






OPEN ACCESS

Burden of fatal drowning in California, 2005–2019

William Koon ^{1,2}, Orion Stewart,³ Robert Brander,¹ Linda Quan ⁴,
Amy E Peden ⁵

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/ip-2023-044862>).

¹School of Biological, Earth, and Environmental Sciences, University of New South Wales, Sydney, New South Wales, Australia

²California Water Safety Coalition, Huntington Beach, California, USA

³Center for Healthy Communities, Injury and Violence Prevention Branch, California Department of Public Health, Sacramento, California, USA

⁴Harborview Injury Prevention and Research Center, University of Washington, Seattle, Washington, USA

⁵School of Population Health, University of New South Wales, Sydney, New South Wales, Australia

Correspondence to

William Koon, School of Biological, Earth, and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia; w.koon@unsw.edu.au

Received 24 January 2023

Accepted 7 May 2023

Published Online First

19 May 2023



© Author(s) (or their employer(s)) 2023. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Koon W, Stewart O, Brander R, et al. *Inj Prev* 2023;**29**:371–377.

ABSTRACT

Objective To characterise risk factors for fatal drowning in California, USA to inform priorities for prevention, policy and research.

Methods This retrospective population-based epidemiological review of death certificate data evaluated fatal drowning events in California from 2005 to 2019. Unintentional, intentional, and undetermined drowning deaths and rates were described by person (age, sex, race) and context-based variables (region and body of water).

Results California's fatal drowning rate was 1.48 per 100 000 population (n=9237). Highest total fatal drowning rates occurred in the lower population density northern regions, among older adults (75–84 years: 2.54 per 100 000 population; 85+: 3.47 per 100 000 population) and non-Hispanic American Indian or Alaska Native persons (2.84 per 100 000 population). Male drowning deaths occurred at 2.7 times the rate of females; drowning deaths occurred mainly in swimming pools (27%), rivers/canals (22.4%) and coastal waters (20.2%). The intentional fatal drowning rate increased 89% during the study period.

Conclusions California's overall fatal drowning rate was similar to the rest of the USA but differed among subpopulations. These divergences from national data, along with regional differences in drowning population and context-related characteristics, underscore the need for state and regional level analyses to inform drowning prevention policy, programmes and research.

INTRODUCTION

Despite progress in reducing death rates and multi-sectoral collaborative action, drowning remains a major health challenge in the United States of America (USA) and globally, with an estimated annual fatal unintentional drowning toll of 4038 and 236 000, respectively.^{1–3} To promote continued action, the World Health Organization (WHO) recommended countries adopt national water safety plans as frameworks to advance multisectoral drowning prevention efforts,⁴ the United Nations General Assembly Resolution on Global Drowning Prevention reaffirmed this recommendation.⁵

Water safety plans should be informed by evidence,⁶ which can include fatal and non-fatal drowning data with location, demographics, activities and other characteristics that improve understanding of the drowning burden and aid the development of effective prevention strategies.⁷ In several countries, robust drowning research informs prevention initiatives prioritised for national, subnational and local populations (online supplemental file 1). Subnational drowning studies assist

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Drowning is a public health challenge requiring multisectoral prevention efforts. Previously identified risk factors include young children and males.

WHAT THIS STUDY ADDS

⇒ In California, the circumstances of drowning events, such as season, intent, body of water and populations affected, differed substantially by region. Traditional case inclusion criteria focusing only on unintentional underlying cause of death severely underestimates the fatal drowning burden.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Results from this study will help inform practitioners and policy-makers in the development of drowning prevention strategies, and prioritisation of populations and locations for drowning prevention research, interventions and policy/regulation. Findings also highlight major gaps and limitations in existing data sources and the need for regional or community-based surveillance and research.

in informing health interventions, policy/regulation and research.⁸ In the USA, recent studies have examined fatal and non-fatal drowning nationally,⁹ however, epidemiological drowning studies from the state level are rare,^{10 11} even though data exist for these regions.

California, the most populated state in the USA with nearly 40 million residents, has thousands of miles of ocean and inland lake coastline, nearly 200 000 miles of rivers, and over 1.34 million swimming pools (online supplemental file 1). Previous studies in the 1980s and 1990s identified characteristics of the California fatal drowning burden (online supplemental file 1), but we are not aware of subsequently published peer-reviewed studies specific to the state. The lack of recent and available in-depth analysis on drowning in California makes the size and scope of the burden unclear. The Centers for Disease Control and Prevention and the California Department of Public Health (CDPH) provide publicly accessible data related to drowning, but these surveillance tools were not designed for research¹² and do not include characteristics of the drowning burden that would be helpful for drowning prevention interventions, policy/regulation and research. The circumstances and details of drowning incidents required to guide

California's prevention efforts and policy are largely unknown and have not been the focus of systematic analysis.

This retrospective descriptive epidemiological study describes personal and context-based risk factors for fatal drowning in California between 2005 and 2019 to inform prevention strategies, help prioritise, adapt and implement recommendations for state and local water safety plans, and identify areas for future research.

