WASHINGTON SQUARE HEALTH FOUNDATION

1995 Heat Crisis in Chicago

Executive Summary:

An Area Morbidity Study of Hospital Emergency Room Treated Prevalence

May 1998

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EXECUTIVE SUMMARY

Study Objectives: To conduct an Emergency Department (ED) based treated prevalence study of heat morbidity. To estimate the rate and risk of heat morbid events for all Chicago MSA EDs (N=95; 2.7 Million visits per year). To describe the relationship between morbidity and mortality (M & M) due to heat, and illustrate the potential usefulness of ED-based real time M & M epidemiologic reporting for improving public health response to environmental disasters.

Methods: ED log information was compiled from 13 randomly selected hospitals located throughout the city and suburbs during the 2 weeks of the 1995 heat disaster and from the same 2 week period in 1994 (controls). Measurements included: patient age, sex, date and time of ED service, up to three ICD-9 diagnoses, and disposition. The technique of ratio estimation under simple random sampling was applied to estimate the number and characteristics of morbid events due to heat for both years. The sample ratio of the number of heat cases (y), and the total number of expected ED visits (x) was used to arrive at an estimated population ratio (Y/X), stratified by city and suburban hospital location. The common odds ratio was computed to compare 1995 heat cases against 1994 controls in order to illustrate the increased magnitude of morbid risk associated with the 1995 disaster. We also compared heat cases against all other diagnoses to illustrate case specific risk factors compared to the ED patient pool for each year. 95% confidence intervals were calculated for all rates and proportions. The relationship of morbidity to

mortality was illustrated using date and time overlay plots of the number of ED heat cases to the number of area deaths due to heat.

Results: Heat specific and heat related morbidity among all Chicago MSA hospital EDs was calculated at 4,224 (95%CI=2964-5488) cases. ED heat related morbidity increased significantly 5 days prior to the first heat related death. In 1995, there was an increase in risk for the city=3.85 and suburbs=1.89 over the control year of 1994. Heat cases were more likely to: be aged 65 plus or <12 years; have comorbid neurologic, endocrine, or respiratory disorders; and be admitted to hospital.

Conclusions: EDs can and should be used to predict the health care burden and epidemiologic consequences of environmental disasters. ED morbidity as determined by this treated prevalence study surfaced a unique set of risk factors compared to area mortality studies. Real time ED-based computer automated databanks should be constructed to improve public health response to infectious or noninfectious outbreaks. Rapid area-wide M & M tabulations can be used for advancing the effectiveness of community-based prevention programs, and anticipating hospital ED resource allocation.

Introduction

Background

During the time period of 7/6/95 to 7/19/95 an outbreak of heat related illness and death occurred in the Chicago metropolitan area. Since the 1995 disaster, two scientific articles (Semenza, 1996; and Whitman, 1997) have been published describing area mortality and risk factors associated with mortality. However, no national, state, or local organizations have attempted to measure and record the rate and risk of heat related illness in Chicago over the summer of 1995. Area hospital emergency departments (HED) were the recipients of population morbid and near fatal events which also characterized the heat epidemic. HEDs became the site of relief for many who sought to ameliorate the ill effects of protracted heat. The focus of this study is on the antecedents of area mortality, namely morbidity or the diminishment of population quality of life due to heat for which emergency medical care was sought. It was reasoned by study authors in 1995, and recommended by the U.S. National Oceanic and Atmospheric Administration (NOAA) in 1996 that such additional epidemiologic information was necessary to devise a truly comprehensive early warning system for the people of the Chicago Metropolitan Area.

Historical Reporting of Heat Disasters

A current review of the scientific literature on the history of recorded epidemics in the US and their consequences during the mid-19th, and the first & second halves of the 20th century (1854-1995) reveals no population community based or institutional based studies which accurately reflect population impact of excess morbidity due to heat. Cities which have largely reported mortality data include Chicago, Memphis, St. Louis,

Washington DC, Philadelphia, Los Angeles, New York City, Detroit, Kansas City, Boston, Chatanooga, Cleveland, Hartford, Cincinnati, Evansville, Newark, Fredericksburg, Louisville, Huntington, Bismarck, and Wichata.

