A case–control study of boat-related injuries and fatalities in Washington State

Sarah Stempski,[1] Melissa Schiff,[2,3] Elizabeth Bennett,[4] Linda Quan[5,6]

[1]Department of Health Education, Seattle Children's Hospital, Seattle, Washington, USA
[2]Department of Epidemiology, School of Public Health, University of Washington, Seattle, Washington, USA
[3]Harborview Injury Prevention and Research Center, Seattle, Washington, USA
[4]Department of External Affairs and Guest Services, Seattle Children's Hospital, Seattle, Washington, USA
[5]Department of Pediatrics, University of Washington School of Medicine, Harborview Injury Prevention and Research Center, Seattle, Washington, USA
[6]Department of Emergency Medicine, Seattle Children's Hospital, Seattle, Washington, USA

Correspondence to
Sarah Stempski, Department of Health Education, Seattle Children's Hospital, 4800 Sand Point Way NE, M/S T5112, Seattle, WA 98105, USA; sarah.stempski@seattlechildrens.org

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ABSTRACT

Objectives To identify risk factors associated with boat-related injuries and deaths.

Methods We performed a case–control study using the Washington Boat Accident Investigation Report Database for 2003–2010. Cases were fatally injured boat occupants, and controls were non-fatally injured boat occupants involved in a boating incident. We evaluated the association between victim, boat and incident factors and risk of death using Poisson regression to estimate RRs and 95% CIs.

Results Of 968 injured boaters, 26% died. Fatalities were 2.6 times more likely to not be wearing a personal flotation device (PFD) and 2.2 times more likely to not have any safety features on their boat compared with those who survived. Boating fatalities were more likely to be in a non-motorised boat, to have alcohol involved in the incident, to be in an incident that involved capsizing, sinking, flooding or swamping, and to involve a person leaving the boat voluntarily, being ejected or falling than those who survived.

Conclusions Increasing PFD use, safety features on the boat and alcohol non-use are key strategies and non-motorised boaters are key target populations to prevent boating deaths.

BACKGROUND

More than 80 million people in the USA participated in recreational boating in 2011.[1] Boating presents a unique injury setting as boaters are subject to the normal risks of land-based activities, including falls, burns and cuts, but are also at additional risk from asphyxia, submersion and hypothermia.[2] In 2012, the US Coast Guard reported 4515 recreational boating incidents that involved 651 deaths, 3000 injuries and approximately $38 million of damage to property.[3] In the USA and Canada, the number of transportation fatalities from recreational boating rank only second to motor vehicles compared with other modes of transportation.[4] Furthermore, boating injury is a global problem and is not limited to industrialised countries.[5–7]

Prior reports on boating in the USA have evaluated risk factors for fatalities, including demographic, boat and operator characteristics. These prior fatality studies have found alcohol,[8] personal flotation device (PFD) use,[9] operator inexperience[10] and non-motor boats associated with increased risk of death. However, much of the literature on boating injury is descriptive without a comparison group, evaluates a single risk factor[8 9] or evaluates data from 20 years ago.[10] In light of the lack of data, our study examined the victim (boater), boat and incident-level risk factors associated with fatalities among boating-related incidents reported to the Washington State Boating Accident Investigation Report Database (WA BAIRD).

METHODS

We conducted a case–control study of risk factors associated with boating-related deaths using WA BAIRD for the calendar years 2003–2010 to answer the research question, among people injured in boating incidents, what factors increase the chances of being fatally injured? The WA BAIRD dataset contains boating incidents resulting in death or injury in Washington State submitted to the Washington State Parks and Recreation Commission (WSPRC) by city or county government law enforcement agencies, resulting in death or injury requiring treatment beyond first aid.[11] A case was defined as a boat occupant that died from a boating-related injury and a control as a boat occupant that was injured but survived the incident. For each fatality in the WA BAIRD from 2003 to 2010, there were approximately three injured survivors to serve as controls. Our study setting included all Washington State bodies of water, including lakes, rivers, canals, the Puget Sound and the Pacific Ocean. We evaluated all victims of boating-related injuries from the WA BAIRD from 2003 to 2010. Study subjects included all ages involved in a boating incident during the study time period. This study was approved by the Washington State Department of Health Institutional Review Board.

