Information. ALD hospital admission rates peak around age 50–60 for both men and women, in all model specifications. For women (Figure 3), period effects reflect a steady overall increase in alcoholic liver disease across the study period, with an especially sharp uptick in the most recent few years. Cohort effects also point to an emerging issue with women's alcoholic liver disease – cohort rate ratios declined from the earliest cohorts but have steadily increased for each birth cohort since roughly the 1950s, such that recent cohorts have rate ratios of 1.5 or higher compared to the reference cohort in 1954.

For men (Figure 4), period effects show a peak in alcoholic liver disease in the late 2000s, which dropped away again during the 2010s before an uptick in the most recent 2 years. Cohort effects are relatively minor, with most birth cohorts having a lower risk of alcoholic liver disease than the reference category (those born in 1954). There is a suggestion of an increase for recent birth cohorts, but the uncertainty around these estimates is marked, and the confidence intervals include 1.0.

Results of the IE models are provided in the Supporting Information. As with the main results, they produce period effects increasingly steadily for women. IE models also show higher morbidity for recent cohorts than for those born in the 1930s–1940s, but produce much higher risk estimates for the oldest cohorts than the main models. Results for men using IE models show steadily

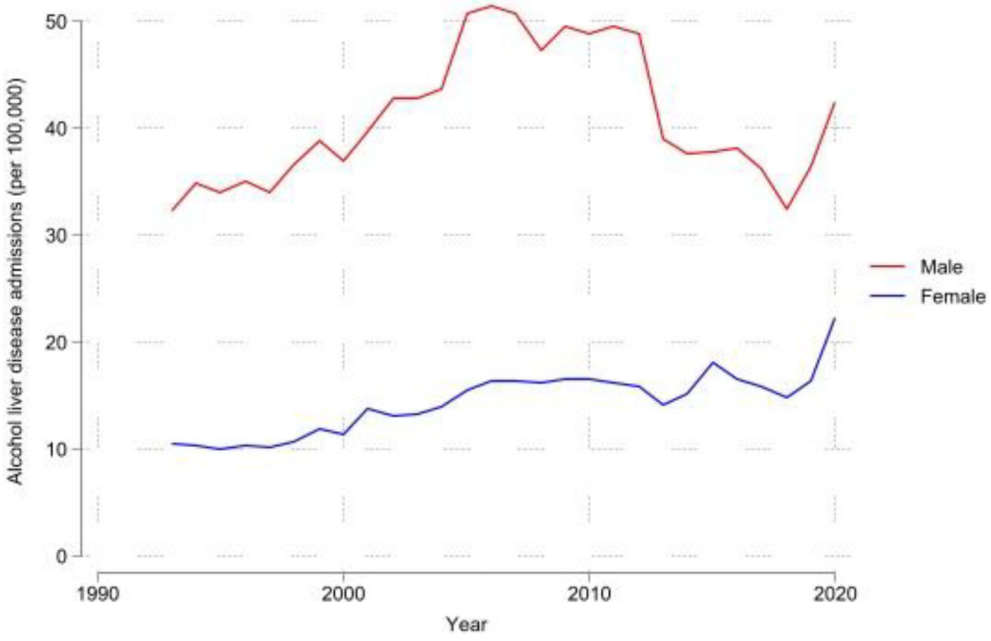

FIGURE 1 Alcohol-related liver disease hospital admissions per 100,000 population, 1993–2020, by sex.

