American Journal of Emergency Medicine 36 (2018) 1195–1201

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Do wave heights and water levels increase ocean lifeguard rescues?☆

William Koon, MPH [a,*,1], Ali Rowhani-Rahbar, MD, PhD, MPH [b,d], Linda Quan, MD [c,d]

[a] Department of Global Health, University of Washington School of Public Health, Seattle, WA, USA
[b] Department of Epidemiology, University of Washington School of Public Health, Seattle, WA, USA
[c] Emergency Department, Seattle Children's Hospital, Seattle, WA, USA
[d] Department of Pediatrics, University of Washington School of Medicine, Seattle, WA, USA

ARTICLE INFO

Article history:
Received 8 September 2017
Received in revised form 20 November 2017
Accepted 2 December 2017

Keywords:
Drowning
Rescue
Lifeguard
Ocean hazards

ABSTRACT

Objective: To investigate the association of wave height and tidal water level changes with the frequency of ocean lifeguard rescues.
Methods: All ocean lifeguard rescues recorded by Newport Beach Lifeguards in 2015 and 2016 were linked by time and location to weather and ocean variables contained in other historical databases. We performed separate multivariable analyses using mixed effects negative binomial regression to evaluate the total effects of wave height, mean water level (primarily set by tidal elevation), and rising vs. falling water level, on the frequency of ocean rescue in the study location, controlling for confounding variables.
Results: Newport Beach Lifeguards made 8046 rescues during the study period. In all areas of the beach, rescue frequency increased as waves got larger (IRR: 3.25; 95%CI: 2.91–3.79) but then decreased in large surf (IRR: 0.52; 95%CI: 0.37–0.73). In two sections of beach, lifeguards made more rescues during lower water levels, but in the third section of beach, made more rescues during higher water levels. Rescue frequency increased in two sections of beach with rising water levels, but did not in the other section.
Conclusions: Wave height, water level, and water level direction were associated with rescue frequency, but the environmental factors included in the analysis did not fully account for most variation in rescue frequency. Other factors need to be evaluated to identify major determinants of rescue frequency.

1. Introduction

Lifeguards are one of the layers of protection in drowning prevention at open water surf beaches [1,2]. Environmental hazards at ocean beaches, along with social dynamics and other demographic risk factors, contribute to drowning risk [3-5]. Lifeguards often prevent the need for rescue or injury by recognizing specific environmental hazards usually unidentified by the typical beach patron. For example, lifeguards protect members of the public by warning about rip currents, pointing out the location of submerged rocks at high tide, or informing parents with small children about in-shore holes where water depth changes suddenly. A recent study from California indicated the majority (54.85%) of lifeguard activity consists of preventative contacts, while aquatic rescues represented only 1.9% of activity, first aid events represented 0.94%, and major medical events represented 0.12% [6].

Multiple factors in the coastal environment lead to both preventative actions and rescues by lifeguards [7]. While, knowledge of physical variables of the coastal environment has expanded, it has mostly focused on rip currents. These concentrated flows of water move away from shore to varying distances beyond the surf zone [8], have been estimated to account for most surf lifeguard rescues in the United States and other locations [9-12], and have dominated the literature on hazards in the beach environment [10,13]. Other ocean and beach factors have been assessed for their contribution to surf zone injuries [14]; and although their role in lifeguard rescue has not been evaluated in the literature, backwash, lateral currents, sandbars, inshore holes, and other hydrodynamic and morphologic beach factors have been included as determinants of rescue for lifeguard training programs [9,15]. These processes arise from the interaction between different environmental variables, such as wave height or varying water levels, to form hazardous conditions that cause rescue. Both wave height and tidal water level are thought to be determinant of rescue frequency due to risk they present directly to bathers, their association with rip current frequency and velocity [16-18], and their role in exacerbating risk from other hazards in the ocean environment. However, the extent of their contribution to rescue and lifeguard activities has not been evaluated. Such information could help front line lifeguards anticipate and prevent rescues, benefiting the lifesaving community and their patrons.

The objective of this study was to investigate the association of wave height and tidal water level changes with the frequency of ocean lifeguard rescue occurrence in Newport Beach, California, using lifeguard

☆ Financial/material support statement: None.
* Corresponding author at: 1510 San Juan Road, Seattle, WA 98195, USA.
E-mail address: wakoon@uw.edu (W. Koon).
[1] Permanent address: 217 W Maple Street, San Diego, CA 92103, USA.

https://doi.org/10.1016/j.ajem.2017.12.006
0735-6757/

rescue records collected in real-time from a Computer-Aided-Dispatch (CAD) system. This data collection method allows linkage of detailed lifeguard activity records to other sources for the analysis of lifeguard rescues and various other factors. Further analysis of oceanic and other environmental variables that affect rescue could provide new knowledge for use in lifeguard training programs, and information beneficial to supervisors and managers preparing staff and allocating resources. We believe the findings of this study could be used to improve lifeguard effectiveness via earlier intervention in the drowning process, resulting in fewer rescues and ultimately a safer experience for the beach patron.