The WA BAIRD dataset contains variables that we assessed as risk factors at three levels: victim-level, boat-level and incident-level. Victim-level risk factors were age, sex and PFD use. Boat-level risk factors included safety features on boat and boat type. Incident-level risk factors included alcohol involvement, type of body of water, time of day and incident type. Although some of our injured and fatally injured boaters may have been on the same boat, we did not have information linking individuals to specific boats.

Variables were defined and operationalised based on the categories on the Washington Boat Accident Report form[11] and the US Coast Guard Recreational Boating Statistics report.[3] Continuous variables were categorised for contextual relevance, consistency with categorisation used in other water recreation literature[8–10] and with input from the WSPRC. Among victim-level variables, age was categorised in years as under 13, 13–19, 20–29, 30–39, 40–49 and 50 and over. Sex was categorised as female or male. PFD use was categorised as yes or no.

Among boat-level variables, operator age was categorised in years as under 19, 20–29, 30–39, 40–49 and 50 and over. Operator sex was categorised as female or male. Boat type was categorised as powerboat, human-powered (non-motorised boats with paddles, such as kayaks, canoes, row boats, stand-up paddle boards, sailboats and rafts), personal water craft and other (drift boat, houseboat, inflatable, inner tube, paddle boat, raft, rigid hull inflatable and rowing shell). We evaluated the risk factors included in our final model stratified by boat type (power boats vs all other boat types) and found no differences in the magnitude or direction of the risk ratios by boat type. Safety features on the boat were categorised as present if any one or more of the following items were noted in the BAIRD: (1) safety lanyard/kill switch, (2) fire extinguisher on board, (3) PFDs or (4) a safety check/inspection sticker verifying the presence of required safety equipment, and absent if none of those features were noted. Safety checks are inspections by water marine patrols on all types of boats. Safety checks primarily entail inspection for equipment carriage requirements, which vary depending on the type of boat. These items include Boater Education Card, sound producing device, navigation lights, proper registration display and documents, ventilation, backfire arrestor, among others.

Among incident-level variables, alcohol was classified as present if any one or more of the following alcohol variables were noted in the BAIRD: (1) alcohol use apparent in the individual who was injured or killed, (2) blood alcohol content (BAC) of greater than zero of the person injured or killed, (3) alcohol on board boat, (4) alcohol taken by passenger(s) on boat, (5) alcohol was involved in boat incident, (6) BAC of greater than zero of the operator, (7) operator arrested for boating under the influence (BUI) and (8) alcohol involved in the incident. Alcohol was classified as absent if none of the above variables was noted in the BAIRD. Water conditions were categorised using the following categories prescribed by the US Coast Guard for all states' boating incident reports wherein individuals observe and estimate the water conditions and wave height: up to 6 inch waves (calm), over 6 inch up to 2 foot waves (choppy), over 2 foot up to 6 foot waves (rough), over 6 foot waves (very rough) and strong/swift current. Type of body of water was categorised as lake, sound, river/dam/cut, strait or ocean. Time of day was categorised as 6:00–11:59, 12:00—17:59, 18:00–23:59 or 00:00–5:59 Incident type was categorised as collision, capsizing/sinking/flooding/swamping, person leaves boat voluntarily/person ejected/person falls overboard or other (fire/explosion, carbon monoxide poisoning, hull failure, line entanglement, dam related, whitewater, swimmer, fall in boat, grounding, struck by boat/propeller, tow sport).

To obtain additional information from Washington State Vital Records, cases from the WA BAIRD were linked to the Washington State Death Certificates and the Washington State Comprehensive Hospitalization Abstract Reporting System (CHARS) for 2003–2009. Data from 2010 were not available at the time of analysis. We linked the WA BAIRD cases to the death certificates using name, birth date, sex and date of death. We linked the WA BAIRD to CHARS using name, birth date, sex and date of injury.

Because the BAIRD had a significant amount of missing data (eg, victim age was missing 3.5% among fatalities and 10.2% among injured; any safety features on boat were missing 17.9% among fatalities and 8.1% among injuries), we used multivariate imputation by chained equations 39 as implemented in Stata to impute 10 datasets.

We compared victim-level, boat-level and incident-level risk factors for deaths and injured survivors. We performed univariate analysis of each risk factor using Poisson regression modelling with robust variance estimator to estimate RR and 95% CIs. Poisson regression was used because fatal outcome was not rare. We performed multivariable analysis controlling for victim age and victim sex. Variables were included in the multivariate model if they were significant in univariate analysis. Because some boating incidents involved more than one vessel, we accounted for clustering in our regression models. The analysis was performed using Stata statistical software V.11 (StataCorp, College Station, TX).