Scientific Problems

There are no standards for conventional reporting of morbidity and mortality in the scientific research to date. Reporting of mortality has been routine through the years including a 1916 Chicago heat epidemic reported by Cook County Hospital statistical records. The 1916 heat outbreak in Chicago was actually more severe than 1995 adjusting for population change.

Mortality studies are plagued and unreconcilable because no standard definition for heat related death has been developed. Morbidity has been reported to a far lesser extent, and risk factors of uncertain magnitude have been assessed in the literature, but using either anecdotal or case series study designs. Prevalent heat related and heat specific diagnoses have been reported in previous epidemics, but their sampling frames due not lend themselves to credible or useful epidemiologic rate information. Our review of the literature pertaining to morbidity studies however, helped us fashion our heat specific diagnostic categories for testing excess rates. The state of the art vis a vis monitoring and surveillance of heat epidemics in US cities and urban regions is improving. Although , efforts such as capturing accurate early indicators (e.g. morbidity or deteriorating quality of life) of heat epidemics are badly needed. We theorized that morbidity data as found and reported in this study provides necessary advancement in use of heath data for testing climatologic research theory (i.e. air mass) and use of health data for testing meteorologic research theory (i.e. apparent temperature, and heat index).

Why Study Institutions?

Hospital emergency departments (HED) are rich sources of epidemiologic data for the country. Ninety six million patient visits occur annually in the United States, a number that is nearly half the population of the entire United States. An unduplicated estimate of 30-40% (33.6/100 persons) of the U.S. population uses a hospital emergency department for health care in any given year. Public health organizations have only recently recognized the potential of examining HED treated prevalence populations for health policy and program development purposes. Emergency medicine physicians have long claimed that their patients: 1) provide a measure of epidemiologic phenomena in the community; 2) mirror clinical preventive and primary health care services capacity and performance in the community; 3) indicate problems with access to noninsitutional care; and 4) can describe populations at morbid and mortal risk during environmental disasters. Given that academic institutions and good government both strive for rational health policy and program development, HED treated prevalence populations may be the most understudied epidemiologic sentinel in urban America.

Use of Study information

In our local area, preventive efforts during heat climatic crises are concentrated in developing Chicago area Departments of Health heat alert prevention programs. The city of Chicago Department of Health (CDOH) program was mounted in light of more than 700 heat related local area excess deaths which occurred during the summer of 1995. Initial efforts to identify the target population for preventive services included only a fraction of the population at risk. It is hoped that this study will help to further fine tune

local area heat alert prevention programs, as well as address the personal preventive care educational needs of individual citizens in both urban and suburban communities.

This research is aimed at quantifying the proportion of the population which was affected by the climatic outbreak enough to seek care for morbid and near mortal conditions in all Chicago area HEDs. In the planning stages of this research, we hypothesized that the ED treated prevalence population may range from four to twenty times the number of heat related deaths recorded by the CDC, the Cook County Medical Examiner, and the CDOH. A second planning goal was to use independent samples epidemiologic methods to identify risk factors uniquely associated with the 1995 cohort versus 1994 controls. Our study provides important information to the urban hospital community with regard to anticipating the additional health care burden for Emergency Medical Systems (EMS transport-e.g. fire departments and paramedics), as well as area HEDs. In another light, our study public provides health preventive and primary care programs a more complete picture of the population at risk for targeting and resource allocation purposes. Finally, as area HEDs progressively automate and computerize their patient databases, we propose that our study will provide a future template for planning and evaluation of public health preventive and primary health care programs during climatic outbreaks or other environmental disasters in the Chicago Metropolitan Area.

Study Methods

Bibliographic Research

Our study team conducted multiple literature reviews on the topic of heat related illness, pathophysiology, death, and epidemics. We also reviewed weather related climatologic and meteorologic research on early warning systems in the US. A capsular

summary of pertinent literature reviewed, along with a matrix of critical commentary for each study is attached in Appendix 4. The results of our literature review on early US warning systems and programmatic recommendations for individual citizens appear in Appendices 5 and 6. respectively. The reader should note that our literature review is current through April 1998.