2. Methods

This observational retrospective study linked records collected between January 1, 2015 and December 31, 2016 on the following variables from related sources: (1) Newport Beach lifeguard rescue data recorded in real-time with a Computer Aided Dispatch (CAD) System, (2) weather measurements from a nearby weather station, (3) wave data measured by three offshore buoys near the study location, (4) tidal water level information from sensors at the Los Angeles Harbor entrance, and (5) visual near-shore wave estimates from Surfline forecasters.

2.1. Study location and lifeguard service

Newport Beach is a suburban beach city in Southern California, USA, with approximately 90,000 permanent residents. The city experiences mild weather conditions and year-round tourism. With approximately 10 million people visits per year, peak summer beach visitation can exceed 100,000 patrons per day [19]. The Newport Beach Fire Department provides robust Emergency Medical Services (EMS) for the city: the department has an average response time of 4 min and 22 s from one of eight fire engines staffed by Emergency Medical Technicians and/or three ambulances with paramedics [20]. Professional lifeguards in Newport Beach are also employed by the Newport Beach Fire Department, and integrated into the city's EMS system. Lifeguards patrol year-round, and are responsible for eight miles (12.8 km) of Pacific Ocean surf beach divided into three operational divisions (Divisions 1, 2, 3) with fixed towers, vehicles, and boats (Fig. 1).

2.2. Variables and data sources

Data from various sources were linked according to an exact deterministic process (Fig. 2). We created a dataset with three records (one each for Division 1, Division 2, and Division 3) for every hour between 7:00 AM and 8:00 PM, for 2015 and 2016 resulting in a panel frame with 28,509 records. Hourly data for each division included a count of rescues and public contacts, the hourly mean of continuous environmental variables, and the hourly mode of categorical environmental variables. Institutional Review Board approval was not required for this study; previously collected de-identified data did not meet the regulatory definition of human subjects research.

2.2.1. Lifeguard activity variables

Newport Beach lifeguards recorded the time and location of all rescues and other interventions (preventative action, first aid, rule enforcement, etc.) in real-time via SunGard Systems Computer Aided Dispatch (CAD) Integrated Public Safety Software (Lake Mary, Florida, USA). Lifeguards in towers and vehicles called dispatch using closed circuit telephones or radios if required to intervene in a situation. The dispatcher recorded the time, location, and type of call into the computer system,