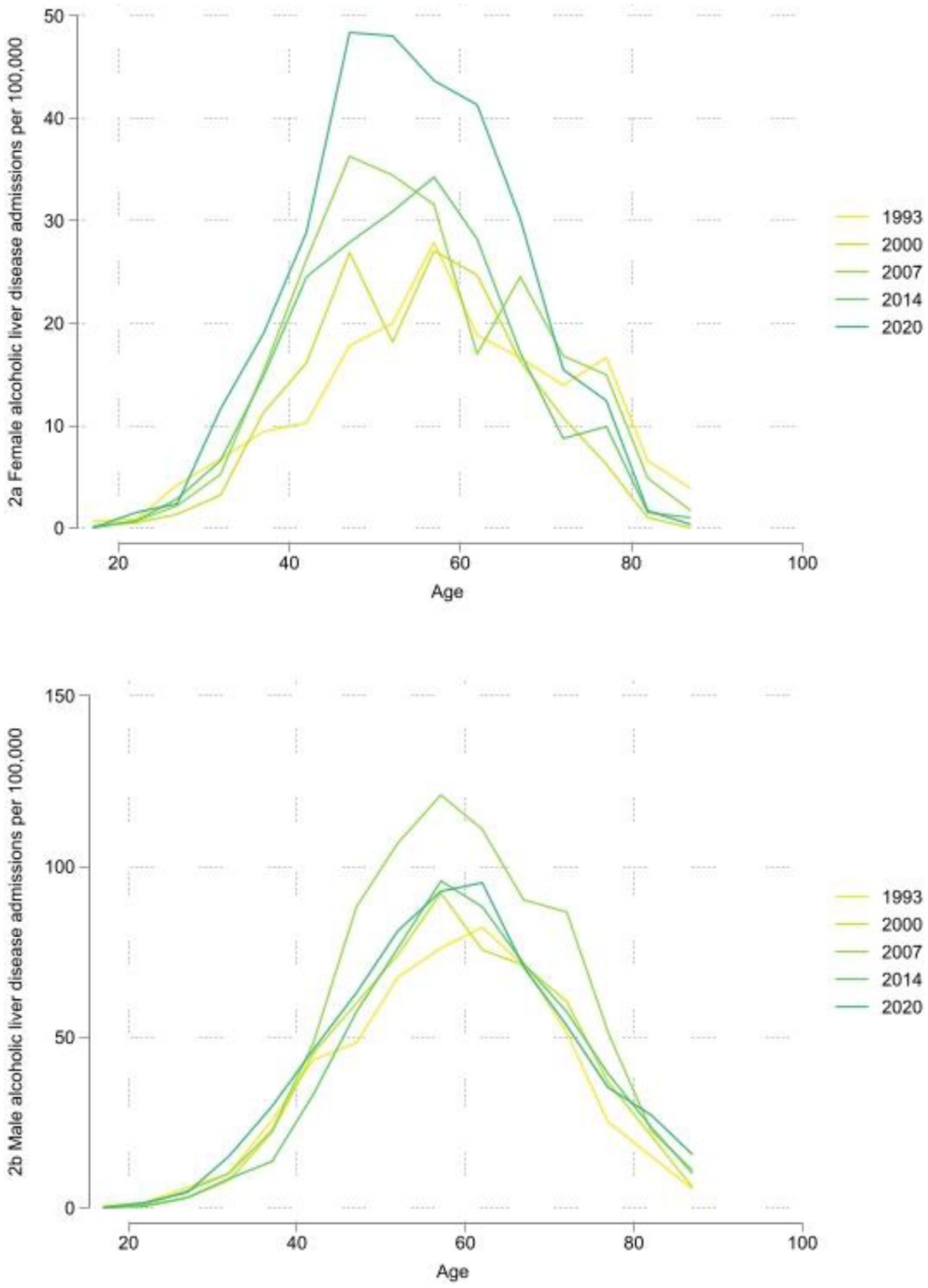

FIGURE 2 Alcohol-related liver disease hospital admissions by age and calendar year, female (a) and male (b).

decreasing effects by cohort, but stronger increases in period effects between 1996 and 2011.

4 | DISCUSSION

Unlike our previous work on alcoholic liver disease mortality [21], our analyses of hospital admission data do not find generally declining levels of alcohol-related harm, despite some evidence of declines in drinking. The differences between the mortality and morbidity results likely reflect the impact of factors related to healthcare provision – hospital admissions are likely driven by a range of factors beyond simple disease incidence. In particular, the key limitation that our data cannot disaggregate multiple admissions for the same individual is likely to be driving at least some of the differences in the long-term morbidity and mortality trends. A recent trend study in Germany highlighted a marked difference in morbidity and mortality trends during the COVID-19

