

Excess Hospital Admissions During the July 1995 Heat Wave in Chicago

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Introduction: This study describes medical conditions treated in all 47 non-VA hospitals in Cook County, IL during the 1995 heat wave. We characterize the underlying diseases of the susceptible population, with the goal of tailoring prevention efforts.

Methods: Primary and secondary discharge diagnoses made during the heat wave and comparison periods were obtained from computerized inpatient hospital discharge data to determine reasons for hospitalization, and comorbid conditions, respectively.

Results: During the week of the heat wave, there were 1072 (11%) more hospital admissions than average for comparison weeks and 838 (35%) more than expected among patients aged 65 years and older. The majority of this excess (59%) were treatments for dehydration, heat stroke, and heat exhaustion; with the exception of acute renal failure no other primary discharge diagnoses were significantly elevated. In contrast, analysis of comorbid conditions revealed 23% ($p = 0.019$) excess admissions of underlying cardiovascular diseases, 30% ($p = 0.033$) of diabetes, 52% ($p = 0.011$) of renal diseases, and 20% ($p = 0.027$) of nervous system disorders. Patient admissions for emphysema ($p = 0.007$) and epilepsy ($p = 0.009$) were also significantly elevated during the heat wave week.

Conclusions: The majority of excess hospital admissions were due to dehydration, heat stroke, and heat exhaustion, among people with underlying medical conditions. Short-term public health interventions to reduce heat-related morbidity should be directed toward these individuals to assure access to air conditioning and adequate fluid intake. Long-term prevention efforts should aim to improve the general health condition of people at risk through, among other things, regular physician-approved exercise.

Medical Subject Headings MeSH: heat, heat exhaustion, patient admission, hospitals, urban (Am J Prev Med 1999;16(4):269–277) © 1999 American Journal of Preventive Medicine

Introduction

High summer temperatures can result in increased mortality among at-risk populations, such as elderly people and urban dwellers.^{1–6} However, only a few studies have characterized nonfatal heat-related illnesses during heat waves. During the heat wave of 1980, hospital admissions in St. Louis and Kansas City were found to be increased by 5.1% and 1.5%, respectively.² Also in 1980, in Memphis, there were 483 emergency department visits for heat-related illnesses. The most common diagnoses were heat ex-

haustion (58%), heat stroke (17%), and heat cramps (6%).⁷ In Adelaide, South Australia, potential medical risk factors identified for heat illnesses included diabetes mellitus, heart failure, and alcoholism.⁸

The health impact of heat depends not only on weather conditions at any given time, but also on previously existing health conditions and socioeconomic status.^{1,9} The heat wave in Chicago in July 1995 provided an opportunity to study the nonfatal health effects of hot weather for the population served by Cook County hospitals. Previous studies have focused on heat-related mortality in Chicago.^{1,10,11} Our objectives were to retrospectively determine if there was an excess of hospital admissions as a result of the hot weather, ascertain the principal reason for hospitalization, and define the underlying medical conditions of the susceptible population. We compared the number of hospital admissions during the heat wave week with an average number for comparison periods without a heat wave.

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A key contribution of this study is that we characterize the population at risk for heat-related morbidity that can be targeted with public health interventions. We propose prevention measures for individuals with specific underlying medical conditions with the goal of preventing heat-related morbidity in the future.

Methods

Chicago weather data for O'Hare airport, the official Chicago measuring station, was obtained from the Mid Western Climate Center. For every day in July 1995, we plotted the highest hourly heat index (apparent temperature), which is a function of temperature (in degrees Fahrenheit) and the relative humidity. The heat index measures the evaporative heat between a typical human and the environment and is a better measure of the effect of heat on the body than temperature alone.

Data Source and Statistical Analysis

Computerized inpatient hospital discharge data for Cook County (which includes the city of Chicago) was obtained from the Illinois Health Care Cost Containment Council (IHCCCC). All Illinois hospitals (except the Veterans Administration [VA] Hospitals) are required by law to provide Illinois with discharge data, including patient diagnoses and treatment procedures. The research data set (RDS) used for this study contains selected data elements for each patient discharge record collected and processed by the IHCCCC. Discharge diagnoses were coded by professional nosologists according to International Classification of Diseases, Ninth Revision (ICD-9). We used the RDS for July 1994 and July 1995 for the 47 non-VA hospitals (17,351 beds total) in Cook County. 1994 was chosen as a comparison year because Cook County did not experience a heat wave that year. The data were analyzed according to patients' date of admission and age group (<65 and ≥65 years of age). For each patient admitted, up to 9 discharge diagnoses can be recorded. Only one of these is listed as the primary health condition for which the patient was hospitalized, while the remaining are secondary discharge diagnoses accounting for (conceivably several) existing or comorbid conditions. Primary discharge diagnoses were analyzed alone to evaluate the reasons for admission during the heat wave study period and to determine the principal disease process treated during hospitalization. In contrast, primary and secondary discharge diagnoses combined were analyzed to determine additional diagnoses recorded by hospital staff, such as underlying medical conditions present at the time of admission, as well as potential interactions among diagnoses.