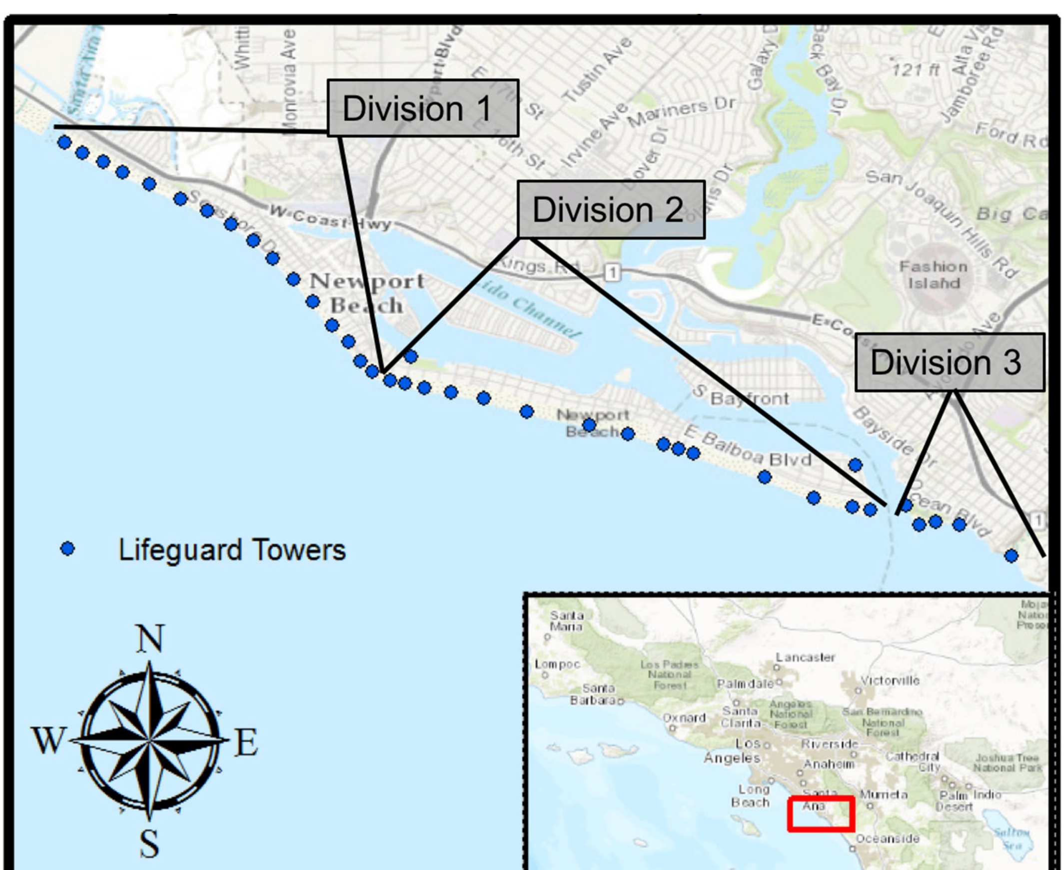

Fig. 1. Map of Newport Beach with operational divisions and lifeguard towers.

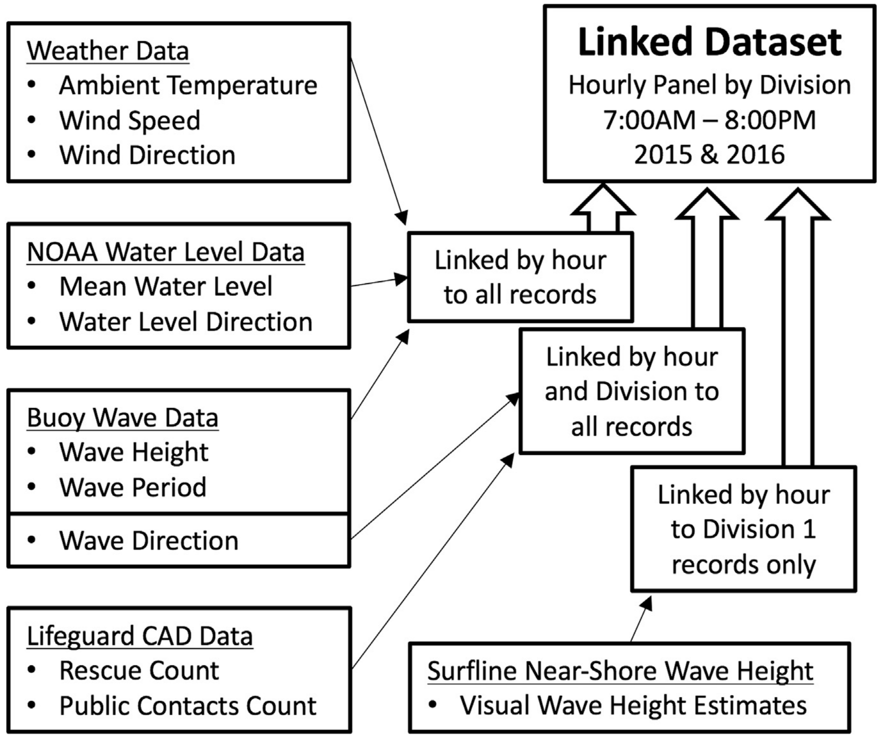

Fig. 2. Data linkage process.

and coordinated response from other lifeguards if necessary. Utilization of CAD software is relatively new in the lifeguard profession, and believed to increase the validity and reliability of data collected by lifeguards [6].

A rescue was defined as physical assistance by a lifeguard from a place of danger in the water to a place of safety (dry land, shallow water, boat, etc.) and recorded in the system as the number of people rescued. We filtered lifeguard CAD data to contain only rescues and public contact interventions (used as a proxy measure for beach visitation), summarized the counts for each intervention by hour and division, and linked to the corresponding hour and division combination in the dataset.

2.2.2. Weather variables

We accessed historical weather data collected from a nearby weather station from weatherunderground.com [21]. We summarized weather data by hour, calculating the mean of continuous variables (wind speed, precipitation, air temperature) and taking the mode of categorical variables (wind direction, weather conditions), and linked weather data to each record by hour.

2.2.3. Tidal water level variables

Water level (e.g. tidal elevation) measurements occur every 6 min at the mouth of the Los Angeles Harbor and are available from the NOAA (National Oceanic and Atmospheric Administration) Tides and Currents website [22]. We offset the measurements to represent conditions near the Balboa Pier in Newport Beach, and calculated mean water level for each hour in the study period. For water level direction (rising vs. falling), we calculated the slope (difference) between each hour's mean water level and the preceding hour's mean water level; positive numbers indicated hours with a rising tide and negative numbers indicated hours with a falling tide. We linked hour-mean water level and categorical water level direction to the dataset by hour.