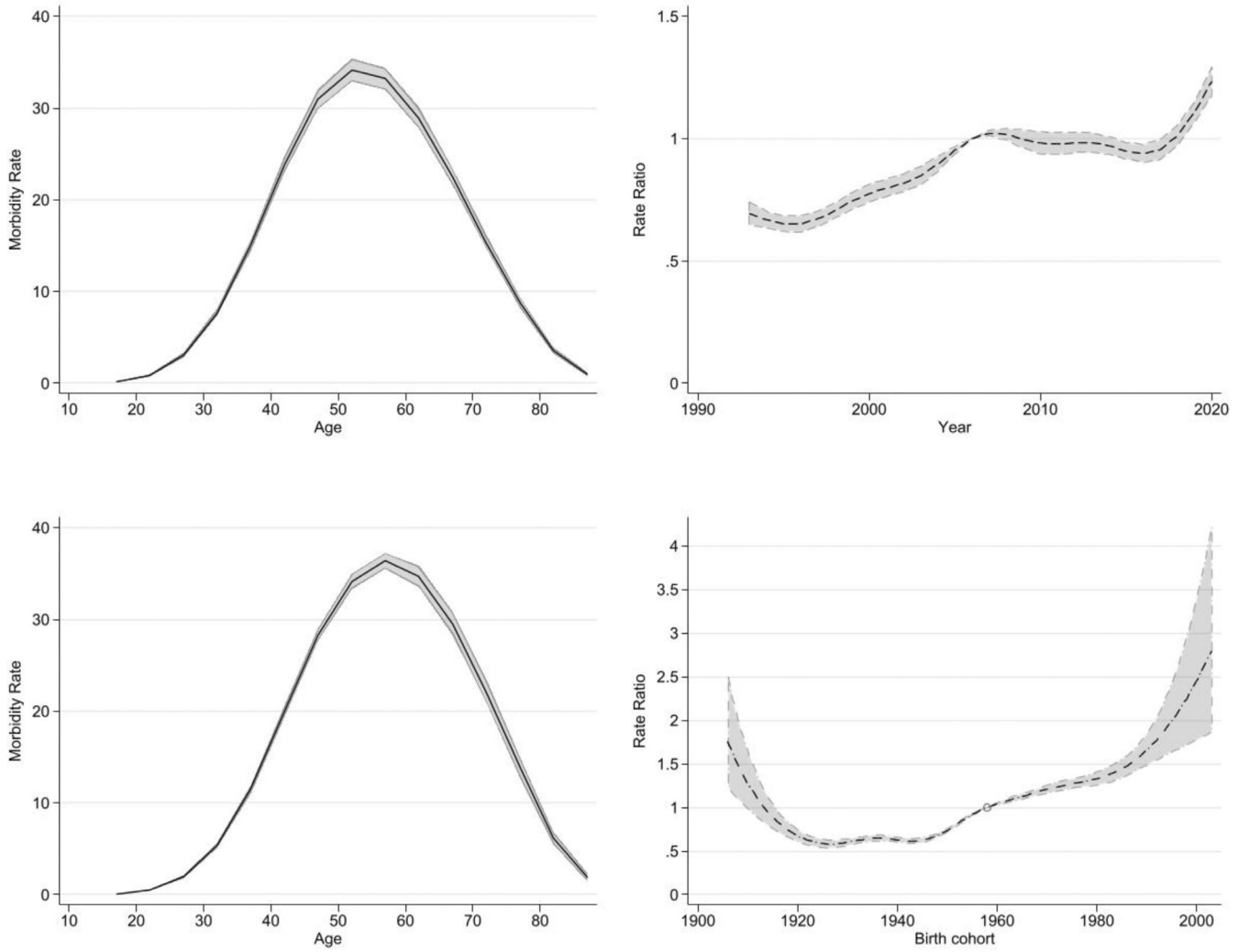

FIGURE 3 Age, period and age, cohort effect estimates from age period cohort (top) and age cohort period (bottom) models of alcoholic liver disease hospital admissions, women. Period reference category = 2006, cohort reference category = 1954.

pandemic [33], highlighting the broader impacts of health systems factors on trends. In contrast, our analyses for hospital admissions show the same uptick during the pandemic years as our previous mortality work, suggesting real increases in harm rates since 2020.

