Mortality across drowning in the view of the meteorological parameters: relative humudity and sea wavelength.

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Abstract

Background: Drowning is a major, but often neglected, public health issue. Many interrelated factors are actively involved in the occurrence of drowning but the one between meteorological events has recently been increasingly the focus of attention.

Objective: To determine the effect of relative humidity and sea wavelength on mortality and weather they are independent risk factors for drowning.

Methods: A retrospective observational study was conducted on unintentional drowning cases aged over 18 years. Two drowning victim groups were formed as Group 1 (died at the time of event) and Group 2 (survived the event). Significant determinants of mortality across groups were evaluated in terms of relative humidity, temperature, sea wavelength, and relative humidity/sea wavelength.

Results: A total of 155 patients were enrolled in the study. Among these, 44 belonged to Group 1 and 111 to Group 2. Relative humidity and mean ratio of relative humidity/sea wavelength were higher but sea wavelength was significantly lower in Group 1 and statistically significant differences were found between groups (p<0.001 and p=0.025, respectively). We determined that age and the level of relative humidity were the significant predictors for mortality (p=0.002 and p<0.001, respectively).

Conclusions: Meteorological parameters along with contribution of geographical features, may cause fatal course in drowning cases especially in persons who are older or have comorbidities. Thus healthcare officials, meteorological services, and local government bodies should notify residents and visitors of coastal regions about the potentially hazardous effects of high ambient temperature and excess humidity.

Introduction

Drowning is an acute respiratory failure in which airways are immersed or submerged in liquid, most commonly water and represents the most common form of unintentional deaths, accounting for at least 500.000 fatalities per year worldwide [1,2]. Literature data suggest that many interrelated factors are actively involved in the occurrence of drowning cases; one such relationship, the one between meteorological events and human health, has recently been increasingly the focus of attention of physicians and meteorologists owing to the growing public and social interest in climatic and seasonal factors affecting human life. Hence, an increasing number of studies investigating the effects of meteorological parameters including seasonal air conditions and sea water temperature on the epidemiology of drowning cases has recently been published [3-6].

In the present study we aimed to determine the effect of relative humidity and sea wavelength on mortality and weather they are independent risk factors for drowning. In PubMed and Medline databases we revealed no studies that investigated the correlation between these meteorological datas and drowning.

Material and Methods

The study setting

This is a retrospective observational study analysing the unintentional drowning cases occured at Antalya Konyaaltı beach which the first responders in the field was made by 112 teams and and brought to the Emergency Department (ED) of Antalya Numune Training and Research Hospital between 1 January 2009- 31 December 2014.

Antalya is one of the main tourism centers of Turkey that is visited by more than 10 million visitors from every country each year. Konyaalti beach, located in the city center, is Turkey's second longest beach with its length of 1.5 km. Easy

access to it due to its central location in Antalya, as well as visitors being able to swim there in every month of year, make it a place where the highest number of drowning cases happens each year.

112 is the sole provider of emergency medical services (EMS) in Turkey and teams consist of paramedics or emergency medical technicians. At Konyaalti beach, Antalya there are two 112 teams located in the western and eastern of the beach and first responders to drownings are made by these teams.

Patient assessment and data collection

The study data were obtained from the patient files archived in the Emergency Department of Antalya Training and Research Hospital and the records of the data recording system of 112 Emergency Health Care Service. Based on these data, two drowning victim groups were formed as Group 1, which consisted of patients who were applied CPR by the 112 Emergency Health Care Service and declared dead upon unresponsiveness to CPR at the time of event, and Group 2, which consisted of patients who were brought to the Emergency Department of Antalya Training and Research Hospital after a successful first aid by the 112 Emergency Health Care Service. Patients who were 16 years or under and intentional cases were excluded from the study.