2.2.4. Buoy wave variables

Wave and other ocean condition data are collected by offshore buoys managed by the Coastal Data Information Program (CDIP) and available from the National Data Buoy Center website [23]. We calculated the mean of hourly measurements for wave height, average wave period, and wave direction from three buoys near the study location, and averaged them for a single hour-mean combined variable.

A localized incident wave direction relative to shore-normal (the line at right angles to the contours of the surf zone) variable was calculated for each division by subtracting that division's coastline orientation from buoy wave direction, resulting in a measurement of wave direction angle relative to that section of beach. Previous research indicates rip current likelihood, and by association rescue frequency, is associated with incident wave direction relative to the local coastline orientation [24,25]. We linked wave height and wave period to each record by hour. We linked wave direction relative to shore-normal to each record by hour and division.

2.2.5. Near-shore visual wave estimates

Professional Surfline wave forecasters record visual estimates of near-shore wave height once per day in person or via fixed cameras at two locations in the lifeguard Division 1 area of Newport Beach; they do not make visual wave height estimates for other locations in the study area. Surfline approved use of historical data for this study. We calculated and then linked the average of the two measurements to the dataset for lifeguard rescues occurring in Division 1, using the daily Surfline estimate for all hours for that day.

2.3. Data analysis

Our goal was to evaluate the total effects of three different environmental variables on the frequency of ocean rescue in the study location: (1) wave height, (2) mean water level (primarily set by tidal elevation), and (3) rising vs. falling water level. We assessed the effect of rising vs. falling water level on rescue frequency because many Southern Californian lifeguards believe that times with an “outgoing” tide (falling water levels) are more hazardous because of stronger rip currents. We refer to rising vs. falling water level as water level direction from this point forward.

We performed multivariable analysis using mixed effects negative binomial regression, with hours as the unit of analysis to estimate incidence rate ratios and 95% confidence intervals (CI). Negative binomial regression can accommodate for potential over dispersion of count outcomes [26]. Additionally, the negative binomial regression alpha parameter is directly related to the amount of over dispersion in the data; increased levels of this parameter indicate amplified heterogeneity not accounted for by the covariates in the model [27]. We included counts of "public contacts" as an offset variable, approximating beach population. Public contacts are recorded by lifeguards as interactions with the public not related to rescue, medical/first aid, or rule enforcement; and were correlated with visual estimates of beach attendance ($r = 0.77$). Directed acyclic graphs, developed based on lifeguard experience and previous literature, aided a priori confounder identification for multivariable analysis [28].

To assess the effects of wave height, two models were developed given the availability of data in the study location: (1) offshore buoy measurements from CDIP were applied to all three Divisions in the entire location and (2) near-shore visual wave height estimates from Surfline were applied to Division 1 only. Wave height as a continuous variable was entered into both models using linear splines, with knots at 4 ft (1.21 m) for the buoy model and 5 ft feet (1.52 m) for the Surfline model, to evaluate varying effects for times with waves of different heights. Both wave height models controlled for wind speed, wave period, wind direction, mean water level, and wave direction relative to shore-normal. Clustering was accounted for with random intercepts for division, month, and day of the week in the buoy model, and month and day of the week in the Surfline model.

Separate models were developed to assess the relationship between rescue frequency and (1) water level (a continuous variable); and (2) water level direction (a binary variable with falling water level as the reference variable). Both models included an interaction term for division to evaluate for varying effects on different sections of beach, and accounted for clustering by adopting random intercepts for month and day of the week.

We used the graphical program DAGitty to develop directed acyclic graphs, and Rstudio and Stata [Computer Software] for statistical analyses [29-32]. We conducted statistical analysis in U.S. Customary Units for use by Newport Beach Lifeguards.

3. Results

Newport Beach Lifeguards recorded 8046 rescues in the CAD system during the study period. Descriptive statistics of the environmental variables of interest are presented by season in Table 1.

Table 1
Environmental variables by season.