For men overall, we find broadly stable rates of hospital admissions, with a peak around 2009 and a sharp increase in the most recent years available. For women, overall period effects point to steady increases in alcoholic liver disease morbidity, with an especially sharp uptick in recent years. For both men and especially women, the increase in admission rates between 2019/20 and 2020/21 was the largest increase observed over the study period, likely pointing to impacts related to the COVID-19 pandemic on heavy drinking and is consistent with mortality increases and recently published per-capita consumption estimates [34, 35] for those years. An increase in chronic alcohol-related harm during the pandemic has also been reported internationally [36–38] and suggests that at least some heavy drinkers increased their consumption to levels that resulted in alcoholic liver disease during the period of COVID-19-related restrictions. Future work examining how trends varied across states and through 2021 and 2022 will provide more insights into impacts that the pandemic may have had on key at-risk drinker groups in Australia, given the marked differences in restrictions experienced [39].

Cohort effects point to further sex differences. The risk of alcoholic liver disease admission increased for cohorts born after about 1940 for women, with recent birth cohorts having age- and period-adjusted risks around twice as high as the reference cohort born in 1956. These findings are at odds with evidence that recent cohorts of young Australians drink less than earlier cohorts. Moreover, the cohort effects in our alternative models provided in the Supporting Information are

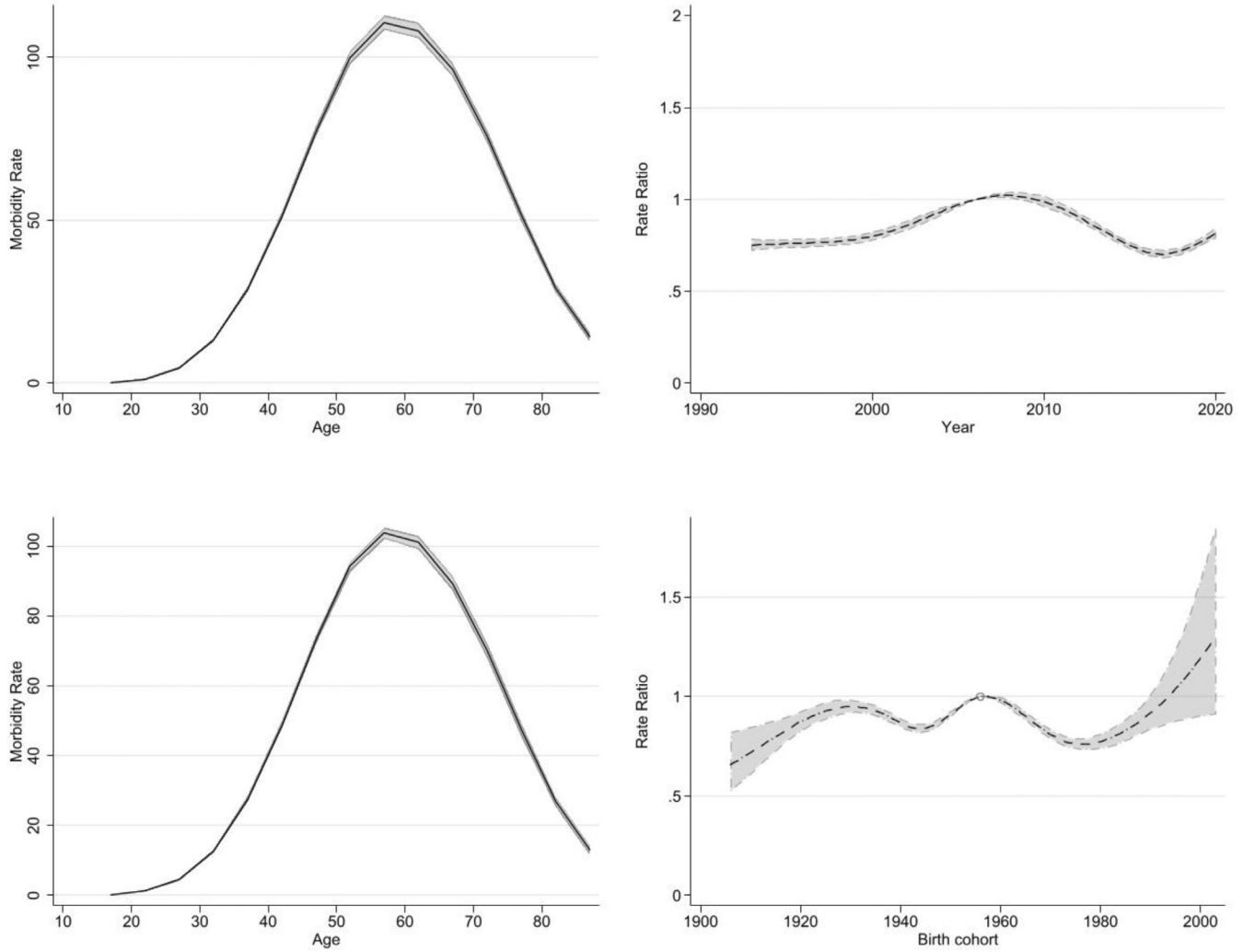

FIGURE 4 Age, period, and age, cohort effect estimates from age period cohort (top) and age cohort period (bottom) models of alcoholic liver disease hospital admissions, men.

not as striking, so these increases for recent cohorts of women should be treated with some caution. Some researchers have argued that age patterns of consumption are changing differentially for men and women [40], which would not be well captured in our modelling, which assumes a stable overall age pattern that is consistent across cohorts. Future work could directly test this assumption using newly developed APC-I approaches [41].

Still, ongoing monitoring of alcoholic liver disease as these cohorts age is essential. The overall narrowing of the gap between men and women in alcoholic liver disease hospital admission rates supports our earlier findings on mortality [21] and general trends towards narrower sex gaps in drinking [42]. Australian survey data has shown a steady narrowing of the drinking gap between men and women for 50–69 year olds [43], who are at their peak age for ALD risk, and these shifts in drinking are likely to at least partly explain the results found here. It is worth noting that