METHODS

Death data were sourced from the California Comprehensive Death File (CCDF) and the US Department of Health and Human Services' Multiple Cause of Death dataset for the years 2005–2013, and the California Comprehensive Master Death File, which includes multiple cause fields, for the years 2014–2019. From these data sources, which include information provided by coroners/medical examiners and physicians, we identified cases where drowning related International Classification of Diseases, 10th Revision (ICD-10) codes were listed as either: (1) the underlying cause of death, the antecedent disease or injury that initiated events resulting in death or (2) a record axis multiple cause code, another condition which contributed to death. Drowning deaths were identified using ICD-10 codes W65, W66, W67, W68, W69, W70, W73, W74, T75.1, V90, V92, Y21, X71 and X92.¹³ We included X38, Victim of flood, cases only if another drowning-related ICD-10 code was listed as the underlying or a contributing record axis cause of death. We excluded drowning deaths of California residents that occurred outside the state. We used ICD-10 codes to categorise the intent as unintentional (W65–W74, V90, V92), intentional (X71, X92) or undetermined (Y21).

To overcome the limitations of ICD-10 codes,¹⁴ namely that all open bodies of water (eg, ocean, river, lake) are grouped together into a single 'Natural Water' classification,¹⁵ we determined the body of water from free-text fields describing the injury location on USA death certificates. We used an ordered, systematic classification process based on key words and ICD-10 codes, followed by manual review of selected cases (n=3406) where key words were conflicting or not present. Body of water was classified as: pool, river/canal, coastal, lake/pond, bathtub, other, unknown natural water or unknown. Body of water definitions and a description of the method used are available in online supplemental file 2.

We described the cohort with frequencies and percentages of deaths by person and context-based variables. We reported race and ethnicity, which are important considerations for drowning risk and prevention,¹⁶ using the CCDF/CCDMF 'multirace status' field which uses race fields on the death certificate to calculate a single race value for all individuals. Race and ethnicity were categorised as non-Hispanic American Indian or Alaska Native (AI/AN), non-Hispanic Black (Black), non-Hispanic Asian (Asian), non-Hispanic Hawaiian or Pacific Islander (H/PI), non-Hispanic White (White), non-Hispanic other (other), two or more races of any Hispanic status (multirace) and Hispanic.

We used the California Census Regions for region-related results, which combines the state's 58 counties into 10 regions. From the death certificate, we determined the decedent's residence region based on the zip code listed and the region of the drowning location based on injury location zip code or, when missing (16.4%), other parts of the injury location address (eg, street, city) and the free-text injury place and location description variables. In accordance with the California Health and Human Services Agency De-identification Guidelines, statistical

masking methods were used to suppress any table cell or value present in written text representing fewer than 11 individuals.

We calculated crude total, unintentional, intentional and undetermined drowning death rates per 100 000 California residents, and 95% CIs by age, sex, race, region and body of water using population estimates from the 2009, 2014 and 2019 American Community Surveys. We also calculated annual age-adjusted and sex-adjusted rates using the direct method and the 2000 US standard population. Non-residents were excluded from rates. Regional death rates were calculated based on the injury location when known; when injury location was unknown or could not be determined (6.6% of cases), we used the region where the death occurred. The impact of using the death region in this small number of cases was likely minimal; for decedents where both death and injury locations were known, 2.5% did not die in the same region as the drowning event. We conducted all analyses and created visualisations and maps using R Studio and Tableau Desktop. Death rates per 100 000 population were calculated using the tidycensus and epiR packages in R (Computer Software); the latter estimates 95% CIs for rates using Ullmann's method. References for datasets, methods and software are available in online supplemental file 1. Joinpoint regression (V4.7.0.0; National Cancer Institute) was used to describe trends and changes in trends in annual drowning death rates.

RESULTS

From 2005 to 2019, 9237 drowning deaths occurred in California, an average of 616 each year (SD=±52.8). Drowning person and context characteristics are presented in table 1 with additional variables available in online supplemental file 3. The total drowning rate (all intents) for California residents was 1.48 per 100 000 population (95% CI 1.45 to 1.51). Total unintentional and intentional crude fatal drowning rates per 100 000 population by 5-year time periods for age, sex, race, body of water and region are presented in online supplemental file 4.

Joinpoint regression results (online supplemental file 5) indicated the unintentional drowning rate decreased significantly from 2005 to 2011 (annual percent change: -4.3 (95% CI -1.1 to -7.4); p=0.013) and did not change significantly from 2011 to 2019 (p=0.08; online supplemental file 5). The intentional drowning rate did not change significantly from 2005 to 2007 (p=0.058), however, it increased by 5% per year from 2007 to 2019 (95% CI 3.7 to 6.3; p<0.001) (figure 1, online supplemental file 5). The total fatal drowning rate for males was 2.7 times that of females. AI/AN persons drowned at the highest rate (2.84 per 100 000 population) of any racial/ethnic group. Older adults (65–74 years: 2.0 per 100 000; 75–84 years: 2.54 per 100 000 population; 85+: 3.47 per 100 000 population) and children 0–4 years of age (2.36 per 100 000 population) drowned at higher rates than other ages (figure 2). Age-adjusted and sex-adjusted annual fatal drowning rates are presented in online supplemental file 6.

