# Risk Factors for Heatstroke

## A Case-Control Study

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• **To identify risk factors associated with heatstroke, a case-control study in St Louis and Kansas City, Mo, was conducted during July and August 1980. Questionnaire data were gathered for 156 persons with heatstroke (severe heat illness with documented hyperthermia) and 462 control subjects matched by age, sex, and neighborhood of residence. A stepwise linear logistic regression procedure was used to identify factors significantly associated with heatstroke. Alcoholism, living on the higher floors of multistory buildings, and using major tranquilizers (phenothiazines, butyrophenones, or thioxanthenes) were factors associated with increased risk. Factors associated with decreased risk were using home air conditioning, spending more time in air-conditioned places, and living in a residence well shaded by trees and shrubs. Being able to care for oneself, characteristically undertaking vigorous physical activity, but reducing such activity during the heat, and taking extra liquid were also associated with decreased risk. Our findings also suggest effective preventive measures. During a heat wave, the greatest attention should be directed toward high-risk groups, and relief efforts should include measures shown to be associated with reduced risk.**

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HEATSTROKE has been known since biblical times,[1] and many descriptions of its clinical manifestations have been published.[2-6] It is the most severe of the illnesses caused by high ambient temperature. During periods of sustained hot weather (heat waves), high rates of severe illness and death due to heatstroke may occur.[3,4] An estimated 1,265 heat-related deaths occurred in the United States during the summer of 1980, many of them from heatstroke.[7]

Some authors have noted certain characteristics among series of heatstroke cases and have suggested these characteristics as risk factors for heatstroke.[5,6,8-11] Epidemiologic studies of heatstroke among athletes and military personnel have been conducted.[12-15] However, predisposing factors for heatstroke in the general population, where cases tend to occur in elderly persons, may differ substantially from the antecedents of heatstroke among relatively young athletes and military recruits.[16] We are unaware of any previous study of heatstroke in the general population that has used systematically collected data from unaffected as well as affected persons to evaluate potential risk factors.

**See also pp 3327 and 3354.**

Many residents of St Louis and Kansas City, Mo, experienced severe heat-related illness during the summer of 1980.[17-19] This situation offered an opportunity to elucidate risk factors for heatstroke by means of a case-control study. There were three objectives of our study: (1) to identify factors associated with heatstroke; (2) to estimate the degree of risk associated with each factor; and (3) to formulate recommendations for the prevention of heatstroke.

### METHODS

#### Data

We identified cases of heatstroke with onset in July 1980 by a review of emergency room, admission, and discharge records of the adult, acute-care hospitals in St Louis and Kansas City, and by a search of the records of the medical examiners of both cities. The following groups were defined as having heatstroke: patients with a presenting temperature (measured anywhere on the body) greater than or equal to 41.1 °C (106 °F); patients with documented temperature greater than or equal to 40.6 °C (105 °F) if altered mental status or anhidrosis was also present; and those pronounced dead on arrival at the hospital or medical examiner's office if the body temperature (usually measured by a liver probe) was greater than or equal to 41.1 °C (106 °F).

Using this definition, we found 208 cases. Of these, 156 cases (73 fatal) were entered in the study. All 75 cases found in Kansas City, the 43 cases in St Louis found through the medical examiner's office, and 38 randomly selected cases from the St Louis hospitals were included. The demographic characteristics of these cases are described elsewhere in this issue of THE JOURNAL (p 3327).

Starting at the residence of the case, going from door to door, and using a standardized, systematic search pattern, we attempted to find three age- and sex-matched neighborhood control subjects for each case. A control subject was considered acceptably matched for age if the age was within five years of that of the case, except for cases 70 years or older, for

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whom any control subject 65 years or older was acceptable. Matching by neighborhood was substituted for matching by race and socioeconomic status.

Three suitable control subjects were found for 94.2% of the cases, and one, two, or four suitable control subjects for all but one of the remaining cases. This unmatched case was excluded from the matched analysis.

Whenever possible, control subjects and surviving cases were interviewed in person. A close friend or family member served as respondent for all of the fatal cases, 35.4% of nonfatal cases (often because of continuing illness or debility in nonfatal cases), 7.7% of the matched control subjects of fatal cases, and 8.9% of the matched control subjects of nonfatal cases. Data were gathered by means of a questionnaire eliciting 123 items of demographic, epidemiologic, and clinical data. Interviewers underwent a one-hour training session to familiarize them with the questionnaire and the control-finding procedure.