In general, the average number of admissions on

weekend days is lower than the average number on weekdays, resulting in a cyclical pattern of the data. To account for this pattern and to estimate the number of excess admissions associated with the heat wave period, we used 2 methods. For the graphic illustration of excess admissions, we calculated the average number of admissions for each day of the week for July 1994. Because it was a holiday, the 4th of July was treated as a Sunday and included in the average for all the Sundays of July 1994. After determining an average for each day of the week in July 1994, we then compared every day in July 1995, on an individual basis, to its corresponding day of the week average from 1994. To determine the excess or deficit in admissions during July 1995, we subtracted the appropriate July 1994 day of the week average from the number of admissions recorded on each day in July 1995. As in the 1994 averages, the 4th of July 1995 was considered a Sunday for these comparisons. We then plotted the resulting excess or deficit for each day of July 1995 along with the heat index for that day.

The observed number of admissions for the heat wave study period, here defined as July 13 through 19, was calculated by totaling all the admissions reported during that week. We chose this week because the rapid onset of the heat wave on July 11 was paralleled by the occurrence of heat-related mortality, with a 2 day delay, beginning on July 13.^{1,11} Furthermore, July 13th represented the peak of the heat wave as defined by the heat index, with the heat index reaching an all-time high of 119°F, and the first heat-related hospital admissions began to appear on July 13 (Figure 1).

For further statistical analysis of our data, we calculated an expected number of weekly admissions by averaging the number of admissions recorded during 4 comparison weeks: the week just prior to the heat wave in 1995 (July 6 through 12, 1995) and 3 weeks in July 1994: July 6 through 12, July 13 through 19, and July 20 through 26. These weeks were chosen to avoid including the 4th of July holiday and to have weeks comparable with the heat wave study period. This weekly average (the expected number of admissions) was then subtracted from the number of admissions recorded during the week long heat wave study period (July 13 through 19, 1995) to determine an excess or deficit in hospital admissions during the heat wave. A 95% confidence interval was calculated, using a standard method based on the *t*-distribution for differences between independent means with unknown but equal population variances, and the significance of this excess or deficit was evaluated by a two-tailed *t*-test.

Results

In July 1995, there were 42,304 people admitted to non-VA hospitals in Cook County (which includes the

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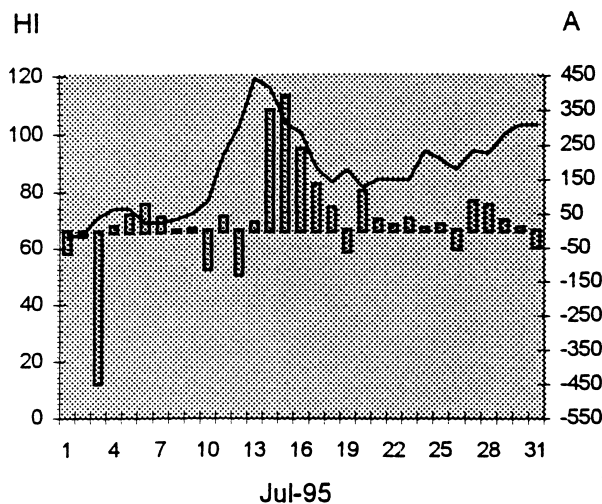


Figure 1. Estimated excess of inpatient hospital admissions for all primary discharge diagnoses combined, Cook County, July 1995. Excess or deficit admissions for every day in July 1995 were calculated by subtracting a day-of-the-week average for July 1994 from the appropriate day-of-the-week in July 1995. The heat index (HI), a function of temperature (in degrees Fahrenheit) and relative humidity is illustrated with a line. Hospital admissions (A) are illustrated by bars above or below baseline.

city of Chicago), compared with 40,910 in the month of July 1994. During the heat wave study period (July 13 through 19, 1995), the number of hospitalizations exceeded the average for non heat wave weeks by 1072 ($p = 0.054$) (Table 1, Figure 1), but no morbidity displacement was observed to supersede this excess. Although the increase for all diagnoses and age groups combined did not reach statistical significance, analysis by age group found a significant increase for individuals aged 65 years and older. There were 838 ($p = 0.004$) more inpatient admissions in this age group during the heat wave week than in the non heat wave comparison weeks.