RESULTS

We evaluated 968 victims of boating-related injuries from the WA BAIRD from 2003 to 2010, of which 249 (26%) persons died and 719 survived. Among people injured in boating incidents, not wearing a PFD, not having safety features present, being on a human-powered boat, having alcohol present, boating on the ocean, boating between the hours of 00:00 and 5:59, incidents that involved capsizing, sinking, flooding or swamping, and incidents that involve a person leaving the boat voluntarily, ejected or fall increase the chances of being fatally injured.

Of the individual victim risk factors evaluated, fatalities were more likely to be 50 years of age or older (34% vs 16%), male (83% vs 64%) and not wearing a PFD (77% vs 42%) compared with injured survivors (table 1).

Of the boat-level risk factors evaluated, fatalities were more likely to be in a human-powered boat (29% vs 6%) with no safety features (35% vs 9%) and have an operator 50 years of age or older (35% vs 19%) compared with injured survivors (table 2).

Of the incident-level variables evaluated, fatalities were more likely to be in an incident that involved alcohol (41% vs 25%) on rough or very rough water (16% vs 8%) in which the boat capsized, sunk or flooded (49% vs 31%) (table 3). Alcohol was involved most often in incidents that occurred between midnight at 5:59 (57%), and increased over the day (9% from 6:00 to 11:59, 19% from 12:00 to 17:59 and 43% from 18:00 to 23:59).

Table 1 Comparison of victim-level variables among boating-related deaths and injured survivors in Washington State 2003–2010

	Fatalities (N=249) Number (%)	Injured survivors (N=719) Number (%)
Age (years)		
0–12	11 (4)	65 (9)
13–19	21 (9)	144 (20)
20–29	41 (17)	173 (24)
30–39	44 (18)	127 (18)
40–49	46 (18)	92 (13)
50+	86 (34)	118 (16)
Sex		
Female	41 (17)	255 (36)
Male	208 (83)	464 (64)
Personal floatation device worn		
Yes	58 (23)	415 (58)
No	191 (77)	304 (42)

Table 2 Comparison of boat-level variables among boating-related deaths and injured survivors in Washington State 2003–2010

	Fatalities N=249 Number (%)	Injured survivors N=719 Number (%)
Operator age (years)		
0–19	19 (7)	125 (17)
20–29	41 (17)	138 (19)
30–39	44 (18)	185 (26)
40–49	57 (23)	136 (19)
50+	88 (35)	135 (19)
Operator sex		
Female	17 (7)	107 (15)
Male	232 (93)	612 (85)
Boat type		
Powerboat	116 (47)	413 (58)
Human-powered boat*	73 (29)	41 (6)
Personal water craft	14 (6)	192 (26)
Other†	46 (18)	73 (10)
Any safety features on boat‡		
Yes	163 (65)	657 (91)
No	86 (35)	62 (9)

*Human-powered boat refers to kayaks, canoes, row boats, stand up paddle boards, sailboats and rafts.
†Other boat type includes drift boat, houseboat, inflatable, inner tube, paddle boat, raft, rigid hull inflatable and rowing shell.
‡Any safety features on boat were categorised as present if any one or more of the following safety features were noted in the BAIRD: (1) safety lanyard/kill switch, (2) safety check, (3) fire extinguisher on board or (4) boat equipped with PFDs and absent if none of those features were noted.
BAIRD, Boating Accident Investigation Report Database; PFD, personal flotation device.

Table 3 Comparison of incident-level variables among boating-related deaths and injured survivors in Washington State 2003–2010

	Fatalities N=249 Number (%)	Injured survivors N=719 Number (%)
Any alcohol involved*		
No	146 (59)	542 (75)
Yes	103 (41)	177 (25)
Water conditions†		
Calm	117 (47)	453 (63)
Choppy	63 (25)	175 (24)
Rough/very rough	39 (16)	55 (8)
Strong/swift	30 (12)	36 (5)
Body of water		
Lake	85 (34)	383 (53)
Sound	29 (12)	104 (14)
River/dam/cut	90 (36)	205 (29)
Strait	34 (14)	21 (3)
Ocean	11 (4)	6 (1)
Time of day		
6:00–11:59	34 (14)	90 (13)
12:00–17:59	100 (40)	374 (52)
18:00–23:59	70 (28)	213 (29)
00:00–5:59	45 (18)	42 (6)
Incident type		
Collision	21 (8)	283 (39)
Capsizing, sinking, flooding, swamping	122 (49)	156 (22)
Person leaves vessel (ejected fall overboard, voluntarily)	71 (29)	61 (8)
Other‡	35 (14)	219 (31)