### Statistical Analysis

Elimination of outcome and redundant and unreliable variables left 45 variables for evaluation as potential risk-factors (Table 1). (In this discussion, the term *risk factor* denotes variables associated with both decreased and increased heatstroke risk.)

A stepwise selection procedure based on the logistic regression model was applied to the matched case-control sets to select those factors most important in determining heatstroke risk.[20-22] A univariate linear logistic regression model was fitted for each variable in turn. Those variables whose regression coefficients were not significantly different from zero at the 5% level were excluded from further consideration.

The remaining variables were added in forward, stepwise fashion into a multivariate logistic regression model. At each step, the variable whose inclusion in the model resulted in the greatest increase in maximized log likelihood was added. Variables were added until the addition of any of the remaining variables no longer resulted in an increase in maximized log likelihood significant at the 5% level. The final model was used to describe the quantitative impact of the various risk factors on heatstroke. Separate analyses were performed for fatal and nonfatal heatstroke cases and their matched control subjects.

To ensure that the variables chosen for the final models were not critically dependent on our choice of selection procedure, we repeated the analyses twice, using first a backward stepwise selection procedure and, second, a forward stepwise procedure selecting from first-order interaction as

Table 1.—Variables: Potential Risk Factors for Heatstroke, St Louis and Kansas City, Mo, 1980

| |
|---|
| **Environmental** |
| Home air conditioning (hr/day) |
| Home fan use (hr/day) |
| Windows open (hr/day) |
| Trees and shrubbery (none, few, moderate, or heavy growth)* |
| Ceiling height (ft) |
| No. of living units in building |
| Height of home floor (in stories) |
| Outside walls made of brick, stone, or concrete (yes or no)† |
| Ground surrounding residence made of concrete or asphalt (yes or no) |
| Height of tallest building within 300 ft (stories) |
| Distance from home to closest building (ft) |
| **Social and Behavioral** |
| Race (white or other) |
| Education (yr) |
| Warned about danger from heat (yes or no) |
| Employed (yes or no) |
| Living alone (yes or no) |
| Frequency of contact with others |
| Reducing activity during heat (yes or no) |
| Wearing lighter clothing (yes or no) |
| Spent increased time in air-conditioned places (yes or no) |
| Took exta cool baths or showers (yes or no) |
| Took extra liquids (yes or no) |
| Spent time in heat wave shelter (yes or no) |
| **Biological and Medical** |
| Able to care for self (yes or no) |
| Characteristic activity level (bedfast, inactive, moderate exercise, or strenuous exercise)‡ |
| Smoking (packs/day) |
| Alcohol consumption |
| Alcoholism (yes or no) |
| Obesity (ponderal index) |
| Previous heatstroke (yes or no) |
| Heart disease (yes or no) |
| Lung disease (yes or no) |
| Liver disease (yes or no) |
| Kidney disease (yes or no) |
| Thyroid disease (yes or no) |
| Arthritis (yes or no) |
| Hypertension (yes or no) |
| Cancer (yes or no) |
| Diabetes (yes or no) |
| Depression (yes or no) |
| Mental illness (yes or no) |
| Use of group 1 drugs§ |
| Use of group 2 drugs‖ |
| Use of group 3 drugs¶ |
| Use of salt tablets (yes or no) |

*Scoring was: none, 0; few, 1; moderate, 2; heavy growth, 3.

†Scoring for all yes-no variables was: yes, 1; no, 0.

‡Scoring was: bedfast, 0; inactive, 1; moderate exercise, 2; strenuous exercise, 3.

§Group 1 drugs were major tranquilizers (phenothiazines, butyrophenones, and thioxanthenes) and other drugs with anticholinergic activity (antihistamines, tricyclics, and "pure" anticholinergics). The variable was scored 0 if neither group was taken; 1 if either a major tranquilizer or an "other anticholinergic" was taken, but not both; or 2 if both a major tranquilizer and an "other anticholinergic" were taken.

‖Group 2 drugs were sedative-hypnotics, sympathomimetics, phosphodiesterase inhibitors, thyroid agonists, and diuretics.

¶Group 3 drugs were all medications taken by study subjects that were not in group 1 or group 2.