Data were collected on a pre-established proforma designed by us where demographic characteristics including age and sex, date and hour of the event, whether cardiopulmonary resuscitation (CPR) was performed, and meteorological information at the time of event including sea wavelength, relative humidity, and temperature (obtained from R.T Ministry of Forestry and Water Affairs, General Directorate of Meteorology, Regional Directorate of Antalya, Station No 17302) were recorded. Sea wavelength was determined using the METU3 (third generation wave estimation model) data obtained by using wind direction and velocity (Table 1). Relative humidity was recorded as percentage (%) and temperature was recorded as Celsius (°C).

Table 1. METU3 sea wave prediction model.

Code	Height(M)
0- Calm (GLASSY)	0
1- Calm (CHOPPY)	0-0.1
2- Flat (RIPPLE)	0.1-05
3- Mild	0.5-1.25
4- Temperate	1.25-2.5
5- Rough	2.5-4
6- Very Rough	4-6
7- High	6-9
8- Very High	9-14
9- Extraordinary	Above 14

Statistical analysis

Data were analyzed with the SPSS software version 21.0 for Windows (Armonk, NY: IBM Corp.). Categorical variables were evaluated using either χ^2 test and Fisher's exact test and presented as frequency and percentage. The distribution of continuous variables were evaluated by the shapiro-Wilk test and while Student's t-test was used for variables with normal distribution, Mann-Whitney U test was used for continuous variables without normal distribution and the values were presented as mean ± standard deviation (SD). Multivariate logistic regression analysis was used to evaluate the independent risk factors of death on the scene. Parameters with a p-value of less than 0.1 in univariate analysis were included in the model. The odds ratios (OR) and 95% confidence intervals (CI) were calculated. Comparison of the groups enrolled in this study in terms of relative humudity/sea wave height were analyzed using Receiver Operating Characteristics (ROC) curve methodology and specificity and sensitivity rates were calculated. A two-tailed p-value of <0.05 was considered statistically significant.

## Results

Between the specified dates, a total of 155 patients were enrolled in the study. Among these, 44 belonged to Group 1 and 111 to Group 2. Group 1 had 40 (90.9%) males and 4 (9.1%) females, and the mean age was 46.2 ± 23.6 years. There were 76 (68.5%) males and 35 (31.5%) females in Group 2 and the mean age was 28.4 ± 18.8 years. There was a significant difference between both groups with respect to both age and sex (p<0.001, p=0.004, respectively).

The comparison of the two groups with respect to seasonal occurrence of drownings revealed that deaths most commonly occurred in summer months in both groups (59.1%, n=26 and 69.4%, n=77, respectively). Deaths least commonly occurred in winter in Group 1 (6.8%, n=3) and spring in Group 2 (13.6%, n=6). Drownings mostly took place at 15:00 in Group 1 and 13:00 in Group 2.

In terms of mean age, relative humidity, temperature, sea wavelength, and relative humidity/sea wavelength statistically significant differences were found between Group 1 (died at the time of event) and Group 2 (survived the event). While relative humidity and mean ratio of relative humidity/sea wavelength were higher in Group 1 at the time of the event, sea wavelength was significantly lower in Group 1 compared to Group 2 (p<0.001 and p=0.025, respectively) as shown in Table 2. Median difference in humudity/sea wavelength level between death on the scene and control group measurement was 6 (31.0 to 37.0) and was shown in Figure 1.
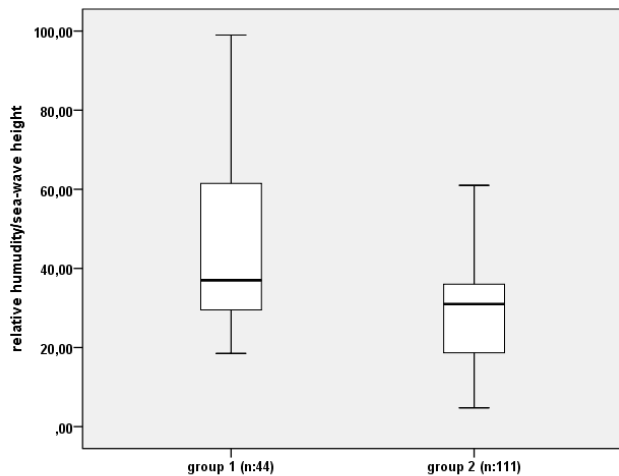
Figure 1. Boxplot diagrams showing humudity/sea wavelength level in study groups (Box plots represent median (horizontal line).