Drowning fatalities varied by region (figure 3). The North Coast region had the fewest deaths (table 1), but the highest rate (figure 2). The San Francisco Bay Area region had the most drowning deaths, 37.5% of which were intentional; the Los Angeles region had the highest number of unintentional drowning deaths (table 1). Most deaths (72.3%) occurred in the decedent's region of residence; 5.5% involved residents of other states or Canadian provinces. The majority (60.4%) of the 250 decedents who resided outside the USA drowned in the San Diego—Imperial region.

Table 1 Characteristics of fatal drowning in California, 2005–2019

	Unintentional		Intentional		Undetermined		All intents	
	n	%	n	%	n	%	n	%
Total	7624	100	1152	100	461	100	9237	100
Coding of drowning cause of death								
Underlying	6550	85.9	899	78	416	90.2	7865	85.1
Contributing	1074	14.1	253	22	45	9.8	1372	14.9
Age group								
0–4	856	11.2	48	4.2	26	5.6	930	10.1
5–14	320	4.2	12	1	12	2.6	344	3.7
15–24	980	12.9	173	15	49	10.6	1202	13
25–34	1020	13.4	197	17.1	69	15	1286	13.9
35–44	872	11.4	190	16.5	76	16.5	1138	12.3
45–54	1102	14.5	200	17.4	97	21.0	1399	15.1
55–64	967	12.7	170	14.8	62	13.4	1199	13
65–74	673	8.8	74	6.4	31	6.7	778	8.4
75–84	514	6.7	52	4.5	24	5.2	590	6.4
85+	291	3.8	*		*		336	3.6
Unknown	29	0.4	†		†		35	0.4
Sex								
Female	1917	25.1	433	37.6	121	26.2	2471	26.8
Male	5707	74.9	719	62.4	340	73.8	6766	73.2
Race								
White, non-Hispanic	3867	50.7	679	58.9	229	49.7	4775	51.7
Hispanic	2042	26.8	166	14.4	102	22.1	2310	25
Asian, non-Hispanic	830	10.9	176	15.3	59	12.8	1065	11.5
Black, non-Hispanic	561	7.4	75	6.5	44	9.5	680	7.4
Two or more races	189	2.5	33	2.9	20	4.3	242	2.6
AI/AN, non-Hispanic	72	0.9	†		†		77	0.8
Hawaiian/PI, non-Hispanic	24	0.3	†		†		31	0.3
Other, non-Hispanic	25	0.3	*		†		39	0.4
Non stated or unknown	14	0.2	†		†		18	0.2
Body of water								
Pool	2326	30.5	146	12.7	49	10.6	2521	27.3
River/canal	1839	24.1	113	9.8	117	25.4	2069	22.4
Coastal	1193	15.6	587	51	83	18	1863	20.2
Bathtub	843	11.1	119	10.3	56	12.1	1018	11
Lake/pond	851	11.2	60	5.2	30	6.5	941	10.2
Other	*		*		†		223	2.4
Unknown natural water	*		†		†		28	0.3
Unknown	351	4.6	104	9	119	25.8	574	6.2
Drowning event region								
North Coast	485	6.4	37	3.2	15	3.3	537	5.8
Superior California	955	12.5	72	6.3	78	16.9	1105	12
San Francisco Bay Area	785	10.3	432	37.5	111	24.1	1328	14.4
Central Coast	535	7	87	7.6	23	5	645	7
N.San Joaquin Valley	755	9.9	39	3.4	15	3.3	809	8.8
S.San Joaquin Valley	693	9.1	*		*		742	8
Los Angeles	1020	13.4	115	10	39	8.5	1174	12.7
Orange	501	6.6	69	6	23	5	593	6.4
Inland Empire	786	10.3	*		†		841	9.1
San Diego-Imperial	690	9.1	148	12.8	12	2.6	850	9.2
Unknown	419	5.5	68	5.9	126	27.3	613	6.6

*Values >11 not visible to protect the confidentiality of individuals summarised in the data.

†Values <11 not visible to protect the confidentiality of individuals summarised in the data.

AI, American Indian; AN, Alaskan Native; PI, Pacific Islander.