Primary Discharge Diagnoses: Principal Reason for Hospitalization

The primary discharge diagnosis, defined as the main disease process that resulted in hospital admission, was analyzed alone, without taking into account underlying conditions. Of the estimated 1072 excess admissions, 443 ($p < 0.001$) were heat-related diagnoses (Table 1, Figure 2), including heat stroke and heat exhaustion. An excess of 245 ($p < 0.001$) primary discharge diagnoses of fluid disorders and electrolyte and acid-base imbalance were found, of which volume depletion alone accounted for almost 200 ($p = 0.001$) excess admissions. Admissions for acute renal failure, possibly a consequence of dehydration, were significantly elevated (388%, $p = 0.003$) (Table 1), whereas admissions for chronic renal failure (-39%, $p = 0.103$) were not.

Dehydration (ICD-9 codes 276.5 and 992.3), heat stroke, and heat exhaustion were the main reasons for hospitalization. In contrast, primary discharge diagnoses of cardiovascular, diabetes, and respiratory diseases were not significantly elevated during the heat wave (Table 1).

Primary and Secondary Discharge Diagnoses: Susceptible Population

Comorbid conditions of those individuals at increased risk during the Chicago heat wave can be described by an evaluation of primary and secondary discharge diagnoses combined. Excess primary and secondary conditions define underlying conditions of the susceptible population. Although no statistically significant excess of hospitalizations with a primary diagnosis of cardiovascular diseases was seen during the heat wave period (see above and Table 1) 461 admissions (Table 2) over expected were found for primary and secondary discharge diagnoses combined, indicating that patients with a history of cardiovascular disease were at increased risk for hospitalization (Figure 3). In particular, patients older than 65 years of age with underlying cardiovascular disease were at increased risk, with an excess of 390 (95%CI, 192 to 588) inpatient admissions in that age group. The number of people admitted with underlying ischemic heart disease was 19% higher than expected; 68% of these patients hospitalized during the heat wave week were over 65 years of age (Table 1). No increase was found for myocardial infarction, but the number of angina pectoris diagnoses was elevated ($p = 0.055$). A 25% ($p = 0.047$) increase was found for several other pre-existing heart diseases combined, including an excess of heart failure admissions, and an excess for cardiac dysrhythmias (Table 1).

There was also an excess of pre-existing diagnoses for hypertensive disease and diseases of arteries, arterioles, and capillaries such as atherosclerosis during the heat wave study period. Admissions of people with cerebrovascular disease were up by 23% ($p = 0.013$), of which late effects of cerebrovascular diseases (sequelae, or present one year or more after the onset of the causal condition) (63%; $p < 0.001$) accounted for the majority of the excess; in contrast, stroke ($p = 0.863$), hemorrhage ($p = 0.611$), transient cerebral ischemia ($p = 0.142$), acute ($p = 0.089$) and ill-defined ($p = 0.451$) cerebrovascular disease did not contribute substantially to this excess. There were excess admissions of individuals with underlying diabetes (Figure 4, Table 1) including a statistically significant increase for noninsulin dependent diabetes (NIDDM) ($p = 0.029$). Ketoacidosis and hypoglycemia admissions were not markedly elevated. Admissions of individuals with a diagnosis specified as drunkenness (ICD-9: 305) were elevated by 97 (95%CI, -3 to 197) and alcoholic cirrhosis of the

Table 1. Excess inpatient admissions by primary discharge diagnosis: principal reason for hospitalization, Chicago, July 1995