*Any alcohol was classified as present if any one or more of the following alcohol variables were noted in the BAIRD: (1) alcohol use apparent in the individual who was injured or killed, (2) blood alcohol content (BAC) of the person injured or killed, (3) alcohol onboard boat, (4) alcohol taken by passenger(s) on boat, (5) alcohol was involved in boat incident, (6) operator BAC, (7) operator arrested for boating under the influence (BUI) and (8) alcohol involved in the incident. Alcohol was classified as absent if none of the above variables was noted in the BAIRD.
†Water conditions were categorised as calm (up to 6 inch waves), choppy (over 6 inch up to 2 foot waves), rough/very rough (over 2 foot up to 6 foot waves or over 6 foot waves) and strong/swift current.
‡Other incident type includes fire/explosion, carbon monoxide poisoning, hull failure, line entanglement, dam related, whitewater, swimmer, fall in boat, grounding, struck by boat/propeller and tow sport.
BAIRD, Boating Accident Investigation Report Database.

We found that those who died were 2.6 times more likely to not be wearing a PFD (95% CI 1.5 to 4.3) and 2.2 times more likely to not have any safety features on their boat (95% CI 1.3 to 3.7) compared with injured survivors, after controlling for age and sex (table 4). In addition, we found that fatalities were 5.4 times more likely to be in a human-powered boat (95% CI 2.6 to 10.9). Among incident-level risk factors, we found fatalities were 70% more likely to have alcohol involved (95% CI 1.1 to 2.8), 90% more likely to be on a river (95% CI 1.2 to 3.1), 3.6 times more likely to be on a strait (95% CI 1.5 to 8.6) and 5.2 times more likely to be on the ocean (95% CI 1.4 to 19.7) compared with injured survivors, after controlling for age and sex. Fatalities were also 3.3 times more likely to be boating between the hours of 00:00 and 5:59 (95% CI 1.5 to 7.6), 4.7 times more likely to be in an incident that involved capsizing, sinking, flooding or swamping (95% CI 2.3 to 10.0) and 10.3 times more likely to involve a person leaving the boat voluntarily, ejected or fall (95% CI 4.8 to 22.1) than injured survivors (table 4).

DISCUSSION

Among people injured in boating incidents, not wearing a PFD, being on a boat that had no safety features and was human-powered increase the chances of being fatally injured compared with those who survived with injuries in a boating incident. They were more likely to be fatally injured in an incident in which the boat capsized, sunk, flooded or swamped, or an incident that involved the person leaving the vessel. Fatalities were more likely in incidents that involved alcohol, took place in the ocean, sound or strait, and between the hours of 00:00 and 5:59.

Our finding of an increased risk of death associated with not using a PFD after controlling for age and sex is consistent with the findings of prior studies. In a matched cohort study, the risk of drowning death was decreased 49% among boaters wearing a PFD compared with those not wearing a PFD.[9] The US Coast Guard reports that in 2012 PFD usage in the USA was 22.6% among all boaters, 67.5% among youth under 18 and 9.3% among adults ages 18 and above.[12] A 2010 observational study of boats in Washington State reported that PFD usage rates were 30.7% among all boaters and 22–18% among those over the age of 12.[13] In Washington State, children ages 12 and under are required to wear a USCG-approved PFD at all times when underway in a boat less than 19 ft in length, unless in a fully enclosed area.[14] An emergency ordinance requiring personal floatation device use for all ages on major King County Rivers for the summer season of 2011 was enacted in response to the

Table 4 Risk factors associated with boating-related deaths in Washington State 2003–2010