even with the different trends for men and women identified here, male rates of alcoholic liver disease remained markedly higher across the whole study period. International data are not entirely consistent on this topic. For example, sex differences in morbidity rates for alcoholic liver disease in the UK [44] have remained relatively stable for the past decade, while in the US, prevalence for women has increased by 50% compared with 30% for men [45].

The overall picture painted by our hospital admission analyses is much more concerning than previous mortality work, which showed relatively stable or declining rates over the equivalent period [21], at least until 2019. Increases in alcohol-related liver disease admissions may reflect improvements in treatment outcomes or screening and do seem to be consistent with data from other, similar jurisdictions [22, 30, 38, 44, 46]. A key limitation of

this study is its use of simple hospital admission data, meaning the increases observed could be driven by repeat admissions for the same patients rather than by increasing incidence per se. A recent data linkage study in Queensland [47] showed that patients admitted for alcohol-related cirrhosis had an average of 2–3 repeat admissions over the follow-up period (average of 5 years), which suggests the impact of repeat admissions on trends could be substantial. Unfortunately, we are unable to determine whether rates of repeat admission have changed over time. Accordingly, future work should use linked data to focus on better understanding trends in incidence and patterns of hospital use for people with alcoholic liver disease. Further, the reliance on primary diagnosis admissions means the true burden is likely under-estimated [48] by as much as half [49]. Future work should also consider the role of comorbidities, including the sharp increase in metabolic-associated steatotic liver disease in recent years [50].

Still, these findings raise some concerns about increasing alcohol harms, especially as these data likely underestimate the level of harm by focusing only on hospital admissions where liver disease was explicitly coded as alcohol-related – a significant proportion of other liver disease is also likely caused by alcohol consumption [51]. Our findings suggest important cohort effects at work, but overall period effects also point towards increases in drinking for high-risk groups across the population, especially in the last few years. Ongoing impacts of the COVID-19 pandemic on alcohol-related harms remain poorly understood, and future analyses should explore how trends varied across Australian jurisdictions with varying lockdown experiences. That said, these data (along with sharp increases in harm elsewhere [37]) point to a need for urgent evidence-informed population-level interventions as well as strategies targeted at heavy drinkers at risk of developing liver disease.