Diagnosis	ICD-9 Code	Observed ^a	Observed ^a >65 years (%)	Expected ^b	Excess ^c (95% CI)	P-Value
All Diagnoses Combined	all	10,739	3230 (30%)	9667	1072 (11%) (-32, 2176)	0.054
Cardiovascular Diseases	390-398 402 404-429 440-448	981	582 (59%)	893	89 (10%) (-111, 288)	0.252
Diabetes Mellitus	250	182	60 (33%)	148	34 (23%) (-72, 139)	0.384
Disorders of Fluid and Electrolyte Balance	276	365	224 (62%)	120	245 (205%) (221, 270)	<0.001
Volume Depletion (Dehydration)	276.5	282	176 (62%)	85	198 (234%) (155, 240)	0.001
Chronic Liver Disease and Cirrhosis	571	44	11 (25%)	32	12 (38%) (-5, 29)	0.11
Nephritis and Nephrotic Syndrome and Nephrosis	580-589	80	29 (36%)	38	42 (109%) (32, 52)	0.001
Acute Renal Failure	584	61	21 (34%)	13	49 (388%) (31, 66)	0.003
Pneumonia and Influenza	480-487	551	223 (41%)	500	52 (10%) (-39, 142)	0.167
Chronic Obstructive Pulmonary Disease and Allied Conditions	490-496	270	79 (29%)	240	31 (13%) (-4, 65)	0.067
Nervous System Disorders	320-389	142	33 (23%)	179	-37 (-21%) (-148, 74)	0.363
Heat Effect	992	445	347 (78%)	2	443 (22, 150%) (438, 447)	<0.001
Heat Stroke	992.0	234	175 (75%)	0.3	234 (78, 000%) (232, 236)	<0.001
Anhydrotic Heat Exhaustion (Dehydration)	992.3	43	36 (84%)	0.3	43 (14, 333%) (41, 45)	<0.001
Heat Exhaustion (unspecified)	992.5	157	127 (81%)	1	156 (15, 600%) (154, 158)	<0.001

^aHospital admissions during the heat wave study period (July 13-19, 1995).

^bAverage hospital admissions for four weeks: a week in 1995, July 6-12, and three weeks in 1994, July 6-12, July 13-19; July 20-26.

^cObserved minus expected admissions.

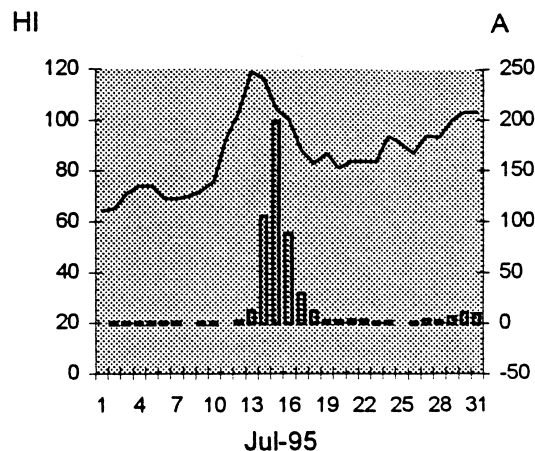


Figure 2. Estimated excess of inpatient hospital admissions for primary discharge diagnoses for effects of heat (ICD-9 code 992), Cook County, July 1995. HI: heat index; A: hospital admissions.

liver (ICD-9: 571.2) by 24 (95% CI, 4 to 44). An excess number of individuals were also admitted with secondary discharge diagnoses of pneumonia- and influenza-related respiratory problems (Table 3), chronic obstructive pulmonary disease, chronic bronchitis, emphysema, and asthma.

Although no statistically significant excess of admissions of people with primary diagnoses of degenerative diseases of the central nervous system (which includes Alzheimer and Parkinson disease) were not a primary reason for hospitalization, but contributed to the excess with 74 admissions ($p = 0.001$) over baseline as an underlying disease. The number of people admitted with diagnoses of the peripheral nervous system or multiple sclerosis was not elevated. However, people with a history of epilepsy were hospitalized with greater than expected frequency during the heat wave ($p = 0.009$).

We found a nonsignificant increase of admissions of diagnoses for mental conditions (excess of 323; $p =$

Table 2. Excess inpatient admissions by primary and secondary discharge diagnoses: underlying or comorbid conditions, Chicago, July 1995