Sample & Design

The technique of ratio estimation under simple random sampling was applied to determine the number and characteristics of morbid events in area hospital emergency departments due to heat during the period of 7/6/95 to 7/19/95. Both period and daily rates of heat morbidity were calculated for all hospitals combined and were further stratified by city and suburban location. In addition, the risk of heat related morbidity for selected age groups, as well as other sample descriptive variables (e.g. sex, comorbitites, time of arrival, and disposition) was determined by computing the common odds ratio through comparisons of the characteristics associated with 1995 heat cases against all other 1995 emergency department cases. The increase in overall risk for heat related morbidity, as well as for subpopulations with selected characteristics was determined by comparing heat cases in 1995 against a control sample of heat cases in the year of 1994.

Our study utilized a two-stage, randomized, self-weighted sampling procedure. Our sample consisted of seven hospitals within the city of Chicago, and six suburban "collar" hospitals immediately adjacent to the borders of the city. All hospitals were selected at random. Our sampling frame consisted of city and suburban hospitals which were operating "full service" emergency departments (ED), i.e. serving all age groups. This comprised our first sampling stage. Once our hospitals were determined, (see

Appendix 3) a 10 percent random sample of ED logbook patient visits calculated on the basis of daily volume were reviewed by research associates experienced in ICD9 diagnostic coding. We obtained daily ED logbooks for our study period 7/6/95-7/19/95, and for the control period 7/6/94-7/19/94. This comprised the second sampling stage. **(Specialty pediatric HEDs within the city were excluded from the analysis. The effects of their omission are addressed in our discussion of results).**

Study Measures and "Case-ness"

Our hospital-level study measurements included: annual and period specific patient volumes, as well as over 150 hospital performance, service, and descriptive organizational variables. These were obtained from the 1994 and 1995 American Hospital Association Annual Survey of Hospitals databases, and the Illinois College of Emergency Medicine's (ICEP) Directory of Emergency Departments for 1995. Normative distributions of ICD9 diagnoses in US HEDs were obtained from the 1996 U.S. National Ambulatory Health Care Survey (NAMCS).

Our patient-level study measurements obtained from hospital specific ED logbooks included: patient age, sex, date and time of arrival, up to three ICD9 discharge diagnoses, and disposition. Heat specific ICD9 diagnoses included: hyperthermia, heat stroke, heat tetany, heat exhaustion, heat cramps, heat exposure, heat syncope, heat edema, heat rash, and sunburn. If any ICD9 codes for these diagnoses were present among the first three diagnoses per patient, that patient was considered a heat case.

Our community-level data for both the study and control periods included: percent of total heat cases, and area mortality by day of week; minimum / maximum ambient temperature, and heat index by day of week for the Chicago Metropolitan area. These

were obtained from the Centers for Disease Control (CDC), the Chicago Department of Health (CDOH), and the U. S. National Oceanic and Atmospheric Administration (NOAA) respectively.

Statistical Procedures

Statistical analyses proceeded temporally in several stages, each addressing a specific study hypotheses.

First, descriptive statistics were run on all variables. For categorical level data, proportions and standard errors were generated. For continuous level data, tests for normality, means, and standard deviations were performed.

Second, we generated the rates for heat specific diagnoses by the independent variables (IV) of year, day of the week (7/6-7/19), age, sex, time of arrival, disposition, and comorbid diagnoses.

Third, a within year (e.g. for 1994 only and 1995 only) crosstabulation of heat diagnoses by all other diagnoses was performed on all independent variables afforementioned. This analysis permitted us to assess risk factors associated or disproportionately extant among heat cases versus all other diagnosis for both 1995 and the 1994 control year, (e.g. Were any age groups more likely to have a heat diagnosis? Were heat cases more likely to be admitted to hospital inpatient care?). Chi-square tests for independence and estimated relative risks (i.e. odds ratios) were calculated with 95% confidence intervals. This analysis was performed using city/suburban stratifications, and for all are hospital locations combined.

Fourth, we compared the characteristics (e.g. age groups, disposition, etc.) associated with heat cases in our control year of 1994 to our epidemic year of 1995 in

order to assess the increase in risk among patients characterized by selected categories of our independent variables e.g. How much more at risk of heat related illness were age groups of 1-12 or 25-44 in 1995 versus 1994). Chi-square tests for independence and estimated relative risks (i.e. odds ratios) were calculated with 95% confidence intervals. Where continuous level data were involved and/or rank transformed, t-tests were employed. This analysis was performed using city/suburban stratifications, and for all are hospital locations combined.