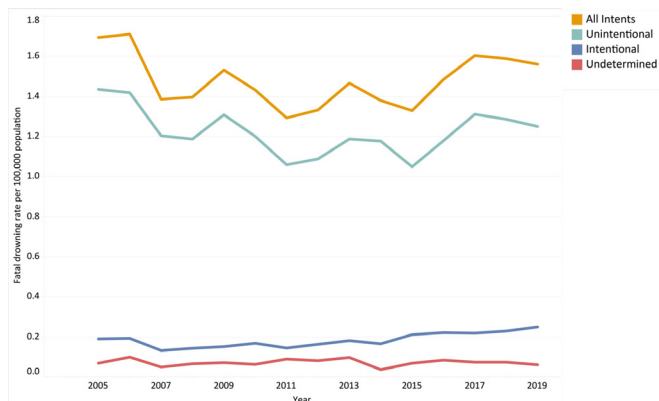


Figure 1

The underlying cause of death was listed as an unintentional drowning-related ICD-10 code (W65–W74, V90, V92) in 70.9%, intentional drowning-related ICD-10 codes (X71, X92) in 9.7%, and drowning of undetermined intent (Y21) in 4.5% of cases. Of the intentional drowning cases, 91.6% were due to self-harm and 8.4% were due to assault. In 14.9% of cases, drowning was listed as a contributing, not underlying, cause of death. Among these cases, the underlying cause of death ICD-10 codes in 43.0% were non-drowning transport accidents (V01–V99 excluding V90 and V92); 17.4% were non-drowning intentional self-harm (X60–X84, excluding X71); 13.2% were hypertensive, ischaemic, pulmonary and other forms of heart disease (I10–I152); 8.5% were accidental poisoning by exposure to noxious substances (X40–X49), and 4.0% were epilepsy (G40).

The location of death from drowning was an emergency room or outpatient facility in 22.1% of cases; an inpatient setting in 10.8%; the decedent’s home in 14.5%; a hospice, nursing home

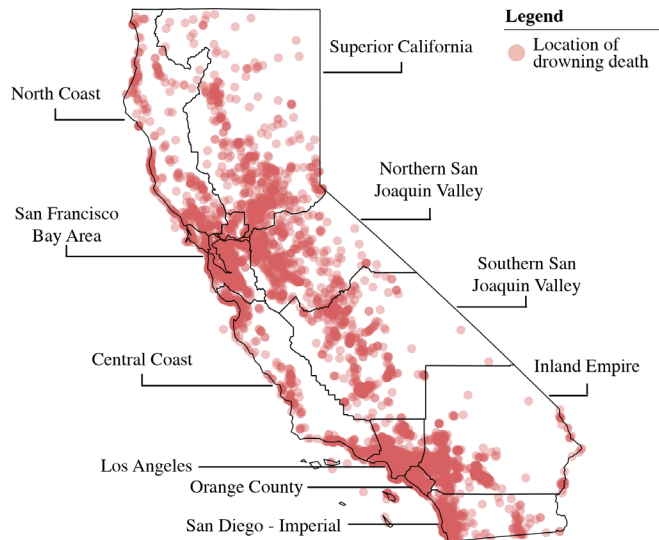


Figure 3

or other long-term care facility in 0.3%; and marked as ‘other’ in 51.8%, ‘dead on arrival’ in 0.3% and ‘unknown’ in 0.2%. The length of time between the drowning event and death was known in 80.4% of the cases; of these, 3 quarters (74.1%) occurred on the same day of the drowning event; 25.2% died between 1 and 89 days after the event, 0.4% died between 90 days and 1 year after the event, and 0.3% died more than 1 year after the event.

The most frequent body of water involved in fatal drowning varied by region. Pools were the most frequent location in Southern California (Inland Empire: 53.1%; Los Angeles: 46.1%; Orange County: 45.6%); rivers were the most frequent location in the Northern and Southern San Joaquin Valley (50.5% and 41.6%, respectively), Superior California (43.5%) and the North Coast (41.1%); and coastal bodies of water were most frequent in San Diego—Imperial (46.9%), the Central Coast region (46.9%) and San Francisco (41.1%) (figure 3).

Demographics varied by type of body of water. Pools were the most frequent body of water for drowning deaths among persons under 15 years and aged 65 years or older (0–4: 69.0%; 5–14: 43.9%, 65–74: 35.7%, 75–84: 45.1%, 85+: 49.4%); as well as for persons with race identified as other (33.3%), Asian (29.5%), Black (25.9%), multirace (29.8%) and White (26.9%). Rivers and canals were the most frequent body of water for persons aged 15–44 years (15–24: 36.8%, 25–34: 32.0%, 35–44 29.4%), Hispanic persons (33.7%) and AI/NA persons (57.1%). Coastal bodies of water were the most frequent drowning death location among persons aged 45–64 years (45–54: 28.1%, 55–64: 29.0%) and for H/PI persons (29.0%). Where drownings occurred varied by sex: females most frequently drowned in pools (32.6%), bathtubs (25.4%) and at coastal locations (14.3%); males most frequently in rivers/canals (25.6%), pools (25.4%) and coastal locations (22.3%).

The proportion of drowning deaths was highest during the summer months of June–August at lakes/ponds (50.5%), pools (47.6%) and rivers/canals (41.4%). Seasonality was less pronounced for bathtubs and coastal sites: June–August represented 24.8% of drowning deaths for bathtubs and 26.1% for the coast. Few (2%) unintentional drowning deaths (n=153) occurred while the decedent was working.