		Winter[a]	Shoulder[a]	Summer[a]	Study period
		Mean (SD) Range	Mean (SD) Range	Mean (SD) Range	Mean (SD) Range
Buoy wave height	ft	3.20 (1.49) 1.13–13.17	3.03 (0.86) 1.48–8.78	2.89 (0.62) 1.65–5.41	3.06 (1.13) 1.13–13.17
	m	0.97 (0.45) 0.34–4.01	0.92 (0.26) 0.45–2.68	0.88 (0.19 0.50–1.65	0.93 (0.34 0.34–4.01
Surfline wave height	ft	3.16 (1.01) 1.0–7.5	3.03 (0.94) 1.0–6.5	2.97 (0.75) 1.0–5.5	3.07 (0.93) 1.0–7.5
	m	0.96 (0.31) 0.30–2.29	0.924 (0.29) 0.33–1.98	0.91 (0.21) 0.30–1.68	0.93 (0.28) 0.3–2.28
Tidal water level	ft	2.65 (1.72) −1.51–7.37	3.16 (1.5) −0.64–6.96	3.47 (1.25) 0.04–6.81	3.03 (1.57) −1.51–7.37
	m	0.81 (0.52) −0.46–2.25	0.964 (0.46) −0.19–2.12	1.06 (0.38) 0.01–2.08	0.92 (0.48) −0.46–2.25
Proportion rising/falling Water level direction		0.90	1.11	1.28	1.05

[a] Season: winter – November, December, January, February, and March; shoulder – April, May, September, and October; summer – June, July, and August.

Multivariable analysis indicated wave height, water level, and water level direction change were associated with rescue frequency (Fig. 3). Full results of multivariable regression models are available in Appendix A. Importantly, amplified heterogeneity, documented by the alpha parameter in all four negative binomial models, indicated the effects of the included environmental variables on rescue occurrence were highly variable (buoy wave height model alpha = 5.48; Surfline wave height model alpha = 5.12; tidal water level model alpha = 7.51; water level direction model alpha = 7.62).

3.1. Wave height

Wave height, from both buoy measurements and Surfline visual estimates, was clearly associated with rescue frequency. In both models, the effect of wave height varied significantly for hours when waves were larger (joint test for spline interaction: buoy model $p < 0.001$, Surfline model $p < 0.001$). For hours with average buoy wave height measured under 4 ft (1.21 m), a one-foot (0.30 m) increase was associated with a 3.25 times increase in rescues after controlling for confounding variables (95%CI: 2.91–3.79). This relationship changed with larger waves; when average buoy wave height was over 4 ft (1.21 m), 1 ft (0.30 m) additional wave height was associated with a 48% decrease in rescues (IRR: 0.52; 95%CI: 0.37–0.73). Similar results were observed in Division One from Surfline near shore wave estimates: rescues increased by a factor of 1.94 for every foot (0.30 m) of increasing wave height under 5 ft (1.52 m), but decreased significantly when estimated near shore wave height was greater than 5 ft (1.52 m; 95%CI: 1.67–2.24).

3.2. Water level

The joint test of coefficients for interaction between water level and division was statistically significant: the effect of water level on rescue frequency varied between the operational divisions in the study location ($p < 0.001$). In Division 1, lifeguards tended to make fewer rescues as water level increased: a one-foot (0.30 m) increase in tidal water level was associated with a 26% decrease in rescues (IRR: 0.74; 95%CI: 0.69–0.79). The estimated effect of tidal water level in Division 2 was similar to that of Division 1, but the opposite effect was observed in Division 3, where rescues increased as water level increased. A one-foot (0.30 m) increase in water level in Division 3 was associated with 1.37 times as many rescues (95%CI: 1.123–1.53).

3.3. Water level direction

For the water level direction model, IRR estimates showed that hours with rising water level experienced increased rescue frequency in Division 1 and Division 2, but rising vs. falling water level had no role in explaining varying rescue frequencies in Division 3. In Division 1, rescue frequency was 2.03 times greater during hours with rising water level compared to hours with falling water level (95% CI:1.66–2.47). Division 2 also exhibited increased rescue frequency with rising water level. Although statistically insignificant, estimates for hours with rising water level in Division 3 indicated decreased rescue frequency.

4. Discussion

In this retrospective study of the role of ocean factors on lifeguard rescues, wave height, water level, and water level direction were associated with ocean lifeguard rescue frequency and the effects of both water level and water level direction varied significantly by location. While statistically associated, the environmental variables included in our models did not account for most heterogeneity in the data, pointing to other undocumented determinants of rescue.

