**Cost of excess hospitalizations and emergency department visits for the 2006 California heat wave**

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## Materials and Methods

We estimated the cost to society for the excess hospitalizations and emergency department (ED) visits using two types of measures: 1) cost of illness (COI) values, including direct medical charges and the indirect costs of lost productivity and leisure time, and 2) people's willingness to pay (WTP) to prevent hospitalizations, derived from their stated preferences to such events (US EPA, 2008). Our approach for each subcategory is described below.

*Cost of illness*

We estimated the main component of the direct medical costs of the morbidity using data on hospital charges. The use of hospital charges, the amount the hospital charged for the hospital stay as opposed to the costs actually collected, may be more comprehensive than costs collected, since charges also include risk and profit sharing for accounts that do not pay completely as well as overhead (Thayer *et al.*, 2003). Charges may overstate costs; for California in 2006, a cost-to-charge ratio of 0.27 was published by the CA Office of Statewide Health Planning and Development (CA OSHPD, 2008). Although both charges and costs are employed in the COI literature (US EPA, 2008), for this study we followed the practices of the California Air Resources Board, which has based analyses on charges (Thayer *et al.*, 2003).

Since hospital charge data were available by primary or first-listed diagnosis only, we estimated the numbers of excess cases of hospitalizations and ED visits for 9 categories

of primary ICD-9 diagnosis codes (electrolyte imbalance (276), acute renal failure (584), nephritis and nephritic syndrome (580-589), respiratory illnesses (460-519), heat-related illnesses (992), diabetes (250), acute myocardial infarction (MI) (410), cerebrovascular disease (430-438), cardiovascular disease (390-98, 402, 404-29, 440-448)) as well as the category of "all causes." Combining both primary and secondary diagnoses, hospitalization and ED cases were greater during the heat wave period relative to the reference period for 8 of the 9 categories; only cerebrovascular disease cases were observed to decline slightly, by 1.55% for hospitalizations. Using only primary diagnosis, however, excess cases were positive for only 6 of the categories for hospitalization and 5 for ED visits. For example, cardiovascular hospitalizations during the heat wave increased according to combined primary and secondary diagnoses (+1.0%), but decreased according to primary diagnosis alone (-1.8%), presumably because some fraction of these cases was first-classified under other diagnoses (*e.g.*, electrolyte imbalance).

Therefore, in order to avoid underestimating the total costs by counting negative excess cases (*i.e.*, health benefits) not indicated from combined primary and secondary diagnoses, we included a diagnosis category in the cost analysis only if excess cases were of the same sign according to both primary diagnosis and primary and secondary diagnoses together. According to these criteria, we considered 7 specific categories for hospitalizations and 6 for ED visits, along with "all causes" for both. (For "all causes," only primary diagnosis codes were used in order to avoid double-counting individual admissions.) Thus, we did not count costs for cardiovascular and acute MI hospitalizations since excess cases for these categories were mildly negative (-0.76 to -1.8%) using primary diagnoses alone, but mildly positive considering the combined primary and secondary diagnoses, indicating health costs rather than benefits from the heat wave. It is likely this approach resulted in a slight underestimate of the overall hospitalization costs. For ED visits, total excess cases by primary diagnosis for the 6 categories numbered only ~3,600 compared to ~16,000 for all causes, so we used the more complete "all cause" category for the ED cost estimates. For hospitalizations, however, using the all cause category instead of the 7 diagnosis groups would have underestimated the costs by ~40%, as the mean charge for all causes was significantly lower than the case-weighted average given the various primary diagnoses.

We derived the mean hospital charges from the US Department of Health and Human Services' Healthcare Cost and Utilization Project (HCUP) online database (HCUP, 2008). For hospitalizations, we used mean hospital charges for California in 2006 for each diagnosis code category, multiplying by the excess numbers of cases by principal diagnosis. For ED visits, cost data for California were unavailable, so we adapted 2005 national statistics for all causes. To adjust for the higher costs of healthcare in California

relative to the national average, we multiplied the national ED costs by the 2005 ratio of California-to-national costs of hospitalizations. For example in California, hospitalizations for all causes cost 1.6 times the national average (HCUP, 2008); we assumed that ED visits for all causes in the state were similarly more expensive. The resulting hospitalization and ED charges were updated to 2008 dollars using the hospital services component of the Consumer Price Index (CPI).

Other direct medical costs include the costs of doctors' fees, medical equipment and other services, prescriptions, and the costs of follow-up medical care for the 6-month period subsequent to the hospital visits. According to 2001 CA survey data compiled by Thayer *et al.* (2003) from HMO respondents who had been hospitalized for respiratory and cardiovascular conditions, the costs of the follow-up doctor's visits dominated this category (66-89%). Thus, we applied an average follow-up cost per hospitalization from that study, ~$1,100 (2001 US $), updated to 2008 $ using the medical services component of the CPI.