Variable	# of drowning deaths	Total cumulative fatal drowning rate per 100,000 population (95% CI), 2005–2019
Region		
California (State)	8,401	1.48 (1.45–1.51)
North Coast	527	3.70 (3.40–4.03)
Superior California	1,091	2.36 (2.22–2.50)
San Francisco Bay	1,326	1.32 (1.25–1.39)
Central Coast	637	1.87 (1.73–2.02)
N San Joaquin Valley	801	2.96 (2.75–3.17)
S San Joaquin Valley	746	2.08 (1.93–2.23)
Los Angeles	1,166	0.78 (0.74–0.83)
Orange County	555	1.20 (1.10–1.31)
Inland Empire	813	1.26 (1.17–1.35)
San Diego - Imperial	739	1.48 (1.37–1.59)
Age group		
0–4	905	2.36 (2.21–2.52)
5–14	314	0.41 (0.37–0.46)
15–24	1,035	1.28 (1.20–1.36)
25–34	1,109	1.32 (1.25–1.40)
35–44	1,009	1.28 (1.21–1.37)
45–54	1,276	1.66 (1.57–1.75)
55–64	1,108	1.76 (1.66–1.87)
65–74	735	1.89 (1.76–2.03)
75–84	559	2.54 (2.34–2.76)
85+	330	3.47 (3.10–3.86)
Sex		
Female	2,316	0.81 (0.78–0.85)
Male	6,085	2.15 (2.10–2.21)
Race		
AI/AN	64	2.84 (2.18–3.62)
Asian	980	1.30 (1.22–1.38)
Black or AA	620	1.91 (1.76–2.06)
HN/PI	29	1.45 (0.97–2.08)
Hispanic	2,094	0.97 (0.93–1.02)
Multi-race	228	1.52 (1.33–1.73)
Other race	35	2.27 (1.58–3.15)
White	4,340	1.93 (1.87–1.99)
Body of water		
Bathtub	986	0.17 (0.16–0.18)
Coastal	1,608	0.28 (0.27–0.30)
Lake/Pond	871	0.15 (0.14–0.16)
Pool	2,377	0.42 (0.40–0.44)
River/Canal	1,801	0.32 (0.30–0.33)
Unknown/Other	758	0.13 (0.12–0.14)

Figure 2 AI/AN, American Indian or Alaska Native; HN/PI, Hawaiian or Pacific Islander.

DISCUSSION

This evaluation of 9237 death certificates is the first in over two decades to describe drowning fatalities in California, the most populated state in the USA. These data demonstrate the complexity of drowning injury, with substantial differences by intent, region, age, body of water and race throughout this large and diverse state; and the need for local level analyses to guide drowning prevention interventions. Importantly, it shows that drowning rates are not meaningfully decreasing and highlights major gaps in drowning data. Fulfilling important recommendations by the WHO,⁶ this work provides an evidence base for state and local decision makers to prioritise prevention activities, underscores the need for dedicated research into several specific domains and highlights the need for both statewide and local public health intervention.

While California's total fatal drowning rate was comparable to the crude total fatal drowning rate for the rest of the country (1.48 vs 1.50 per 100 000 population),¹⁷ key differences exist. Of note, total fatal drowning rates in California were lower than the rest of the country for persons aged 0–44 (0–4: 2.36 vs 2.55; 5–14: 0.42 vs 0.65; 15–24: 1.28 vs 1.61; 25–34: 1.32 vs 1.45; 35–44: 1.28 vs 1.42 per 100 000 population); males (2.15 vs 2.35 per 100 000 population); and for persons identified as Hispanic (0.98 vs 1.17).¹⁷ Moreover, total fatal drowning rates in California were higher than the rest of the country for persons 55 and older (55–64: 1.76 vs 1.56; 65–74: 1.89 vs 1.56; 75–84: 2.54 vs 1.81; 85+3.47 vs 1.83 per 100 000 population) and White persons (1.93 vs 1.49 per 100 000 population).¹⁷

Despite expanded lifeguard and rescue services, updated drowning prevention legislation and education efforts by government and communities, California's total fatal drowning rates did not continuously decrease between 2005 and 2019, mirroring trends observed in the rest of the country during the same time period.¹⁷ However, important reductions were seen in specific demographics, such as children aged 0–4 years, and in certain regions like the Northern San Joaquin Valley (online supplemental file 4). In contrast, there were increases in other aspects, such as intentional and coastal drowning, which require further research focus and attention from prevention practitioners.

Drowning deaths of intentional intent comprised an important proportion of the problem, 12.5% in California, but have not been a focus of drowning research in the USA.¹⁸ Intentional fatal drowning rates also increased during the study period, as did overall suicide rates in California and the USA,¹⁷ underscoring the need for increased attention. Other countries, such as Ireland, have investigated suicidal drowning and engaged in prevention activities informed by their data.¹⁹ Following their lead, drowning prevention practitioners and researchers should adopt a more inclusive problem definition that addresses intentional drowning, partnering with the suicide prevention community to conduct research and promote evidence-based prevention strategies. Barriers, for example, are highly effective at preventing suicides by jumps from high places,²⁰ including those from bridges over water that may end in a drowning fatality. Installation of suicide barriers on the Golden Gate Bridge is estimated to save 14 lives per year.²¹