Fifth, we plotted overlays of daily heat morbidity against daily heat mortality, and percent of heat cases by day of week from 7/6/94 to 7/19/94 and 7/6/95 to 7/19/95. This was done to illustrate a left shift in the time differential between the onset of excess heat morbidity in relation to the onset of heat mortality. We conducted Cochran-Mantel-Haentsel chi-square, general association, and nonzero correlation tests. These tests, along with multivariable discriminant function analyses revealed trends in heat case rates over time by day of week. This analysis permitted detection of statistically significant sentinel rates useful for early warning systems monitoring ED heat incidence or prevalence rates.

Finally, we performed five major Pearson and Spearman correlational analyses, as well as linear regression procedures using daily heat morbidity rates (and extrapolated number of heat cases for the sample and all Chicago MSA EDs) as our dependent variable against: daily ambient temperature, daily heat indexes, daily rates for all other diagnoses, and daily mortality. This analysis was performed in an attempt to detect and illustrate the intercorrelation of independent population, climatologic, and meteorologic data.

Results

Overall Prevalence of Heat Disorders

Analysis of overall prevalence for heat related illness identified 2,523 (95%CI=1720-3287) cases in our sampling frame (N=50 hospitals; 1.56M visits/annum), and 4,224 (95%CI=2964-5488) cases when extrapolating city and suburban rates to the entire network of Chicago MSA hospitals (N=95 hospitals; 2.7M visits/annum). Specific rates for urban EDs were 4.38/100 in 1995 versus 1.18/100 in the 1994 control year (OR=3.85). Specific rates for suburban EDs were 3.90/100 in 1995 versus 2.10/100 in the 1994 control year (OR=1.89). Heat related illness rates in combined area HEDs during the period of 7/6/95 to 7/19/95 ranged from a low of 0.7/100 patients to a high of 12.3/100 patients (**see Text Tables 1-2, Text Figures 1-2 and Appendix 1, Tables 1-12B**). This amount of heat related illness was found to be roughly six times the upper limit estimated rate of heat related mortality (N=700) reported by previous investigators in Chicago. The three most frequent heat related diagnoses were hyperthermia (61.7%), heat exhaustion (20.2%), and heat stroke (5.3%). These were followed by: heat tetany (4.2%), nonspecific heat diagnoses (4.2%), heat cramps (2.1%), heat syncope (1.0%), heat rash (1.0%), and sunburn (1.0%).

The Relationship of Morbidity to Mortality

Text Figures 3-4 and **Appendix 2** depict the relationship of both sample and population morbidity estimates to mortality by day of the week during 7/6/-7/19/95. These figures reveal a statistically significant rise in HED heat cases on the 8th of July 1995, five days before the first recorded heat related fatality on 7/13/95. There is a continual upward trend in HED heat morbidity peaking on the 14th of July, and tapering

downward, but still higher than normal through the end of the study period on 7/19/95. One day, 7/12/95 marks an exception to the continuous upward trend. We have no ready explanation for this, except that area HEDs may have been on bypass that day. This occurrence has not been reconciled as of this date. **Text Tables 1-2** also illustrate the daily ranges of heat rates as well as the proportional distribution of all period heat cases by day of the week.

The Relationship of Morbidity to Mortality, Ambient Temperature and Heat Index

Text Tables 1-2 demonstrate intercorrelations of morbidity to mortality, ambient temperature, and heat index. During 1994, HED heat morbidity was highly correlated with the only heat related death recorded (r=.58; p=.03), but not ambient temperature or the heat index. For 1995, however, HED morbidity was not only related to heat related deaths (r=.48; p=.10); but also ambient temperature (r=.72; p=.004); and the heat index (r=.80; p=.000). **Text Figures 5 and 6** depict the relationship of HED heat morbidity to the meteorologic independent variable data. These correlations are quite high suggesting that HED surveillance of heat morbidity covaries more closely with the meteorologic data than heat related mortality. As a result, we believe HED morbidity is a better indicator of the sequelae of extreme weather related phenomena than mortality, which was correlated with temperature at r=.38; p=.17 and heat index at r=.46; p=.09. This finding alone may justify the re-application and investigation of 1995 NOAA meteorologic research with Chicago area HED morbidity research.