Diagnosis	ICD-9 Code	Observed ^a	Observed ^a >65 years (%)	Expected ^b	Excess ^c (95% CI)	P-Value
Cardiovascular and Cerebrovascular Diseases						
Cardiovascular Diseases	390–398	2485	1660	2024	461 (23%)	0.019
	402		(67%)		(146, 777)	
	404–429					
	440–448					
Hypertensive Disease	401–405	2107	1206	1699	408 (24%)	0.045
			(57%)		(19, 797)	
Ischemic Heart Disease	410–414	1086	741	916	170 (19%)	0.019
			(68%)		(52, 288)	
Acute Myocardial Infarction	410	130	76	134	–4 (–3%)	0.424
			(58%)		(–19, 10)	
Angina Pectoris	413	149	89	123	27 (22%)	0.055
			(60%)		(–1 54)	
Other Heart Diseases*	420–429	1660	1188	1324	337 (25%)	0.047
			(72%)		(10, 663)	
Heart Failure	428	907	687	723	184 (25%)	0.053
			(76%)		(–4, 372)	
Cardiac Dysrhythmias	427	846	649	633	214 (34%)	0.012
			(77%)		(89, 338)	
Diseases of Arteries, Arterioles and Capillaries	440–448	276	194	226	50 (22%)	0.025
			(70%)		(12, 88)	
Thrombosis	453	106	56	92	14 (15%)	0.257
			(53%)		(–18, 45)	
Cerebrovascular Disease	430–438	525	365	428	97 (23%)	0.013
			(70%)		(39, 154)	
Late Effects of Cerebrovascular Disease (Sequelae)	438	194	152	119	75 (63%)	<0.001
			(78%)		(61, 88)	
Stroke	433–434	156	115	153	3 (2%)	0.863
			(74%)		(–44, 49)	
Endocrine						
Diabetes Mellitus	250	1322	686	1015	307 (30%)	0.033
			(52%)		(47, 567)	
Insulin Dependent Diabetes (Type I)	250.01	290	155	238	52 (22%)	0.056
			(53%)		(–2, 107)	
Noninsulin Dependent Diabetes (Type II)	250.00	492	287	370	122 (33%)	0.029
			(58%)		(24, 221)	
Disorders of Fluid and Electrolyte Balance	276	2445	1390	1377	1068 (78%)	0.002
			(57%)		(746, 1389)	
Volume Depletion	276.5	1194	740	468	726 (155%)	0.001
			(62%)		(556, 896)	

^aHospital admissions during the heat wave study period (July 13–19, 1995).

^bAverage hospital admissions for four weeks: A week in 1995, July 6–12, and three weeks in 1994, July 6–12, July 13–19, July 20–26.

^cObserved minus expected admissions.

*Pericarditis, Endocarditis, Myocarditis, Cardiomyopathy, Conduction Disorders, Cardiac Dysrhythmias, Heart Failure.

0.061), including diagnoses of psychoses (excess of 155; $p = 0.092$) and neuroses (excess of 191; $p = 0.117$). The numbers of homicides and injury inflicted by other persons requiring legal intervention, suicides and self-inflicted injury, or accidents (Figure 5) during the heat wave study period were not elevated. Complications related to pregnancies and medical conditions originating in the perinatal period were not elevated; neither were chronic conditions such as cancer, anemia, or complications from HIV infection requiring inpatient admission (Table 3).

Discussion

Overall, during the Chicago heat wave study period in July 1995, we found 11% more inpatient hospital admissions in Cook County than expected. One quarter of the excess primary discharge diagnoses were specifically coded as dehydration, followed by heat stroke (22%) and heat exhaustion (15%). The susceptible population had specific underlying or comorbid medical conditions that increased their risk for dehydration; effective public health interventions need to be directed toward these individuals.

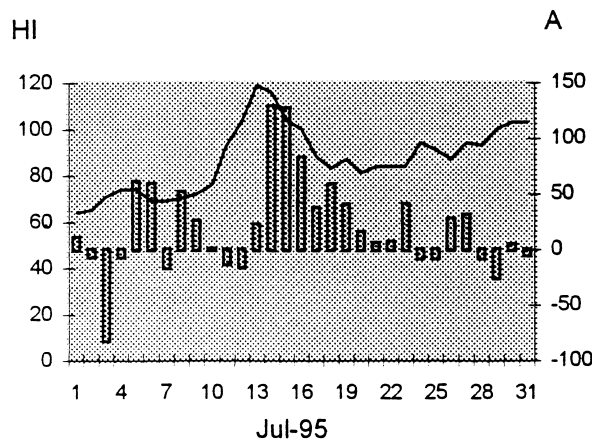


Figure 3. Estimated excess of inpatient hospital admissions for primary and secondary discharge diagnoses for cardiovascular diseases (ICD-9: 390-398; 402; 404-429; 440-448), Cook County, July 1995. HI: heat index; A: hospital admissions.