AUTHOR CONTRIBUTIONS

M. L.: conceptualisation, lead data analysis, lead write-up, lead interpretation. **W. G.:** data extraction, contribution to write-up. **N. T.:** conceptualisation, contribution to write-up. **T. C.:** data access and extraction, conceptulaisation, contribution to write-up. **W. S. Y.:** contribution to analysis, contribution to write-up. **J. H.:** conceptualisation, contribution to write-up and interpretation. **E. F.:** contribution to write-up and interpretation. **M. C.:** contribution to write-up. **P. D.:** contribution to conceptualisation, write-up and interpretation.

ACKNOWLEDGEMENTS

The Australian Institute of Health and Welfare provides access to the hospital data used here. Open access publishing facilitated by Curtin University, as part of the Wiley - Curtin University agreement via the Council of Australian University Librarians.

FUNDING INFORMATION

This work was funded by the Australian Research Council via ML's Future Fellowship FT 210100656 and by funding from the Australian Government under the Drug and Alcohol Program (NDRI core funder) and from Curtin University, Western Australia. J. H. is supported by a National Health and Medical Research Council Investigator Fellowship. The funders have not had a role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available via the Australian Institute of Health and Welfare and the original files are referenced in the manuscript. Repackaging and rehosting the AIHW data is not permitted, so we have not added it to a separate repository.

ORCID

Michael Livingston https://orcid.org/0000-0002-8995-9386
Nic Taylor https://orcid.org/0000-0002-8700-5909
Tanya Chikritzhs https://orcid.org/0000-0001-8871-3205
Wing See Yuen https://orcid.org/0000-0002-2791-6858
Michael Curtis https://orcid.org/0000-0002-1814-0867
Paul Dietze https://orcid.org/0000-0001-7871-6234

REFERENCES

1. Australian Bureau of Statistics. Apparent consumption of alcohol, Australia, 2017–18. Canberra: Australian Bureau of Statistics; 2019.
2. Gilmore W, Lensvelt E, Jones P, Dorocicz J, Sherk A, Churchill S. Australian alcohol-attributable harm visualisation tool version 2.1. Perth, Australia: National Drug Research Institute, Curtin University and Canadian Institute for Substance Use Research, University of Victoria; 2023.
3. Turning Point. AOD Stats, Melbourne. Australia: Turning Point; 2023.
4. Livingston M, Callinan S, Raninen J, Pennay A, Dietze PM. Alcohol consumption trends in Australia: comparing surveys and sales-based measures. Drug Alcohol Rev. 2018;37:S9–S14.
5. Australian Institute of Health and Welfare. 2019 National Drug Strategy Household Survey - report. Canberra: AIHW; 2020.
6. Grucza RA, Sher KJ, Kerr WC, Krauss MJ, Lui CK, McDowell YE, et al. Trends in adult alcohol use and binge drinking in the early 21st-century United States: a meta-