The Risk of Heat Related Morbidity

Text Tables 3-4 illustrate two sets of relative risk data. **Text Table 3** shows the stratum specific heat rates, and proportion of period heat cases, as well as estimated

relative risks for each multi-level category of location, age, sex, arrival time, primary diagnosis co-morbid with a heat diagnosis, and patient disposition. Differences were found in age groups, comorbid primary diagnosis, and disposition. No differences were found in location, gender, or arrival time. The highest rates of heat illness were found among persons aged 1-12, followed by ages 65 plus, and 45-64. The second highest proportion of all period heat cases was found among persons age 25-44 years, but the large denominator of this group rendered it to be protective epidemiogically. This 25-44 year age group remains of importance to clinicians however, as they may tend to contain the modal number of actual cases in any given heat outbreak. Primary diagnostic groups most likely to have a comorbid heat diagnosis were persons with nervous disorders (e.g. on certain medications), endocrine disorders (e.g. diabetics), respiratory disorders (e.g. COPD, asthma) and mental disorders (e.g. on neuroleptics or antidepressants). If patients had a heat related diagnosis, they were admitted to the hospital inpatient wards more often (OR = 1.73) than all other diagnoses combined. This nearly twofold risk of hospital admission from the ambulatory service for ED heat cases demonstrates an additional burden on the cost and utilization of health care likely during heat epidemics.

Text Table 4 illustrates the increase in risk for heat illness patients in 1995 over the 1994 control year by independent variable strata. For example, city residents demonstrated a more serious increase in risk (OR=3.85) than suburban residents (OR=1.89). Residents aged 45-64 and 25-44 also demonstrated more risk than other age groups in the combined city/suburban sample. This shift in middle age population susceptability was more pronounced in suburban locations which saw the mean age among heat cases jump from 19 years in 1994 to 36 years in 1995. The mean age of city

heat cases actually decreased from 50 years to 44 years, putting younger people more at risk of heat illness. Other 1994 to 1995 comparisons revealed increased risk among males; arrival times of 6PM-12AM; persons with primary diagnoses of endocrine, respiratory, and mental disorders; and total numbers of persons discharged home with a heat diagnosis.

Text Tables 5-6 portray the 1995 distribution of daily morbidity rates and period mean rates for heat cases and the 11 most frequent ICD9 diagnoses. The purpose of this analysis was to twofold. First, in order to further validate our sample (albeit to the exclusion of seasonal norms) we compared the period mean Chicago area HED treated prevalence population rates against national norms from the US NAMCS (**see Table 5**). Second, we correlated the heat rates against all other diagnoses (**see Table 6**) in order to detect a possible misclassification bias of heat cases in other diagnostic categories, e.g. infection rather than hyperthermia, or circulatory disorders rather than heat stroke. A misclassification bias as described above may result in an underestimate of heat cases. Indeed, several diagnostic categories were found to be elevated over national norms. These include: infections, endocrine disorders, mental disorders, circulatory disorders, signs and symptoms ill defined, and injury and poisonings. We do not know if these elevated rates are due to misclassification, or to seasonal or geographic variation. It is important to note that two major diagnostic categories were also depressed compared to national norms. These may have caused an offsetting overestimate of rate results. They include: nervous and respiratory disorders. Overall however, the only diagnostic category which also correlates with the epidemic time curve is injury and poisonings ($r=.47$; $p=.10$). This may have been a "catch all" diagnostic category as it contains a

subtype of "all other injury," therefore suppressing a possible larger estimate of heat cases overall. The comparative increased risk of heat cases in 1995 versus 1994 would also be underestimated by this, although, such a potential bias in the annual comparison would most likely offset by the propensity of physicians to misclassify heat cases over a broader array of other diagnostic categories during a normal or control year, e.g. when less attention was given to environmental factors influencing diagnoses.

Text Table 7 shows the odds of a heat case having a comorbid diagnosis among any of the three ICD9 diagnoses measured for each patient for years 1994 and 1995. This is different from **Tables 3-4** which represent heat cases with a primary comorbid diagnosis. In the 1994 control year, heat cases were positively related to infections, nervous system disorders, signs and symptoms ill defined, and inversely related to injury and poisoning. During 1995 however, comorbidities were the positively related to endocrine disorders, signs and symptoms ill defined, and injury and poisoning. Digestive and genitourinary disorders were inversely related.