Table 2.—Patterns of Variable Occurrence in the Two Final Models

| Risk Factors | Fatal Heatstroke | Nonfatal Heatstroke |
|---|---|---|
| Home air conditioner | Yes | Yes |
| **Able to care for self** | **Yes** | **Yes** |
| Increased time in air-conditioned places | Yes | Yes |
| **Reduced activity** | **Yes** | **No** |
| Alcoholism | Yes | No |
| **Characteristic activity level** | **Yes** | **No** |
| Drug group 1 | Yes | No |
| **Height of home floor** | **No** | **Yes** |
| Extra liquids | No | Yes |
| **Trees and shrubbery surrounding residence** | **No** | **Yes** |

Table 3.—Risk Factors for Fatal Heatstroke, St Louis and Kansas City, Mo, 1980

| Order of Variable Selection | Factor | Regression Coefficient | SE of Regression Coefficient | t | Relative Risk (RR) | RR Lower 95% Confidence Limits | RR Upper 95% Confidence Limits | Increment in Factor Associated With RR |
|---|---|---|---|---|---|---|---|---|
| 1 | Daily hr of home air conditioning | −0.16 | 0.04 | −3.98 | 0.85 | 0.79 | 0.92 | 1 hr/day of air conditioning |
| 2 | Ability to care for self | −1.59 | 0.55 | −2.88 | 0.20 | 0.07 | 0.60 | Was able to care for self |
| 3 | Reduction of activity | −1.68 | 0.43 | 3.89 | 0.19 | 0.08 | 0.43 | Did reduce activity |
| 4 | Alcoholism | 2.71 | 1.06 | 2.55 | 15.02 | 1.87 | 120.43 | Was alcoholic |
| 5 | Characteristic activity level | −0.87 | 0.33 | −2.62 | 0.42 | 0.22 | 0.80 | 1 Increment in 4-point scale: (1) bedfast; (2) inactive; (3) moderate exercise; (4) strenuous exercise |
| 6 | Increased time spent in air-conditioned places | −1.34 | 0.65 | −2.06 | 0.26 | 0.07 | 0.93 | Did increase time spent in air-conditioned places |
| 7 | Drug group 1 | 1.09 | 0.57 | 1.90 | 2.98 | 0.97 | 9.18 | One increment in scale running from 0 to 2 (footnote, Table 1.) |

Table 4.—Risk Factors for Nonfatal Heatstroke, St Louis and Kansas City, Mo, 1980

| Order of Variable Selection | Factor | Regression Coefficient | SE of Regression Coefficient | t | Relative Risk (RR) | RR Lower 95% Confidence Limits | RR Upper 95% Confidence Limits | Increment in Factor Associated With RR |
|---|---|---|---|---|---|---|---|---|
| 1 | Increased time spent in air-conditioned places | −1.31 | 0.45 | −2.94 | 0.27 | 0.11 | 0.65 | Did increase time spent in air-conditioned places |
| 2 | Ability to care for self | −1.68 | 0.49 | −3.45 | 0.18 | 0.07 | 0.49 | Was able to care for self |
| 3 | Height above ground level of floor of residence | 0.46 | 0.13 | 3.64 | 1.59 | 1.24 | 2.03 | One additional floor above ground level |
| 4 | Daily hr of home air conditioning | −0.07 | 0.03 | −2.72 | 0.93 | 0.89 | 0.98 | 1 hr/day of air conditioning |
| 5 | Taking extra liquids | −1.30 | 0.45 | −2.89 | 0.27 | 0.11 | 0.66 | Did take extra liquids |
| 6 | Extent of tree and shrub growth surrounding residence | −0.65 | 0.29 | −2.21 | 0.52 | 0.30 | 0.93 | One increment in 4-point scale: (1) none; (2) few; (3) moderate; (4) heavy growth |

well as main effects variables. There was substantial agreement between the models thus obtained and our final models.

## RESULTS

Forty-five variables were entered into the selection procedure (Table 1). A total of ten factors were selected in one or both models (Table 2).

The following were the seven important risk factors for heatstroke death (Table 3): (1) daily hours of home air conditioning, (2) ability to care for self, (3) reduction in physical activity during the heat, (4) history of alcoholism, (5) characteristic activity level, (6) spending increased time in air-conditioned places, and (7) use of a drug from "group number one" (major tranquilizers and anticholinergics).

Because of the somewhat arbitrary scoring of the drug group 1 variable (see footnote, Table 1), we analyzed in detail all questionnaire responses for drugs in this group. Frequency of use of all three major tranquilizer subgroups (phenothiazines, butyrophenones, and thioxanthenes) was notably higher in cases than in control subjects. Frequency of use of the anticholinergic subgroups (antihistamines; tricyclics; anticholinergic antiparkinsonian agents; "pure" anticholinergics, such as atropine and belladonna; and tricyclics) was similarly compared for cases and control subjects. Only for the antiparkinsonian anticholinergics was the frequency of use by cases markedly higher than by control subjects. However, with only one exception, all heatstroke cases taking an antiparkinsonian anticholinergic were also taking one of the major tranquilizers.