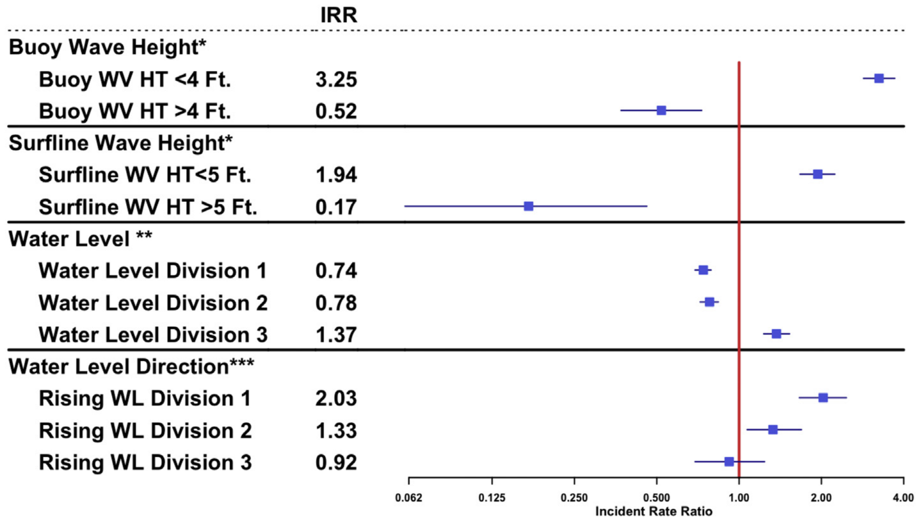

Fig. 3. Mixed effects negative binomial regression results. *Adjusted for wind speed, water level, shore-normal wave direction, wave period, wind direction; IRR indicates the ratio of change in rescue rate for a one-foot increase in wave height, limited to the corresponding wave height spline. IRR > 1 indicates increased rescue frequency, <1 indicates decreased frequency. **IRR indicates the ratio of change in rescue rate for a one-foot increase in water level, for each corresponding Division. IRR > 1 indicates increased rescue frequency, <1 indicates decreased frequency. ***IRR indicates the ratio of change in rescue rate between rising and falling water levels, for each corresponding Division. IRR > 1 indicates increased rescue frequency, <1 indicates decreased frequency.

The failure to fully attribute variance in rescue frequency to a few ocean factors is not surprising. Multiple factors in addition to ocean conditions contribute to rescue frequency. These include a) person factors such as age, race, residency, socioeconomic status, swimming ability, alcohol, or activity at time of rescue; b) factors related to beach and bather population such as air temperature, water temperature, or temporal elements (weekend, holiday, school break); c) aspects of the built environment such as beach accessibility and proximity to restaurants or bars; and d) lifeguard related human factors such as experience and training. Further evaluation of these other factors is a priority for those seeking to decrease the need for rescue through primary prevention efforts.

Although excess heterogeneity and other undocumented factors limit our ability to explain the effects of these environmental variables on rescue frequency, this analysis contributes new information in this understudied field. For the purpose of this study, we focused on the total effect that specific environmental variables of interest had on rescue frequency regardless of other mechanisms on the causal pathway to rescue, such as rip currents, shore-break, inshore holes, or sand bars. Further study that addresses the impact of these other physical mechanisms on rescue frequency would be valuable.

The concave relationship observed between rescues and wave height implied some factor or combination of factors significantly altered the association, decreasing rescue frequency in larger surf. During times with large surf, lifeguards may have been more preventative and contacted beach patrons before they entered the water; alternatively, beach patrons may have self-limited their exposure to risk due to fear of obviously bigger surf, as postulated by Dusek et al. [24]

We hypothesize that decreased rescue frequency at higher water levels in Divisions 1 and 2 were related to rip currents in this area, as previous research has documented rip velocity (and subsequent risk to bathers) increases at lower tidal water levels [8]. The opposite association observed in Division 3 suggests that some other causal mechanism was operating there. Anecdotal information provided by lifeguards suggests a generally less water competent population frequents this location, that the association between increased rescue frequency and higher water levels here may be related to a non-swimming population confronted with deeper water in swim areas during higher tidal water levels.

That the direction of water levels would be associated with rescue frequency in any location was surprising. Many Californian lifeguards believe falling water levels increase the likelihood and strength of rip currents, although the literature has explicitly clarified that rip velocity is not the result of tidal forcing [33]. We hypothesize increased rescue frequency during rising water levels in Divisions 1 and 2 relates to the large spatial variation in water depths throughout the surf zone, where there may be sandbars, troughs, channels, and other bedforms. The sea floor can change rapidly in large surf, creating and moving channels and sandbars of varying depths that may last hours or days depending on conditions [34]. During the summer months, the seafloor in Divisions 1 and 2 often is characterized by a deep trough close to shore, with a shallow sandbar just offshore of the trough. It is possible that during lower water levels bathers are able to wade through the trough to make their way out to the sand bar, but find themselves in deeper water upon their return to shore as rising water levels increase the depth of the same near shore trough. This change in water level may be just enough to cause distress for a non-swimmer.