analysis of 6 national survey series. Alcohol Clin Exp Res. 2018;42:1939–50.
7. Institute for Alcohol Studies. Factsheet: alcohol consumption. London, UK: IAS; 2018.
8. Office for National Statistics. Alcohol-specific deaths in the UK. London: ONS; 2022.
9. National Health Service. Health survey for England, 2019: data tables. London: NHS; 2020.
10. Fosse E, Winship C. Analyzing age-period-cohort data: a review and critique. Annu Rev Sociol. 2019;45:467–92.
11. Keyes KM. Age, period, and cohort effects in alcohol use in the United States in the 20th and 21st centuries: implications for the coming decades. Alcohol Res. 2022;42:2.
12. Meng Y, Holmes J, Hill-McManus D, Brennan A, Meier PS. Trend analysis and modelling of gender-specific age, period and birth cohort effects on alcohol abstention and consumption level for drinkers in Great Britain using the general lifestyle survey 1984–2009. Addiction. 2014;109:206–15.
13. Livingston M, Raninen J, Slade T, Swift W, Lloyd B, Dietze P. Understanding trends in Australian alcohol consumption—an age–period–cohort model. Addiction. 2016;111:1590–8.
14. Corrao G, Ferrari P, Zambon A, Torchio P, Aricò S, Decarli A. Trends of liver cirrhosis mortality in Europe, 1970-1989: age-period-cohort analysis and changing alcohol consumption. Int J Epidemiol. 1997;26:100–9.
15. Corrao G. Liver cirrhosis mortality trends in Eastern Europe, 1970–1989. Analyses of age, period and cohort effects and of latency with alcohol consumption. Addict Biol. 1998;3:413–22.
16. Rosén M, Haglund B. Trends in alcohol-related mortality in Sweden 1969–2002: an age-period-cohort analysis. Addiction. 2006;101:835–40.
17. Kraus L, Østhus S, Amundsen EJ, Piontek D, Härkönen J, Legleye S, et al. Changes in mortality due to major alcohol-related diseases in four Nordic countries, France and Germany between 1980 and 2009: a comparative age–period–cohort analysis. Addiction. 2015;110:1443–52.
18. Specht S, Schwarzkopf L, Braun-Michl B, Seitz N-N, Wildner M, Kraus L. Age, period, and cohort effects on trends in outpatient addiction care utilization in the general Berlin population from 2008 to 2016. BMC Public Health. 2022; 22:320.
19. Keyes KM, Rutherford C, Smith GS. Alcohol-induced death in the USA from 1999 to 2020: a comparison of age–period–cohort methods. Curr Epidemiol Rep. 2022;9:161–74.
20. Walsh D, McCartney G, Minton J, Parkinson J, Shipton D, Whyte B. Deaths from 'diseases of despair' in Britain: comparing suicide, alcohol-related and drug-related mortality for birth cohorts in Scotland, England and Wales, and selected cities. J Epidemiol Community Health. 2021;75: 1195–201.
21. Livingston M, Room R, Chikritzhs T, Taylor N, Yuen WS, Dietze P. Trends in alcohol-related liver disease mortality in Australia: an age-period-cohort perspective. Addiction. 2023; 118:2156–63.
22. Liang W, Chikritzhs T, Pascal R, Binns C. Mortality rate of alcoholic liver disease and risk of hospitalization for alcoholic liver cirrhosis, alcoholic hepatitis and alcoholic liver failure in Australia between 1993 and 2005. Intern Med J. 2011;41: 34–41.
23. Haflidadottir S, Jonasson JG, Norland H, Einarsdottir SO, Kleiner DE, Lund SH, et al. Long term follow-up and liver-related death rate in patients with non-alcoholic and alcoholic related fatty liver disease. BMC Gastroenterol. 2014;14:166.
24. Australian Institute of Health and Welfare. Principal diagnosis data cubes. Canberra, Australia: AIHW; 2022.
25. Australian Bureau of Statistics. National, state and territory population. Canberra, Australia: ABS; 2021.
26. Jalal H, Burke DS. Hexamaps for age-period-cohort data visualization and implementation in R. Epidemiology. 2020;31: e47–9.
27. Kupper LL, Janis JM, Karmous A, Greenberg BG. Statistical age-period-cohort analysis: a review and critique. J Chronic Dis. 1985;38:811–30.
28. Carstensen B. Age–period–cohort models for the Lexis diagram. Stat Med. 2007;26:3018–45.
29. Rutherford MJ, Lambert PC, Thompson JR. Age–period–cohort modeling. Stata J. 2010;10:606–27.
30. Mann RE, Smart RG, Govoni R. The epidemiology of alcoholic liver disease. Alcohol Res Health. 2003;27:209–19.
31. Yang Y, Schulhofer-Wohl S, Fu WJ, Land KC. The intrinsic estimator for age-period-cohort analysis: what it is and how to use it. Am J Sociol. 2008;113:1697–736.
32. Schulhofer-Wohl S, Yang Y. APC: Stata module for estimating age-period-cohort effects. 2006.
33. Kraus L, Möckl J, Manthey J, Rovira P, Olderbak S, Rehm J. Trends in alcohol-attributable morbidity and mortality in Germany from 2000 to 2021: a modelling study. Drug Alcohol Rev. 2024;43:1662–75.
34. Australian Institute of Health and Welfare. Apparent consumption of alcohol in Australia. Canberra, Australia: AIHW; 2023.
35. Australian Bureau of Statistics. Causes of death, Australia 2021. Canberra: ABS; 2022.
36. Australian Institute of Health and Welfare. Alcohol, tobacco & other drugs in Australia. Canberra, Australia: AIHW; 2022.
37. Holmes J, Angus C. Alcohol deaths rise sharply in England and Wales. BMJ. 2021;372:n607.
38. White AM, Castle IJP, Powell PA, Hingson RW, Koob GF. Alcohol-related deaths during the COVID-19 pandemic. JAMA. 2022;327:1704–6.
39. Miller M, Mojica-Perez Y, Callinan S, Livingston M. A timeline of alcohol-relevant restrictions during the COVID-19 pandemic. Melbourne: La Trobe University; 2022.
40. Keyes KM, Jager J, Mal-Sarkar T, Patrick ME, Rutherford C, Hasin D. Is there a recent epidemic of women's drinking? A critical review of national studies. Alcohol Clin Exp Res. 2019; 43:1344–59.
41. Luo L, Hodges JS. The age-period-cohort-interaction model for describing and investigating inter-cohort deviations and intra-cohort life-course dynamics. Sociol Methods Res. 2022;51: 1164–210.
42. Slade T, Chapman C, Swift W, Keyes K, Tonks Z, Teesson M. Birth cohort trends in the global epidemiology of alcohol use and alcohol-related harms in men and women: systematic review and metaregression. BMJ Open. 2016;6:e011827.