Discussion & Conclusions

Perhaps the most compelling finding of this study is reflected in the 1994-1995 differential increase in the estimated relative risk of 3.85 for the city of Chicago with a period prevalence of 4.38/100 patients seen in area HEDs. In the 1994 control year the identical period rate of heat cases was only 1.18/100. The city customarily provides a protective effect against rises in ambient temperature due to the cooling effect of the lake waters. This is further evidenced by a higher suburban heat case rate of 2.10 in the 1994 control year, and the comparative risk of only 1.89 in the suburbs from 1994 to 1995. The fact that suburban heat cases were on average much older in 1995 than the control

year suggests a possible outmigration of city residents to collar suburban hospitals as well. This is an occurence for which suburban area HEDs should be prepared. The phenomenon worthy of attention in 1995 is when the city experiences protracted heat, coupled with large hot air masses (the remaining factor in the equation), it loses its protective effect and becomes the ill-famed "urban heat island"...an area of high risk for HED morbidity and residential mortality.

There were several challenges to our study plan which are worthy of notation. First, one of our sample hospitals selected at random closed in 1996, forcing us to replace it with another randomly selected hospital due to the unavailability of ED logbooks Second, as with any study of this size, there were problems with the ED logbook entries themselves as a source of patient data. These included: nonstandardization of data fields, illegible entries, incomplete entries, and uncodable information. In each of these cases, our 10% random sampling of logbook entries included up to a 5% daily volume oversample to replace unusable patient records.

One limitation of this study was the omission of pediatric HEDs in our study sample. Our hospital sampling plan included only "full service" HEDs serving all age groups. This omission may have resulted in an underestimate of HED treated prevalence heat rates in the city of Chicago due to the fact that the 1-12 year age group was at abnormally high risk for heat illness. This omission was less serious for estimating the total numbers of city heat cases given that the expected volumes in pediatric HEDs were used to produce total numbers. Given our associated standard errors and 95% confidence intervals, we predict any decrease in rate estimation to be within our reported limits.

Another limitation of this study is the stability of heat period prevalence rate estimates using only one control year. Ideally, as many as ten or more control years of identical periods should be used to maximize precision of control year estimates, if available. The problem with morbidity data (unlike mortality data available from routine vital statistics reporting) is that local HED treated prevalence rates are not routinely available.

EDs can and should be used to predict the health care burden and epidemiologic consequences of environmental disasters. This is especially true in an era of high speed computers and networking capability. It took our study team nearly 30 months to compile and analyse the data in this report, something which could potentially be accomplished by the technology of today in real time. Such a system would further hone the diagnostic skills of physicians, further capacitate EMS reaction time, and standardize physician treatment protocols during this or other disasters which may occur in the future, be they infectious, noninfectious, or terrorist in nature.

Recommendations

Meteorologic/Climatologic Analysis

Our first recommendation is to form a scientific partnership with NOAA investigators to perform a more in depth analysis of Chicago area heat morbidity data against historical air mass and humidity, and ambient temperature data. Findings from such an analysis may provide more insights for early detection programs, and National Weather Service Programs and Products.

Health Impact

Our second recommendation is to seek funding from a variety of government, community corporation, and private foundation sources to begin the construction of a computerized network of HED M & M databases for areawide treated prevalence reporting in real time. We intend to capitalize on the formation of the hospital consortium accomplished in this and other ongoing studies, and to include the 50 hospital network in an areawide epidemiologic network with real time capability for reporting noninfectious and infectious disease epidemics.

Provision of NWS Products and Services

Our third recommnedation is to link the areawide M & M HED database to the National Weather Service (NWS) strategies and programs to further refine the criteria for heat watches, alerts, and warnings.

Communication Emergency Preparedness, and Community Response

Our fourth recommendation is to tie existing HED reporting mechanisms into the heat preparedness programs in our local area. Increases in HED heat prevalence cases are presently used in three major cities see Appendix 5-7. None of these formally include Chicago as yet. We recommend that if the daily rate of heat related illness seen in area HEDs rises above 2.0/100 in the city, and 2.50/100 in the suburbs-a heat alert should be in effect. If the HED rates reach 2.5/100 in the city and 3 0/100 in the suburbs-a heat warning should be issued. Special attention should also be given to the patient characteristics of heat cases seen in the HED. For example, if lower risk groups are being

seen among the HED treated prevalence population, then it may be more likely that an outbreak of heat related illness is eminent.