In the model using demographic properties and meteorological parameters to determine significant determinants of mortality at the time of event we first used univariate logistic regression analysis and then a multivariate logistic regression analysis. We determined that age and the level of relative humidity were the significant predictors for mortality (p=0.002 and p<0.001, respectively). Statistical analyses of other variables are shown on Table 3.

For all surviving and deceased cases a ROC analysis was performed for relative humidity/sea-wave height, and area under curve was found 0.720 (95% CI: 0.633-0.807). shown on Figure 2. Accordingly, a cutoff value of 22 for a relative humidity/sea-wave height had a sensitivity of 36% and a specifity of 95% (p<0.001).

Figure 2. ROC analysis of relative humudity/sea wavelength in both study groups.

Table 2. Comparison of Group 1 and 2 in terms of demographical characteristics and meteorological data.

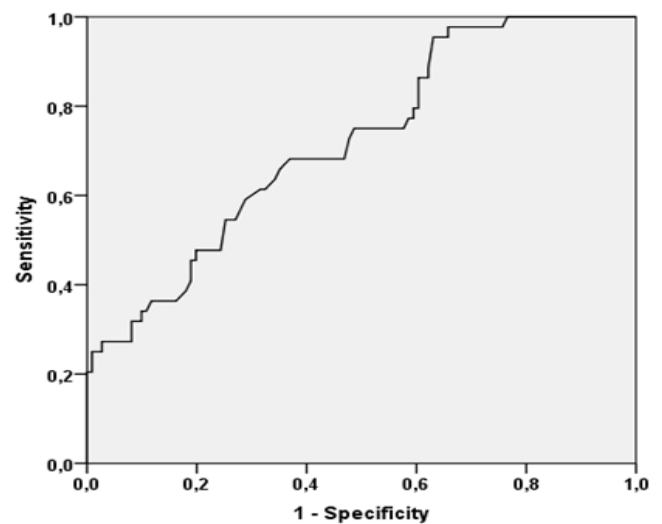| Variable	Group 1 (n=44)	Group 2 (n=111)	P value
Age, years	46.2 ± 23.6	28.4 ± 18.8	<0.001
Male gender, n(%)	40 (90.9%)	76 (68.5%)	0.004
Relative humudity (%)	71.2 ± 13.4	57.5 ± 18.3	<0.001
Temperature, °C	23,9 ± 5.8	27.8 ± 4.5	0.033
Sea wavelength (MTUC3)	1.8 ± 0.7	2.1 ± 0.8	0.025
Relative humudity/sea wavelength	44.8 ± 21.9	32.2 ± 18.5	<0.001

Table 3. Effects of demographical characteristics and meteorological data on mortality from drowning by univariate and multivariate logistic regression analysis.

Variable	OR (95% CI)	P value	Adjusted OR(95% CI)	P value
Age (years)	0.963 (0.946-0.979)	<0.001	0.970(0.951-0.989)	0.002
Gender	0.217 (0.072-0.654)	0.007	3.779(1.272-11.230)	0.017
Relative humudity (%)	0.945 (0.919-0.971)	<0.001	0.934 (0.904-0.966)	<0.001
Temperature, °C	1.086 (1.013-1.164)	0.019	1.042 (0.954-1.139)	0.361
Sea wavelength	1.550 (0.979-2.454)	0.062	1.433 (0.827-2.481)	0.199

Discussion

Although drowning is a potentially preventable cause of unintentional injuries, it continues to be a major, but often neglected, public health issue that is a major source of morbidity and mortality, with at least one third of survivors living the rest of their lives with moderate-to-severe neurological sequalae [7,8].

Being a poor swimmer or self-exaggerating one's swimming performance, taking unnecessary risks, using alcohol or illicit drugs, infants or children swimming without their parents' supervision, hypothermia, myocardial infarction or cardiac dysrhythmias, epileptic seizures, hyperventilation, dementia, frailty, and various conditions causing loss of consciousness including hypoglycemia in diabetics and developmental or mental disorders in children are all risk factors for drowning [3,9,10].