Cardiovascular Diseases

Cardiovascular disease was not a primary reason for admission, but as a pre-existing condition it was a risk factor for hospitalization. We found diagnoses of chronic cardiovascular diseases (e.g., hypertensive disease) rather than acute cardiac events (e.g., myocardial infarction) to be elevated during the heat wave. This suggests that susceptible individuals were not able to mount appropriate cardiac compensatory measures, such as increasing cardiac output, required during heat stress. Our data indicate that chronic heart insufficiency and/or the inability to increase cutaneous circulation, both of which can impede dissipation of heat, increased the risk for hospitalization. These observations are particularly pronounced in individuals 65 years and older. Restricting the comparison to individuals 65 years and older, we found a statistically signifi-

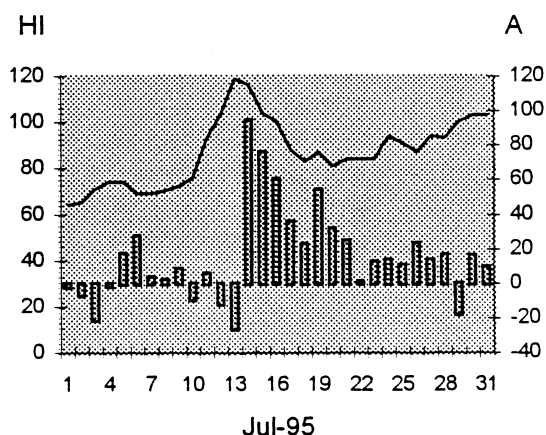


Figure 4. Estimated excess of inpatient hospital admissions for primary and secondary discharge diagnoses for diabetes mellitus (ICD-9:250), Cook County, July 1995. HI: heat index; A: hospital admissions.

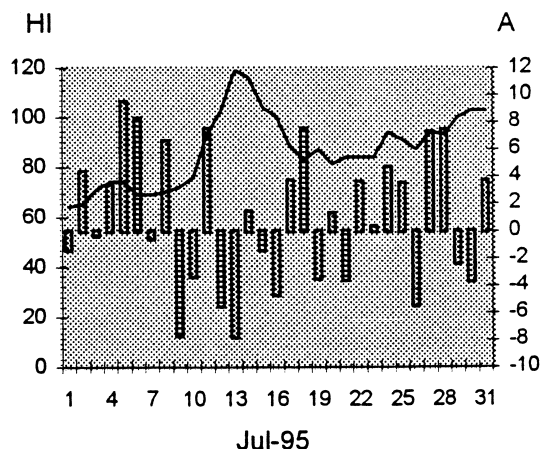


Figure 5. Estimated excess of inpatient hospital admissions for primary and secondary discharge diagnoses for accidents and injuries (ICD-9: E800-899), Cook County, July 1995. HI: heat index; A: hospital admissions.

cant excess (31%; $p = 0.008$) of cardiovascular admissions during the heat wave. During the heat wave study period, this age group accounted for 67% of all those admitted with cardiovascular disease, compared to 63% during the non heat wave baseline. This finding could be explained in part by physiological observations that left ventricular diastolic filling declines with age as does cardiac output and heart rate at rest or during exercise.^{12,13} It has also been demonstrated that older individuals have less active vasodilatation of cutaneous vessels,^{14,15} which severely limits their ability to increase the skin blood flow during heat challenge,¹⁶⁻¹⁸ and thus to divert heat from the core to the skin, where evaporating sweat dissipates heat to the environment. However, greater aerobic activity can partially offset these physiologic changes in the elderly and improve heat acclimatization.^{12,19,20} Although air conditioning is probably the most effective short-term intervention, regular physician-approved exercise, as part of a general preventive health program, can increase tolerance to heat stress, and thus decrease heat morbidity.