These findings have practical implications for lifeguard operations and public health practitioners. Evidence for increased rescue frequency in specific environmental conditions allows lifeguard supervisors to appropriately staff and allocate resources. This information may also be used to aid accurate and consistent communication of levels of risk to the public. Although specific estimates of association between environmental variables and rescue frequency identified in this study may not be generalizable to other beaches, operational and training implications of the findings will be of value to lifeguard departments in other settings. Moreover, methodologies employed here could be applied to datasets from other locations.

4.1. Limitations

Our outcome measure, rescue, did not differentiate as to cause or type of rescue (assist versus critical). While the relationship between rescues and fatal and nonfatal drowning has not been described, rescues represent a bather at risk for drowning, potentially put the lifeguard at risk and constitute a significant proportion of lifeguard activity at this beach location.

Our data and subsequent models were limited to environmental factors and did not include other possible risk factors. Presently, such data is not reliably collected in lifeguard data sets, thus we decided to evaluate environmental factors systematically recorded in other data systems and link them to CAD lifeguard data. Although new technology such as tablet computers may aid with recording some information on the persons rescued, lifeguards are still likely to face the problem described by Williamson of balancing water safety responsibility with requirements of data collection [35].

While the covariates included in this analysis were statistically associated with rescue frequency and advance our understanding of the determinants of ocean rescue, they primarily expose the breadth of what remains unstudied. The statistically significant estimates and joint tests for interaction, along with high alpha parameters from this regression analysis, show that there are many determinants of ocean rescue.

Generalization of the findings of this study is limited. This study actually evaluated three separate locations and showed differences among them. Thus, inference from a particular section of beach should be generalized with caution to the entire study location or other beaches and future research on determinants of rescue should evaluate differences by location. Moreover, this study involved only one lifeguard service and may not be generalizable to other locations where lifeguard services may vary considerably in training requirements and operational activity.

The measurements from the various data collection systems used may have affected results. We used the mean wave height measurement from three different buoys with varying depths and distances from shore. However, the buoy wave height measurement does not represent swell interaction with the beach environment, a critical component of wave height and behavior in the surf zone. Future research using modeled near-shore wave height data for the study location would increase the accuracy of estimates of the relationship and potentially the predictions that could be used for operational purposes.

We were unable to specifically evaluate the beach population. While not an ideal measure of population, we used public contacts as a proxy indicator that could be allocated by division and by hour, and were assumed to be a more reliable indicator than visual estimates made by lifeguards. Estimating the number of people on a highly populated beach is very difficult; previous research has shown that agencies tend to overestimate beach visitation [36]. Use of a more reliable population count might improve modeling of environmental variables effect on rescue frequency. Future research should also consider use of a more accurate count of bathers as opposed to general beach population.

Lastly, the results may have been affected by the study period which occurred during El Niño years in which winter water temperatures were unusually warm throughout the winter months, and rain and thunderstorms occurred during the typically dry summer months.

5. Conclusions

Wave height, tidal water level, and, the water level direction in two sections of beach, were associated with rescue frequency. Importantly, the presence of heterogeneity unaccounted for by the covariates in multivariable regression indicated other factors were important determinants of ocean rescues. Ascertaining why lifeguards are rescuing people from the water is paramount for efforts that aim to reduce these incidents. Identification of the multiple factors leading to rescue should be a priority for the lifesaving and injury prevention community and benefit both safety, lifesaving, and enjoyment of swimmers at recreational surf beaches.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

None.

Acknowledgements

The authors thank Newport Beach Fire Department — Marine Safety Division Assistant Chief Rob Williams and Battalion Chief Michael Halphide, along with Surfline and Kevin Wallis for their assistance with data acquisition. We also thank Melissa Moulton from the University of Washington (UW) Applied Physics Laboratory for consulting on ocean dynamics pertinent to ocean lifeguard rescues, and Orvhalo Augusto (UW Department of Global Health) for assistance with statistical analysis.

Appendix A. Multivariable regression analysis results

Table A.1
Buoy wave height model.