43. Livingston M, Callinan S, Dietze P, Stanesby O, Kuntsche E. Is there gender convergence in risky drinking when taking birth cohorts into account? Evidence from an Australian national survey 2001–13. Addiction. 2018;113:2019–28.
44. Office for Health Improvement and Disparities. Liver disease profiles: November 2021 update. London: UK Government; 2021.
45. Mellinger JL. Epidemiology of alcohol use and alcoholic liver disease. Clin Liver Dis (Hoboken). 2019;13:136–9.
46. Armstrong PR, Ring É, MacNicholas R. A decade of rising alcoholic liver disease hospital admissions and deaths in Irish hospitals, 2007–2016: a retrospective cross-sectional analysis. Eur J Gastroenterol Hepatol. 2022;34:671–7.
47. Sarraf B, Skoien R, Hartel G, O'Beirne J, Clark PJ, Collins L, et al. Rising hospital admissions for alcohol-related cirrhosis and the impact of sex and comorbidity – a data linkage study. Public Health. 2024;232:178–87.
48. Hayward KL, Johnson AL, Mckillen BJ, Burke NT, Bansal V, Horsfall LU, et al. ICD-10-AM codes for cirrhosis and related complications: key performance considerations for population and healthcare studies. BMJ Open Gastroenterol. 2020;7: e000485.
49. Manthey J, Jacobsen B, Kilian C, Kraus L, Reimer J, Schäfer I, et al. Alcohol-specific inpatient diagnoses in Germany: a retrospective cross-sectional analysis of primary and secondary diagnoses from 2012 to 2021. Addiction. 2024;119:2031–7.
50. Mahady SE, Adams LA. Burden of non-alcoholic fatty liver disease in Australia. J Gastroenterol Hepatol. 2018;33(Suppl 1):1–11.
51. Idalsoaga F, Kulkarni AV, Mousa OY, Arrese M, Arab JP. Non-alcoholic fatty liver disease and alcohol-related liver disease: two intertwined entities. Front Med (Lausanne). 2020; 7:448.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Livingston M, Gilmore W, Taylor N, Chikritzhs T, Yuen WS, Howell J, et al. Age, period and cohort trends in hospital admissions for alcohol-related liver disease in Australia, 1993–2020. Drug Alcohol Rev. 2025; 44(4):1254–63. https://doi.org/10.1111/dar.14063