Cerebrovascular Diseases

Similar to the above finding, cerebrovascular disease was not a principal condition requiring treatment during hospital visits, but, as an underlying illness, was a risk factor for hospitalization. Admissions for acute cerebrovascular disease (e.g., stroke) were not elevated, but complications resulting from a previous cerebrovascular event, coded as late effects, were in excess. These findings are in contrast to previous reports that showed stroke to be an important cause of heat wave-associated mortality.²¹⁻²³ Several physiologic studies have suggested that the blood of heat stressed individuals coagulates more readily.^{24,25} Our results found no significant increase in the number of admissions for disorders

Table 3. Excess inpatient admissions by primary and secondary discharge diagnosis: underlying and comorbid conditions, Chicago, July 1995

Diagnosis	ICD-9	Observed ^a	Observed ^a >65 years (%)	Expected ^b	Excess ^c (95% CI)	P-Value
Gastrointestinal Diseases						
Chronic Liver Disease and Cirrhosis	571	158	31 (20%)	120	38 (31%) (11, 65)	0.021
Respiratory Pneumonia and Influenza	480-487	1480	724 (49%)	1237	243 (20%) (58, 429)	0.025
Emphysema	492	113	80 (71%)	76	38 (50%) (20, 56)	0.007
Asthma	493	486	91 (19%)	423	63 (15%) (-15, 141)	0.082
Chronic Obstructive Pulmonary Disease	496	338	267 (79%)	285	53 (19%) (-33, 139)	0.146
Central Nervous System (CNS)						
Nervous System Disorders	320-389	1001	463 (46%)	832	170 (20%) (36, 303)	0.027
Degenerative Diseases of CNS (Parkinson, Alzheimer)	330-337	220	152 (69%)	147	74 (50%) (58, 89)	0.001
Multiple Sclerosis	340	26	5 (19%)	29	-3 (-10%) (-25, 19)	0.72
Epilepsy	345	53	11 (21%)	42	11 (26%) (5, 17)	0.009
Migraine	346	40	5 (13%)	39	0.75 (2%) (-31, 33)	0.945
Kidney						
Nephritis and Nephrotic Syndrome and Nephrosis	580-589	392	177 (45%)	259	134 (52%) (57, 210)	0.011
Chronic Renal Failure	585	129	73 (57%)	111	18 (17%) (-30, 67)	0.318
Acute Renal Failure	584	161	73 (45%)	70	91 (131%) (35, 148)	0.014
External Causes						
Excessive Heat	E900	82	56 (68%)	1	82 (8, 200%) (80, 84)	<0.001
Accidents and Injuries	E800-899	251	78 (31%)	263	-12 (-5%) (-39, 15)	0.258
Homicide and Legal Intervention	E960-978	44	0 (0%)	76	-32 (-42%) (-99, 36)	0.232
Suicide	E950-959	33	1 (3.0%)	28	5 (19%) (-8, 18)	0.283
Cancer						
Malignant neoplasms, including neopl. of lymphatic and hematopoietic tissues	140-208	759	379 (50%)	725	34 (5%) (-177, 245)	0.643
Symptoms						
Heat Effect	992	655	347 (53%)	4	651 (16, 275%) (641, 662)	<0.001
Syncope and collapse	780.2	140	91 (65%)	94	46 (49%) (31, 61)	0.002

^aHospital admissions during the heat wave study period (July 13-19, 1995).

^bAverage hospital admissions for four weeks: a week in 1995, July 6-12; and three weeks in 1994, July 6-12, July 13-19; July 20-26.

^cObserved minus expected admissions.

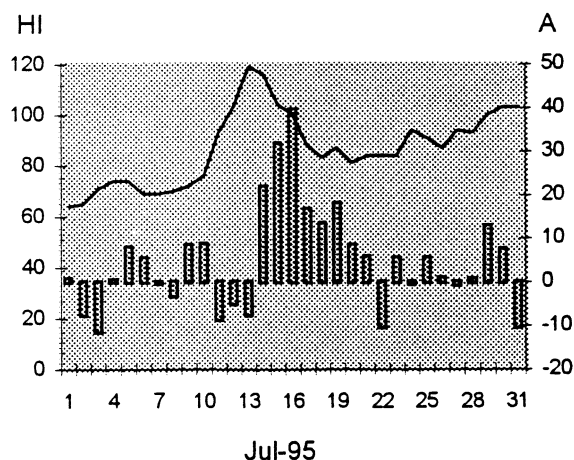


Figure 6. Estimated excess of inpatient hospital admissions for primary and secondary discharge diagnoses for renal disease (ICD-9: 580-589), Cook County, July 1995. HI: heat index; A: hospital admissions.

associated with hypercoagulability (i.e., deep venous thrombosis, pulmonary embolism, or thrombophlebitis).