Variable	Adjusted RR (95% CI)*
Personal floatation device worn	
Yes	1.0
No	2.6 (1.5 to 4.3)
Boat type	
Powerboat	1.0
Human-powered	5.4 (2.6 to 10.9)
Personal water craft	0.9 (0.4 to 2.1)
Other	1.9 (1.0 to 3.4)
Any safety features on boat	
Yes	1.0
No	2.2 (1.3 to 3.7)
Any alcohol involved	
No	1.0
Yes	1.7 (1.1 to 2.8)
Body of water	
Lake	1.0
Sound	0.6 (0.3 to 1.1)
River	1.9 (1.2 to 3.1)
Strait	3.6 (1.5 to 8.6)
Ocean	5.2 (1.4 to 19.7)
Time of day	
6:00–11:59	1.0
12:00–17:59	0.9 (0.5 to 1.8)
18:00–23:59	1.1 (0.5 to 2.2)
00:00–5:59	3.3 (1.5 to 7.6)
Incident type	
Collision	1.0
Capsizing, sinking, flooding, swamping	4.7 (2.3 to 10.0)
Person leaves vessel (ejected fall overboard, voluntarily)	10.3 (4.8 to 22.1)
Other	2.8 (1.4 to 5.6)

*Adjusted for age and sex.

potential dangers that strong and swift current poses.[15] This study confirms the importance of PFD use for surviving a boating incident and supports the need for interventions such as legislation to increase PFD wear.

Our finding of increased risk of death among boaters in a human-powered boat supports findings of recent studies. Among recreational boating fatalities in Ohio, the greatest number of fatalities involved motorboats, but fatality rates were higher for incidents involving smaller boats, such as canoes and rowboats; human-powered boats were associated with a 2.1-fold increased risk of death compared with those in other types of boats.[10] The risk of death may be greater among vessels without engines because the operators are more inexperienced than those in motorised boats. Greater lethality may be inherent to a non-motorised vessel since it is often smaller, more prone to capsizing and cannot return to shore as quickly as a motorised boat in the case of emergency or changing water or weather conditions.[16] This study supports the need for interventions targeted specifically to those on non-motorised boats, such as life jacket wear and boating safety education.

We found an increased risk of death among boaters who did not have any safety features on their boat. Prior studies including analysis of safety features as a protective factor[5 17] are descriptive and cannot address the magnitude of the risk factor. It is unclear how safety features such as safety lanyard, safety check, fire extinguisher on board or PFDs on board could directly temper the risk of death during the event phase of the incident. This risk factor may be related to other risk factors, such as recklessness, ignorance, unfamiliarity with boating and alcohol use, that may more directly lead to the incident. There is more to be learned about the characteristics of individuals who do not have safety features on their boat.

Our finding of increased risk of death among boaters in incidents involving alcohol is consistent with prior studies. In 2002, 8.7% of the non-fatal and 22.6% of the fatal boating-related injuries in the USA had alcohol or drugs as a contributing factor.[18] In 2012, the US Coast Guard reported that alcohol use was the leading contributing factor in fatal boating incidents, contributing to 16% of the deaths.[3] Unlike alcohol use among drivers of motor vehicles, surveyed boaters report that use of alcohol among boaters is a commonly accepted practice.[19] However, the estimates of alcohol as a risk factor highlight the associated danger, even if it is not being consumed by the victim, but is consumed by other passengers on the boat.[8] All 50 states have legislation prohibiting BUI. However, enforcement of and penalties under to these laws varies widely. Effective prevention strategies should employ lessons learned from motor-vehicle injury prevention strategies, including targeted social awareness of alcohol as a risk factor, as well as increased law enforcement and penalties for BUI.

Increased risk of death among boaters in incidents on the ocean, sound or strait in our study supports previously described observations.[2 6 17] The Canadian Red Cross Society[6] posits that boaters on the ocean are subject to greater environmental factors and are at a greater distance from help when an incident occurs compared with smaller and often warmer bodies of water such as lakes and rivers. Water temperatures of ocean and straits in Washington State remain around 40°F year round, increasing the risk of cold water shock and hypothermia. Targeting sea survival messages to boaters on these types of bodies of water may offer an injury prevention strategy.

The increased chance of being fatally injured on the water between midnight and 5:59 has not been identified previously. Over half of the incidents at that time involved alcohol. The nature of boating activities occurring at this time differs from those occurring in the morning, like the social norm of alcohol use in the afternoon and evening. We hypothesise that incidents that occur at this time have greater risk due to operator-related factors such as impaired sighting of hazards, fatigue and environmental factors such as slower access to police or rescue. The increased risk of death at these hours may relate to concomitant alcohol use or that there were few people to report or assist with the incident. Further study is needed to evaluate the factors involved in fatal boating injury and time of day.