	IRR	$p > \|z\|$	95% CI
Constant	0.0000438	0.000	0.000018–2.144579
Buoy wave height < 4 ft (1.21 m)	3.256116	0.000	2.858263–3.709347
Buoy wave height > 4 ft (1.21 m)	0.5178226	0.000	0.3660333–0.732557
Wind speed (mph)	1.08418	0.000	1.053784–1.115453
Water level	0.6810103	0.000	0.574990–0.80657
Shore-normal wave direction	0.9803506	0.000	0.976283–0.984434
Wave period	1.35466	0.000	1.283015–1.430305
Wind direction — none*	0.684193	0.523	0.2136384–2.19118
Wind direction — east	0.3176742	0.031	0.11226–0.898884
Wind direction — north east	0.4918465	0.153	0.185835–1.30175
Wind direction — north west	0.6001865	0.365	0.198791–1.81207
Wind direction — south east	0.689375	0.374	0.303787–1.56437
Wind direction — south west	1.247162	0.251	0.855160–1.81885
Wind direction — south	0.8494718	0.447	0.557907–1.29340
Wind direction — variable	0.7174967	0.110	0.477654–1.0777
Wind direction — west	1.45648	0.057	0.989161–2.14457
Ln(alpha)	1.700543	0.000	1.63652–1.76455
Random intercept: division	0.0883756		0.00029–26.2059
Random intercept: division, month	2.237327		1.20882–4.14089
Random intercept: division, month, day of week	0.568168		0.396907–0.81332

*Reference variable: Wind direction — north.
Joint test for interaction: buoy wave height < 4 ft, buoy wave height > 4 ft.
Chi^2[2]: 318.01.
Prob > Chi^2: <0.0001.

Table A.2
Surfline wave height model.

	IRR	$p > \|z\|$	95% CI
Constant	0.0002601	0.000	0.000074–0.000912
Surfline wave height < 5 ft (1.52 m)	1.937049	0.000	1.674914–2.240209
Surfline wave height > 5 ft (1.52 m)	0.1715919	0.000	0.06385–0.461074
Wind speed (MPH)	1.107164	0.000	1.06263–1.153564
Water level	0.4575829	0.000	0.357418–0.585817
Shore-normal wave direction	0.9974541	0.391	0.991658–1.00328
Wave period	1.351299	0.000	1.242956–1.469086
Wind direction — none†	1.304995	0.726	0.294905–5.77477
Wind direction — east	1.07e − 09	0.998	0–
Wind direction — north east	0.6670203	0.525	0.191578–2.32237
Wind direction — north west	0.4389276	0.403	0.063686–3.02510
Wind direction — south east	0.8148989	0.717	0.2696001–2.46313
Wind direction — south west	1.683277	0.066	0.965852–2.93359
Wind direction — south	1.014525	0.964	0.544623–1.88986
Wind direction — variable	1.046459	0.881	0.577105–1.89753
Wind direction — west	1.880822	0.030	1.061747–3.331765
Ln(alpha)	1.633909	0.000	1.54246–1.725358
Random intercept: month	2.59708		1.079589–6.247589
Random intercept: month, day of week	0.4913267		0.278553–0.866626

†Reference variable: Wind direction — north.
Joint test for interaction: Surfline wave height < 5 ft, Surfline wave height > 5 ft.
Chi^2 [2]: 79.47.
Prob > Chi^2: <0.0001.

Table A.3
Water level model.

	IRR	$p > \|z\|$	95% CI
Constant	0.0900224	0.000	0.029517–0.274547
Water level (ft)	0.7433965	0.000	0.690861–0.799926
Division 2‡	0.5138049	0.000	0.36124–0.730787
Division 3‡	0.026611	0.000	0.016301–0.043440
Water level * Division 2§	1.049447	0.362	0.946003–1.16420
Water level * Division 3§	1.84478	0.000	1.61675–2.10496
Ln(alpha)	2.016442	0.000	1.95555–2.07733
Random intercept: month	3.582436		1.530789–8.383811
Random intercept: month, day of week	0.6759126		0.420383–1.08676

‡Reference group: Division 1.
§Interaction term, reference group: Water level * Division 1.
Joint test for interaction: Water level * Division.
$Chi^2[2]$: 89.25.
Prob > Chi^2: <0.0001.

Table A.4
Rising vs. falling water level model.

	IRR	$p > \|z\|$	95% CI
Constant	0.0265503	0.000	0.009467–0.074455
Water level direction — rising**	2.025811	0.000	1.659494–2.47299
Division 2††	0.7607795	0.017	0.607707–0.952408
Division 3††	0.325522	0.000	0.249709–0.424350
Water level direction * Division 2‡‡	0.6587868	0.006	0.490636–0.884565
Water level direction * Division 3‡‡	0.4563771	0.000	0.319458–0.651977
Ln(alpha)	2.028434	0.000	1.96737–2.08949
Random intercept: month	3.105827		1.31908–7.31278
Random intercept: month, day of week	0.6611475		0.4124974–1.059682

**Binary categorical variable, Reference group: Water level direction — falling.
††Reference group: Division 1.
‡‡Interaction term, Reference group: Water level direction * Division 1.
Joint test for interaction: Water level direction * Division.
$Chi^2[2]$: 20.14.
Prob > Chi^2: <0.0001.

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