Slight variations of the final logistic model for heatstroke death were fitted to clarify further the role of drug use. A dichotomous major tranquilizer-no major tranquilizer variable was substituted for the drug group 1 variable. The $t$ score for the major tranquilizer-no major tranquilizer variable obtained from the fitted model approached significance at the 5% level. However, when a dichotomous anticholinergic-no anticholinergic variable was substituted for drug group 1, the $t$ score obtained was not statistically significant.

The following were the six important risk factors for nonfatal heatsroke (Table 4): (1) spending increased time in air-conditioned places, (2) ability to care for self, (3) height of home floor, (4) daily hours of home air conditioning, (5) taking extra liquids, and (6) extent of tree and shrubbery growth around the residence.

When the variable selection procedure was applied both to main effects and first-order interactions, all seven risk factors for fatal heatstroke were chosen (either as main effects or as components of first-order interactions). Similarly, five of the six risk factors for nonfatal heatstroke (all except "taking extra liquids") were chosen when selection was made from

both main effects and first-order interactions.

## COMMENT

The stepwise selection procedure we used is based on the same rationale as the forward stepwise selection procedure for multiple linear regression problems. The step-by-step addition of variables to the multivariate model identifies, in order of decreasing importance, the variables most strongly associated with the outcome (heatstroke) and at the same time adjusts for confounding among variables. The application of the selection procedure to interaction as well as main effects variables and its application in a backward stepwise manner were supplementary analyses designed to demonstrate the consistency of our results. That the different procedures yielded similar results provides an internal check on the validity of the selection technique.

We observed a strong inverse association between daily hours of home air conditioning and heatstroke. Calculations based on our final models indicate that, other factors being equal, the relative risk of heatstroke death for persons without home air conditioning was 49.4 (95% confidence limits, 7.4 and 286.4) times the risk for those using home air conditioning 24 hr/day. Our model for nonfatal heatstroke yielded an estimated relative risk of 5.7 (95% confidence limits, 1.6 and 16.4) for persons without home air conditioning compared with those with 24-hour air conditioning. Though hardly unexpected, the strong protective effect of home air conditioning is an important finding, especially in view of previous suggestions that air conditioning might actually increase heatstroke risk by inhibiting proper acclimatization to hot weather.[23]

Spending increased time in air-conditioned places (IAC) was also associated with decreased risk of heatstroke. Estimates from our models suggest that this preventive behavior reduced the risk for both fatal and nonfatal heatstroke by approximately a factor of 4. The IAC variable was selected along with home air conditioning in both models, implying that IAC had an additional protective effect beyond that provided by home air conditioning alone. This finding supports the preventive efficacy of providing air-conditioned places outside the home as a part of heat wave relief efforts.

Air-conditioned heat wave shelters were provided by the health officials of both St Louis and Kansas City during the 1980 heat wave, but reported use of these shelters was not a significant risk factor in our study (that is, the variable was not selected). However, evaluation of shelter use as a risk factor was hampered by the fact that only 18 of 618 study subjects reported using shelters, which suggests that the shelters were underutilized. Our finding of a strong protective effect from spending increased time in air-conditioned places outside the home nevertheless suggests that these shelters may be of benefit.

Increasing height of floor of residence above ground level was associated with increasing risk of nonfatal heatstroke. This finding is consistent with an earlier report, which noted that a disproportionate number of persons with heatstroke lived on the top floors of buildings.[6] Heat stress is apparently greater on the higher floors of buildings, possibly because hot air rises within a building or because of increased proximity to a roof heated by the sun. We cannot distinguish between these possibilities, since we noted only distance from the ground and not distance from the roof.

The extent of tree and shrubbery growth was inversely associated with nonfatal heatstroke. Trees and shrubs may shield a residence from direct sunlight and thus reduce heat stress to the occupants. Living in a well-shaded home may serve as a marker for high socioeconomic status, a characteristic shown to be inversely associated with heatstroke (see article of Jones and co-workers, p 3327). The association between tree growth and heatstroke requires further clarification.

Reducing activity during the heat was an important inverse correlate of heatstroke death. Exercise is an important determinant of hyperthermia in laboratory animals[24] and has been linked to heatstroke among military personnel.[16] Our findings confirm that failure to decrease activity also increases heatstroke risk among the general population.