We found that those in a fatal boating incident were more likely to have involved capsizing, sinking, flooding or swamping, or a person leaving the boat, a frequently reported observation. The Canadian Red Cross Society[6] reported that falling, capsizing and swamping were the most frequent types of incidents among motorised and non-motorised motorboats. Changes made in boat design to decrease risk of capsizing and swamping have likely contributed to a decrease in boating-related fatalities over the past decade.[6] Our study highlights the need for prevention strategies such as PFD use in mitigating the risk of death when a person enters the water even in calm waters. Importantly, most fatal and non-fatal incidents occurred when waters were calm. This counters a commonly held misconception among boaters that PFDs only need to be worn during

rough conditions. These findings have recently been corroborated by boaters in focus groups.[19]

Our study has several limitations. Individual-level risk factors collected in the WA BAIRD were limited to age, sex and PFD use. Additional individual risk factors that would be valuable for evaluation include race and ethnicity, which would allow culturally appropriate prevention strategies aimed at specific racial and ethnic groups. In addition, while the BAIRD includes swimming ability, data are only collected for boating fatalities. Swimming ability could help inform whether knowing how to swim is a preventive factor for boating fatality. Ascertainment of boating incidents in the WA BAIRD relied primarily on law enforcement personnel who were required to submit reports when they responded to a boating-related incident. When law enforcement was not involved, the WA BAIRD relied on self-reporting by boat owners. This likely resulted in under-ascertainment of non-fatal events. Prior studies on recreational boating have reported finding an inverse relationship between severity of incident and under reporting.[18] This selection bias may have affected the magnitude of the associations we found, with potential underestimation of risk associated with sinking, capsizing or flooding, overestimation of risk associated with not using a PFD or alcohol involvement. Standardisation of ascertainment methods and less reliance on self-reporting would decrease bias but may not be feasible. Case ascertainment will remain a limitation in this field of research.

Our findings substantiate risk factors described in previous descriptive studies of boating deaths and identify several new risk factors. Moreover, we identified boating populations at risk for death compared with injury: those not wearing a PFD and those on non-motorised craft; boats that are human-powered and those without safety features; and environmental conditions, boating on ocean waters and late nights and especially the use of alcohol onboard. Our study findings support legislation and increased law enforcement as critical strategies in addition to educational and environmental interventions to increase PFD use and decrease alcohol use among recreational boaters. Moreover, this study identifies the need to focus on those using human-powered boats. Areas of future research include study of the characteristics of safety features, body of water and time of day in boating incidents. Further study is also needed to evaluate the characteristics of individuals from various racial and ethnic groups in boating incidents.

What is already known on the subject

- Boating presents a unique injury setting as boaters are subject to the normal risks of land-based activities, including falls, burns and cuts, but they can also incur additional injuries from asphyxia, submersion and hypothermia.
- Prior boating injury studies have shown increased risk for death is associated with alcohol (52.4-fold), untrained operator (2-fold risk), operator inexperience (132.3-fold risk) and non-motor boats (2.1-fold risk) and decreased risk (49%) for death is associated with personal flotation device use.
- Much of the literature on boating injury is observational, evaluates a single risk factor or evaluates data from 20 years ago.

What this study adds

- Uses case–control methodology to analyse the data and estimate magnitude of risk.
- Adds to limited body of literature on boating-related risk factors, including body of water, time of day and safety features on boats.
- Suggestions for intervention strategies and further research on alcohol use, personal flotation device wear and boat type.

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Road deaths in the EU

Twelve thousand three hundred and forty-five car occupants were fatally injured in 2012 in the European Union. The European Transport Safety Council report notes that 900 lives could be saved annually if manufacturers were required to fit front and rear seat-belt reminder sensors (noted by IBP).

Smoke detectors in rentals

An MP wants smoke alarms to be compulsory in rented properties in the UK. About 20% do not now have a smoke alarm. Death rates due to fires involving children whose parents are unemployed are 38 times higher than those for children of parents in higher level occupations (noted by IBP).

E-cigarette-related poisoning

Calls to US poison centres related to e-cigarettes have increased from 1 in September 2010 to 215 in February 2014. The liquid nicotine can be hazardous through ingestion, inhalation, or absorption through skin or eyes. These cigarettes are not required to be childproof, often come in appealing flavours, and many states don't restrict their sale to minors (noted by IBP). *Morb Mortal Wkly Rep* 2014;63:292–3.

A case–control study of boat-related injuries and fatalities in Washington State

Sarah Stempski, Melissa Schiff, Elizabeth Bennett, et al.

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