Males are at greater risk of drowning owing to some unfavorable behavioral and gender-related factors they possess, including spending more time in aquatic environments, more frequent risk-taking behavior and alcohol intake with resulting poor decision-making capabilities, underestimating potential risks, exaggeration of own capabilities, and increased self-esteem [1,4,11,12]. Mortality rates given in the literature are higher in the population victims who are 45 years or over intercompatible with our study probably due to the increasing comorbidities and a lower exercise capacity with advanced age and a higher incidence of drowning cases are seen in summer months as a consequence of increased time spent in water (sea) as well as more common sea tourism activities due to increased temperatures [1,12-15]. Aging causes an increase in cardiovascular, cerebrovascular and respiratory diseases.

As the elderly have limited thermoregulatory capacity associated with aging, they are more prone to untoward effects of extreme temperatures; in addition, they also possess some forms of cardiovascular and respiratory illnesses and these make them prone to potentially fatal effects of climate change and meteorological factors [16-24]. Comfortable temperature or the temperature with the lowest risk of mortality varies for different geographical locations and meteorological parameters. Therefore; when the relationship between relative humidity and pressure is considered, the cut-off level of effective temperature was calculated 16.7°C-24.7°C. Below or above this temperatures some physical, physiological, and psychological effects occur, and hence life-threatening medical conditions may emerge [16-19]. These findings support the significant correlation between air temperature and event mortality because mean air temperature was $27.8 \pm 4.5°C$ in Group 2, which had a higher mortality rate (p<0.033).

Relative humidity refers to the ratio of the amount of the available water vapour in air to the maximum amount of water vapour (maximum humidity) that air can carry at that temperature. Relative humidity is varied by air temperature and the amount of water vapor in air, and it is disproportional to air temperature. Studies have reported that air's relative humidity should be between 30% and 70% to be felt comfortable. However, in Black Sea and Mediterranean coastal lines relative humidity is increased by sea breezes during summer, making Antalya's air excessively humid that reduces heat loss through skin via skin respiration and augment sensible temperature. These events in turn trigger medical illnesses, and a correlation exists between hospital admissions and mortality [17,20-23].

Our study confirmed and found new predictors of drowning-related mortality including high relative humidity and low

wavelength which were associated with significant mortality as well as relative humudity/wavelength ratio which were correlated with very low mortality rates when the value was under the cut-off point of statistically calculated value of 22 with a specifity of 95%. We are of the opinion that the above findings suggest that when sea wave height is lower, people take courage to swim away and they face an increased risk of drowning due to reduced effort capacity when air is excessively humid.

Limitations

This is a single center study representing the characteristics of one geographical location. Also the type of the study (retrospective) is another limitation factor. Despite this, we were able to show some statistically significant results suggesting the meteorological predictors of drowning-related mortality.

Conclusion

In coastal line regions where sea tourism is widespread, alterations in meteorological parameters in summer months, along with a possible contribution of geographical features, cause an increase in the number of drowning cases, which have a fatal course especially in persons who are older or have comorbidities. Considering that drowning is a potentially preventable cause of injury, healthcare officials, meteorological services, and local government bodies should notify residents and visitors of coastal regions about the potentially hazardous effects of high ambient temperature and excess humidity. Air temperature, humidity, and sea condition warnings should ideally incorporate mobile applications that provide general public with necessary alerts. Drowning cases can be effectively minimized by local authorities by notifying people about unfavourable meteorological conditions before they get into water, and by lay people who are inexperienced in swimming or have certain comorbidities by swimming in shallow water and close to shore, wearing a life jacket, and stay close to others during the entire swimming period.

Former studies on unintentional drowning mortality were largely epidemiological and they usually reported data from a single country and children. This study is the first that studied the impact of relative humidity and sea wavelength on drowning cases we hope its results will be validated by future large-scale studies with the collaboration of medical and environmental sciences.

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