The inverse association between nonfatal heatstroke and taking extra liquids observed in this study is consistent with earlier observations that adequate fluid intake is important in helping the body deal with high ambient temperatures.[25,26] The rise in heart rate and rectal temperature of volunteers walking in desert heat was lessened by the frequent replacement of evaporative fluid losses.[25] Subjective feelings of fatigue and rise in rectal temperatures were both improved by scrupulous attention to fluid replacement in men exercising in the heat.[26]

The inability to care for oneself was associated with an approximately fivefold increase in the relative risk of both fatal and nonfatal heatstroke. Persons unable to care for themselves probably make up a diverse group of individuals with various degenerative diseases or with a history of disabling injury. Such persons may be less able to avoid the heat (for example, by leaving a hot room) or to take other appropriate preventive actions. Although we sought histories of ailments affecting several different organ systems (Table 1), no specific disease category was significantly associated with heatstroke. Thus, no history of a specific ailment was as effective a predictor of heatstroke as was the more general category of inability to care for oneself.

A variable closely allied with the ability to care for oneself was the characteristic activity level (rated as one of the following: confined to bed, mostly inactive, undertaking moderate exercise, or undertaking strenuous work or exercise). This variable was inversely associated with heatstroke death, indicating that those who were bedfast or who could not exert themselves were at increased risk. The characteristic activity level was a risk factor distinct from reducing activity during the heat.

A history of alcoholism was significantly associated with heatstroke death (relative risk, 15.0; 95% confidence limits, 1.9 to 120.4). This relationship, which has been suggested by others,[5,6] is biologically plausible, since alcohol inhibits the secretion of antidiuretic hormone and thus induces relative dehydration.[27] However, our failure to demonstrate an association between quantitative al-

cohol intake and heatstroke casts some doubt on a direct alcohol-heatstroke association. Increased risk of heatstroke among alcoholics may not be due to alcohol ingestion, but to some aspect of the syndrome of alcoholism. This finding requires further study.

Taking a group 1 drug (major tranquilizers and anticholinergics) was a risk factor for heatstroke death. More detailed analysis of the agents in this group implicated major tranquilizers (phenothiazines, butyrophenones, and thioxanthenes) as the component responsible for increased risk of heatstroke. Previous reports have suggested that these drugs are contributing causes of heatstroke.[9,28,29] The study findings are also consistent with animal studies in which chlorpromazine significantly reduced the survival time of rats subjected to high ambient temperatures.[30] Psychiatric patients may sometimes be given maintenance regimens of more antipsychotic medicine than is needed.[29] In view of our findings, this practice would seem particularly unwise during hot summer months.

We could not demonstrate a significant inverse association between the use of electric fans and heatstroke. This finding is supported by other studies, which have shown that increased air movement is associated with increased thermal discomfort when the ambient temperature exceeds approximately 38 °C.[31] The distribution of fans was a prominent part of the emergency response to the 1980 heat wave. Our failure to find a demonstrable protective effect of fan use suggests that scarce relief resources should not be allocated in this manner in future heat waves.

That we could not find a significant association between heatstroke and variables not selected for the models should not necessarily be interpreted to mean that heatstroke is not associated with any of these variables. In particular, neighborhood matching may have made cases and control subjects quite similar on certain variables of interest, thus reducing our ability to detect any effect those variables may have had on heatstroke (overmatching). Characteristics that tend to be constant within a neighborhood would be particularly susceptible to this sort of overmatching. Our failure to find ceiling height, number of living units within a building, composition of outside walls and ground surfaces, height of nearby buildings, or distance from home to closest building significantly associated with heatstroke may therefore be an artifact of the neighborhood match.

Persons with a history of diabetes, obesity, heart disease, or previous heatstroke have been said to be at increased risk of heatstroke.[13,23] The lack of significant relationship of any of these to heatstroke in our analysis casts some doubt on these earlier assertions, especially since these comparisons would not be expected to suffer from overmatching.

During heat wave emergencies, relief efforts should be preferentially directed toward the high-risk groups identified in this study: those unable to care for themselves, the bedfast, alcoholics, those taking major tranquilizers, those on the higher floors of buildings, and those whose residences are not well shaded by trees and shrubs. The preventive measures advocated by health officials should include those found to be associated with significantly decreased risk. If acquiring a home air conditioner is not economically feasible, persons at risk should attempt to spend more time in air-conditioned places. Strenuous activity should be reduced or rescheduled to the coolest part of the day. If no medical contraindications exist, those at risk should greatly increase their fluid intake. Patients being treated with antipsychotic drugs should be advised of their increased susceptibility to the heat.

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