This analysis showed the highest total fatal drowning rates in California were among those aged 75 and older, followed by children under 5, then middle-aged individuals aged 45–74. Older adults have not historically been a priority population for drowning prevention researchers and practitioners. However, older adults in California are drowning at higher rates than the

rest of the USA and, in contrast with national trends,¹⁷ have higher fatal drowning rates than adolescents and young adults aged 15–24. Understanding why fatal drowning rates in this population are higher in California compared to the rest of the nation is a major research priority. Clemens *et al* recently described drowning among older adults as a 'growing epidemic' in other high-income countries, calling for further research exploring the contribution of medical conditions and medication use to drowning in this population and the embedding of drowning prevention into healthy ageing agendas.²² Data in the current study also identify the need to prioritise prevention efforts for adults aged 45–74 years in California. Encouragingly, California's fatal drowning rates for children 0–4 decreased during the study period (online supplemental file 4) and were lower than 0–4 drowning rates for the rest of the country.¹⁷ Further work is required to evaluate if these decreases were the result of the drowning prevention sector's decades of focus on children, including statewide legislation and community education.²³

In this analysis of data from a racially and ethnically diverse state, racial disparities in fatal drowning rates were not as pronounced in California as in other parts of the country.¹⁷ Fatal drowning rates among Black and White persons were nearly the same in California, a trend also observed in Florida,¹¹ but not nationally.^{17,24} The highest fatal drowning rates were among AI/AN persons, 1.5 times that of White persons in California. Indigenous populations have also been identified as high risk for fatal drowning in Australia, New Zealand and Canada as well the USA as a whole.^{24,25} Prior research in North America suggests this may be due to differences in exposure (greater use of natural bodies of water) and behaviour (lower rates of life jacket use, higher rates of alcohol involvement),²⁶ which may be downstream effects of cultural heritage, systematic inequities and Eurocentric aquatic programmes.^{27,28} Culturally responsive prevention practices show promise²⁹ and should be designed and led by the communities they intend to serve. Race and ethnicity are one dimension of a complex system of determinants of health that influence risk for drowning.¹⁶ Future research seeking to identify and characterise drowning risks should also consider language, culture, socioeconomic factors and residency/migration status to better understand, characterise and address drowning inequities in California.

The circumstances of drowning events, such as season, body of water and populations affected, including age group and race, differed substantially by region. Existing drowning prevention efforts in California have focused on urban population centres in the southern part of the state,²³ although the highest drowning rates were in the northern and central parts of California where population density is lower. The higher risk for drowning in remote populations in other locations underscore the need for future efforts to address this challenge in California's rural areas.³⁰

This study also contributes new insights into the bodies of water where people drown in California by providing more specific categories than are available from ICD-10 codes. While swimming pools were the location with the highest number of deaths and have been the primary drowning prevention focus for decades,²³ this study showed that California must also focus on its rivers, canals, and coastal bodies of water to address adolescent and adult drowning fatalities. Australia's recent research focus on rivers as major drowning sites prompted increased intervention efforts, a potential model for understanding and preventing these deaths in California.³¹

Despite the presence of robust ocean lifeguard and marine safety services along hundreds of miles of coast, the specific

circumstances leading to coastal drowning in California remain unclear. A recent scoping review identified risk factors for coastal drowning including physical features of the coastal environment, dynamic ocean and weather conditions, and individual factors such as sociodemographic characteristics, behaviours and ocean experience.¹⁵ While findings from other locations provide potential explanations for the high frequency of coastal deaths observed in this study, further investigation is needed, especially given the diverse beach types, usage patterns and rescue services along the California coast. Future research should aim to distinguish between types of bodies of water (eg, lifeguarded vs unlife-guarded beaches) and evaluate regional differences within these categories (eg, coastal drowning in northern vs southern California). More broadly, additional information is needed about specific populations at risk in different bodies of water, coastal and other. Recognising variations in population characteristics and regional drowning trends among different bodies of water carries significant implications for public health policy and education programmes. Gaining insight into these differences is crucial for effectively reducing the occurrence and impact of drowning incidents in the state.

Strengths and limitations

A major strength of this paper was the large number of cases analysed, due in part to the state's population, a 15-year study period, and broad inclusion criterion that incorporated all intents and cases where drowning was either the underlying or a contributing cause of death. The extended study period showed the importance of assessing long-term trends. The expanded problem definition identified the size of the burden of intentional drowning and the need to include cases where drowning was a contributing, not underlying, cause of death. The traditional use of unintentional underlying cause of death only would have missed approximately 30% of California's fatal drowning burden. Cases where a non-drowning cause of death code was listed as the underlying cause warrant further investigation; understanding trends in these deaths by age, sex, ethnicity, body of water and other variables will be useful to inform prioritised prevention activities.

This study was limited by reliance on death certificate data. First, race categories do not capture the variation of how individuals identify themselves and may be subject to misclassification depending on who completes the death certificate and the availability of an informant. While the multirace status field used in this study is helpful for research, it simplifies complexities of race and ethnicity and is prone to mismatch between death data numerators and population data denominators. Identification of body of water categories beyond what was available from cause of death codes was an additional strength of the study, but was time-consuming and potentially subject to misclassification. Knowing the exact location of the drowning event would remove some limitations and allow identification of drowning 'hotspots' within a very specific geographical area. Death certificate data did not provide consistent information on what the person was doing before the drowning event (eg, swimming, boating, surfing), which would help inform prevention efforts.³² The forthcoming ICD-11 may address some of these challenges,³³ but data limitations and barriers to timely research and surveillance require other solutions.