Diabetes

We found that people with a history of diabetes were at increased risk for hospitalization. Increased numbers of admissions were seen for NIDDM and approached significance for those with insulin dependent diabetes. Although only a few studies show that people with diabetes are at increased risk for illness during hot weather, our findings are consistent with Schuman's study, which showed that the number of deaths among people with diabetes increased 117% during a heat wave in New York.²² People with diabetes may be at greater risk during periods of extreme heat because fluid and electrolyte disturbances may exacerbate poorly controlled glucose. Furthermore, a decreased sweating response due to peripheral neuropathy and structural impairment of blood flow to the periphery might be responsible for the poor thermoregulation associated with diabetes.

Renal Diseases

Acute renal failure was the primary discharge diagnosis of almost 50 excess hospitalizations and was solely responsible for the increase in renal diseases. We did not see diagnoses over baseline for chronic renal failure, hypertensive renal disease (ICD-9: 403), or calculus of the kidney or urinary systems. The excess in acute renal failure is (Figure 6) possibly due to advance prerenal azotemia, which represents a physiologic response to mild to moderate renal hypoperfusion. It is also possible that circulatory adjustments necessitated by extreme heat exposure placed additional stress on the renal system. Under heat exposure and physical exertion, blood is redistributed away from splanchnic

and renal vascular beds.^{26,27} Elderly people with poor left ventricular function might not be able to overcompensate this physiological phenomenon, resulting in hypoperfusion of the kidneys and liver. Interestingly, rates of chronic renal failure did not increase significantly, which could reflect reduced risk because of close medical supervision during long air conditioned dialysis treatments in the hospital during the heat wave period.

Respiratory Diseases

We found a 20% increase in pneumonia and influenza admissions. These could be considered markers for underlying conditions. Excess of inpatient admissions during the hot and humid weather were significant for emphysema, but not for asthma or chronic obstructive pulmonary disease, which might have been treated on an outpatient basis and thus not detected in our study.

Neurologic Diseases

During the heat wave, the number of admissions for several neurologic conditions increased, including a significant increase in the number of admissions for degenerative diseases of the central nervous system, which includes Parkinson disease and Alzheimer disease. Some patients with these disorders are unable to adequately care for themselves and therefore do not drink sufficient amounts of fluid to avoid dehydration. Thirst sensation may not always be an adequate measure of fluid needs, since thirst sensation can be compromised in the elderly.²⁸⁻³⁰ Particularly under heat stress and water deprivation, elderly men have been shown to experience reduced thirst resulting in inadequate water intake. Consequently, prevention efforts should assure adequate fluid intake of elderly individuals during hot weather.

Limitations

There are several limitations to our study. We did not have access to information regarding less severe illnesses that did not require inpatient admission, such as those seen in emergency departments only or those seen by health care providers in their offices. Because external cause codes (E codes) are not required to be reported by law along with other hospital discharge data, E codes might be under-representing the actual excess.³¹ It is unlikely that there is inconsistent coding among broad disease categories, but within disease categories such inconsistencies are possible.³² However, primary and secondary discharge diagnoses were obtained from discharge summaries. In these reports, clinicians had a better understanding of a patient's medical condition than when they were first admitted to the hospital. Thus, the use of medical records should generally provide greater accuracy regarding diagnoses

and medical history, since they report more specific disease categories than death certificates.

Prevention

Analysis of excess hospital admissions during the heat wave study period defines who was admitted and why. During this period, the primary reasons for a hospital visit were predominantly dehydration, heat stroke, or heat exhaustion. The susceptible population at risk for admission relating to these conditions had comorbid cardiovascular illnesses, endocrine disorders, liver and kidney diseases, respiratory illnesses, or nervous system disorders. Within this population, elderly individuals were disproportionately represented and efforts to prevent heat related morbidity should be directed toward these people. Elderly people often experience altered thirst sensation and other physiological changes discussed above that make them more prone to chronic (and acute) dehydration and less resilient to hot weather. People with reduced heat tolerance, especially the ill and those lacking mental capacity, should also be monitored very carefully, perhaps through supervised fluid intake. As simple indicators, a patient's state of dehydration could be monitored (by health care providers or individuals themselves) on the basis of skin tests, urine color, or weight loss. Because aerobic fitness increases overall health and has been shown to improve heat tolerance in the elderly,^{12,19,20} long-term public health interventions (during non-heat wave periods) should include efforts to raise the fitness levels of sedentary older people in particular. In addition, communities should provide sufficient cool environments for the elderly and those at increased risk,^{1,33,34} and public health officials should coordinate public service announcements that inform the public of the risks associated with hot weather and the need to take appropriate prevention measures such as increasing fluid intake.

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