Differences in crude fatal drowning rates may be influenced by the underlying age and sex distribution of the population or within subgroups. However, the higher male drowning rates compared with female drowning rates is consistent with other

regions.¹ In keeping with the original goal of this research to inform prevention efforts and be of use to practitioners and policy-makers, we chose to present crude fatal drowning rates as they are easier to interpret, reflect the actual burden among populations in California and did not differ greatly from the annual age-adjusted and sex-adjusted rates provided in online supplemental file 6. Research providing more direct comparison with age-adjusted and sex-adjusted rates would provide further insight to differences between populations, regions and time periods.

This study excluded the non-fatal component of the drowning problem; publicly available CDPH data indicate as many as three non-fatal hospital or emergency department visits occur per fatality.³⁴ Lacking data from lifeguards, prehospital emergency medical systems and hospitals, this study's ability to inform policy and programme development was limited. A funded fatal and non-fatal drowning registry, as in Australia or the UK,^{35 36} would allow for timely analysis, more robust research and the ability to evaluate several of the gaps identified in this paper.

CONCLUSION

This investigation of fatal drowning in California showed that state and regional level analyses are important for informing drowning prevention policy and prevention activities. In many ways, California does not fit national USA drowning trends and regions within California showed significant variation in person and context-related characteristics. This study identified several gaps in existing datasets; an improved drowning surveillance system is a critical next step with the addition of more detailed relevant variables, use of text-searching techniques of multiple data sources to find information and mapping of drowning sites to guide analysis. While further evaluation of drowning is needed at a regional level within the state, identification of commonalities among regions would promote efficiency and implementation of prevention measures, including policy solutions. The complexity and diversity of drowning in California evidenced in these findings justifies strong collaboration between multisectoral drowning prevention partners in the state.

Correction notice This article has been corrected since it first published. The open access licence type has been changed to CC-BY-NC on 17/07/2023.

Acknowledgements The authors would like to acknowledge Lea Uebelhoefer from the UNSW Beach Safety Research Group for her assistance in data processing, and Dr. Tessa Clemens and Briana Moreland from the Centres for Disease Control and Prevention for their assistance with analysis and data interpretation.

Contributors WK led study conceptualisation with input from AEP and LQ. WK conducted data analysis with input from OS and AEP. WK drafted the manuscript with input from OS, RB, LQ and AEP. All authors were involved in subsequent edits and revisions, and approved the submitted version. WK is responsible for the overall content as gaurantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Disclaimer The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views or opinions of the California Department of Public Health or the California Health and Human Services Agency.

Competing interests WK is a board member of the California Water Safety Coalition.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The CDPH (Order Number 21-03-0139) approved the study; the California Committee for the Protection of Human Subjects (Project Number 2021-077) provided ethics approval.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. Supporting data are not available due to ethical/legal restrictions.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

William Koon <http://orcid.org/0000-0003-4708-4347>

Linda Quan <http://orcid.org/0000-0001-7224-9604>

Amy E Peden <http://orcid.org/0000-0002-6424-1511>

REFERENCES

- Franklin RC, Peden AE, Hamilton EB, *et al*. The burden of unintentional drowning: global, regional and national estimates of mortality from the Global Burden of Disease 2017 study. *Inj Prev* 2020;26:183–95.
- Baldwin G, Gilchrist J, Noonan R. The burden of drowning: Issues in selected countries - the United States. In: Bierens J, ed. *Drowning prevention, rescue, treatment*. New York, 2014: 99–100.
- Meddings DR, Scarr J-P, Larson K, *et al*. Drowning prevention: turning the tide on a leading killer. *Lancet Public Health* 2021;6:e692–5.
- World Health Organization. *Global report on drowning: preventing a leading killer*. Geneva, Switzerland: World Health Organization, 2014. Available: <https://www.who.int/publications/i/item/global-report-on-drowning-preventing-a-leading-killer>
- United Nations General Assembly. Resolution on global drowning prevention (A/RES/75/273). 2021. Available: <https://documents-dds-ny.un.org/doc/UNDOC/GEN/N21/106/27/PDF/N2110627.pdf?OpenElement> [Accessed 4 Feb 2022].
- World Health Organization. *Preventing drowning: an implementation guide*. Geneva, Switzerland: World Health Organization, 2017. Available: <https://www.who.int/publications/i/item/preventing-drowning-an-implementation-guide>
- McClure R, Stevenson M, McEvoy S. Intervention development: Introduction. In: McClure R, Stevenson M, McEvoy S, eds. *The scientific basis of injury prevention and control*. Melbourne: IP Communications, 2014: 175–201.
- Jagnoor J, Kobusingye O, Scarr JP. Drowning prevention: Priorities to accelerate Multisectoral action. *Lancet* 2021;398:564–6.
- Theodorou CM, Rajasekar G, McFadden NR, *et al*. Epidemiology of Paediatric drowning Hospitalisations in the USA: A population-based study. *Inj Prev* 2022;28:148–55.
- Girela-López E, Beltran-Aroca CM, Dye A, *et al*. Epidemiology and autopsy findings of 500 drowning deaths. *Forensic Sci Int* 2022;330:111137.
- Gorsuch MM, Myers SL, Lai Y, *et al*. Vanishing racial disparities in drowning in Florida. *Inj Prev* 2019;25:487–93.
- Ballesteros MF, Webb K, McClure RJ. A review of CDC's web-based injury Statistics query and reporting system (WISQARSTM): Planning for the future of injury surveillance. *J Safety Res* 2017;61:211–5.
- Peden AE, Mahony AJ, Barnsley PD, *et al*. Understanding the full burden of drowning: a retrospective, cross-sectional analysis of fatal and non-fatal drowning in Australia. *BMJ Open* 2018;8:e024868.
- Branche C, van Beeck E. The epidemiology of drowning: summary and recommendations. In: Bierens J, ed. *Drowning*. Springer, 2014: 81–3.
- Koon W, Peden A, Lawes JC, *et al*. Coastal drowning: a scoping review of burden, risk factors, and prevention strategies. *PLoS One* 2021;16:e0246034.
- Quan L. Risk factors for drowning: culture and ethnicity. In: Bierens J, ed. *Drowning: prevention, rescue treatment*. 2nd ed. Berlin; New York: Springer, 2014: 127–30.
- Centers for Disease Control and Prevention, National Center for Health Statistics. Multiple cause of death, 1999-2020 on CDC WONDER online database. 2021. Available: <http://wonder.cdc.gov/mcd-icd10.html> [Accessed 5 Feb 2022].
- Ryan KM, Dugas J, Pina T, *et al*. Drowning injuries in the United States: patient characteristics, mortality risk, and associated primary diagnoses. *Injury* 2020;51:2560–4.
- Lunetta P, Connolly J. Risk factors for drowning: suicidal drowning. In: *Drowning*. Berlin Heidelberg: Springer, 2014: 131–4.
- World Health Organization. *Live life: an implementation guide for suicide prevention in countries*. Geneva, Switzerland: World Health Organization, 2021. Available: <https://www.who.int/publications/i/item/9789240026629>
- Atkins Whitmer D, Woods DL. Analysis of the cost effectiveness of a suicide barrier on the golden gate bridge. *Crisis* 2013;34:98–106.
- Clemens T, Peden AE, Franklin RC. Exploring a hidden epidemic: drowning among adults aged 65 years and older. *J Aging Health* 2021;33:828–37.
- Barnes M, Inganamort M. California water safety: lessons and landscape. California water safety coalition workshop. 2021. Available: <https://www.cawatersafety.org/workshop21> [Accessed 4 Feb 2022].
- Clemens T, Moreland B, Lee R. Persistent racial/ethnic disparities in fatal unintentional drowning rates among persons aged ≤ 29 years — United States, 1999–2019. *MMWR Morb Mortal Wkly Rep* 2021;70:869–74.
- Peden AE, Franklin RC, Clemens T. Exploring the burden of fatal drowning and data characteristics in three high income countries: Australia, Canada and New Zealand. *BMC Public Health* 2019;19:794.
- Strayer HD, Lucas DL, Hull-Jilly DC, *et al*. Drowning in Alaska: progress and persistent problems. *Int J Circumpolar Health* 2010;69:253–64.
- Giles AR, Brooks Cleator L, McGuire-Adams T, *et al*. Drowning in the social determinants of health: understanding policy's role in high rates of drowning in aboriginal communities in Canada. *Aps* 2014;3:198–213.
- Willcox-Pidgeon SM, Franklin RC, Leggat PA, *et al*. Identifying a gap in drowning prevention: high-risk populations. *Inj Prev* 2020;26:279–88.
- Crozier M, Giles AR. Promising practices for boating safety initiatives that target indigenous peoples in New Zealand, Australia, the United States of America, and Canada. *IJARE* 2020;12.
- Spencer MR, Hedegaard H, Warner M. Unintentional drowning deaths among children aged 0-17 years: United States, 1999-2019. *NCHS Data Brief* 2021:1–8.
- Peden AE, Franklin RC, Leggat PA. Developing drowning prevention strategies for rivers through the use of a modified delphi process. *Inj Prev* 2020;26:240–7.
- Idris AH, Bierens JLM, Perkins GD, *et al*. Revised Utstein-style recommended guidelines for uniform reporting of data from drowning-related resuscitation: an ILCOR advisory statement. *Resuscitation* 2017;118:147–58.
- World Health Organization (WHO). ICD-11 for mortality and morbidity statistics. 2018. Available: <https://icd.who.int/browse11/l-m/en> [Accessed 4 Feb 2022].
- California Department of Public Health (CDPH). Epi center California injury data online. injury and violence prevention branch, California Department of public Health (producer). 2020. Available: <https://epicenter.cdph.ca.gov/>
- Hills SP, Hobbs M, Tipton MJ, *et al*. The water incident database (WAID) 2012 to 2019: a systematic evaluation of the documenting of UK Drownings. *BMC Public Health* 2021;21:1760.
- Peden AE, Scarr J-P, Mahony AJ. Analysis of fatal Unintentional drowning in Australia 2008-2020: implications for the Australian water safety strategy. *Aust N Z J Public Health* 2021;45:248–54.