Indirect costs include lost earnings for the patient and the patient's family and friends. We estimated these costs for the excess hospitalizations only, as lost productivity is proportional to the average duration of the hospital stay, which we estimated to be 52 times greater for the hospitalizations (5.15 days) than the ED visits (0.1 days) considered here. Lost earnings may be calculated for patients and caregivers in two age groups: 18-64 years old and 65 yr and older, but not for 0-17 yr. For each diagnosis category, the actual numbers of excess heat wave cases, $D_{\text{heat wave}}$, were recorded in 3 age groups: 0-4 yr, 5-64 yr, and 65+ yr. To extract the fraction of excess heat wave cases in the 18-64 yr category, we used a multiplier derived from HCUP data on 2006 CA hospital discharges, $D_{\text{HCUP}}$, age-sorted into 3 groups: 0-17 yr, 18-64 yr, and 65+ yr:

$$(1)\quad D_{\text{18-64 yr, heat wave}} = (D_{\text{0-4 yr, heat wave}} + D_{\text{5-64 yr, heat wave}}) \cdot [D_{\text{18-64 yr, HCUP}} / (D_{\text{0-17 yr, HCUP}} + D_{\text{18-64 yr, HCUP}})]$$
$$= D_{\text{0-64 yr, heat wave}} \cdot (D_{\text{18-64 yr, HCUP}} / D_{\text{0-64 yr, HCUP}}).$$

We also compiled HCUP data on 2006 CA hospital stay duration by age group. Then we estimated hours of lost work by assuming 65% of patients in the 18-64 age group were employed at 40 hrs/wk, compared to 5% in the over-65 group at 25 hrs/wk, based on survey data from Thayer *et al.* (2003). We calculated patients' at-home recovery times and family/friends' days lost from work by multiplying the HCUP mean hospital stay duration for each diagnosis and age group by approximate factors derived by Thayer *et al.* (2003) from survey data. According to that study, patients' at-home recovery times following hospitalizations were ~6.7 times as long as their average hospital stay durations, whereas their family and friends' lost days of work were 67% of the length of their hospital stays. Finally, we multiplied the total hours of lost work

productivity for each age and diagnosis category by the CA average hourly wage rate, obtained from the Bureau of Labor Statistics (average work year = 2,080 hours; 2006 4th quarter average CA wage updated to 2008 $ = $16,800). We assumed patients' family and friend caregivers to be in the 18-64 age group.

We calculated the values of lost household productivity and lost leisure time following the approach by Thayer *et al*. (2003). For lost household production, Thayer and coworkers' survey results indicated ~199 lost hrs per hospitalization on average, assessed at the estimated CA wage rate for housekeepers and maids of $10.90/hr (US 2008 $). For lost leisure time, their survey data showed a 2.12 hr/day loss per patient for the duration of the hospital stay plus 31.3 days following hospitalization, which they valued at 50% the average wage rate.

*Willingness to pay*

Last, we estimated WTP measures based on the detailed survey of Thayer and coworkers from which they derived the values respondents placed on avoiding hospitalizations. The survey results reflected how respondents valued physical pain and discomfort, emotional distress, lost time from work and household and recreational activities, as well as related out-of-pocket expenses. They reported WTP values of $1,600 to avoid a 1-day hospitalization and $2,500 in total to avoid a 5-day visit, which we fit to a linear function and applied to the mean hospital stay durations for each diagnosis category of excess hospitalizations from the heat wave.

**Results**

Table 1 summarizes the COI and WTP results. According to COI measures only, the overall societal costs are dominated by the direct medical charges incurred during the hospital visits, nearly 90% of the total COI of $133 million (Total 1). Alternately, the WTP measure may substitute for the estimated values of lost household productivity and lost leisure time (Thayer *et al.,* 2003). This second approach gives a societal cost of $132 million (Total 2), which is likely very similar to the first estimate because the hospital charges are the chief expenses.

**Table 1**. Summary cost estimates, using cost-of-illness measures (COI), and willingness-to-pay (WTP) measures. Two totals are shown, the first using COI measures only, and the second using both COI and WTP measures.

| | | | COI | WTP |
|---|---|---|---|---|
| | Primary diagnoses | Category | US $ 2008 | US $ 2008 |
| Hospitalizations | Electrolyte imbalance (276), acute renal failure (584), nephritis and nephritic syndrome (580-589), respiratory illnesses (460-519), heat-related illnesses (992), diabetes (250), (410), cerebrovascular disease (430-438) | Mean hospital charges | 82,793,712 | |
| | | Lost work productivity | 4,807,572 | |
| | | Follow-up medical costs | 2,773,207 | |
| | | Lost household productivity | 3,933,305 | 4,653,993 |
| | | Lost leisure time | 2,156,176 | |
| Emergency department visits | All causes | Mean hospital charges | 36,718,715 | |
| | | | | |
| Total 1. COI only | | | 133,182,686 | |
| Total 2. COI and WTP | | | 131,747,198 | |

## Discussion

As discussed earlier, hospital charges may potentially overstate the morbidity costs. In addition, in calculating hospital charges we did not use data organized by age group. If we had done so, the estimates may be slightly lower since heat wave patients were generally older than average patients for the 7 hospitalization diagnosis categories. For these diagnosis groups, the ratio of mean hospital charges for patients 65+ yr and patients 18-64 yr ranges from 0.84 - 1.09 (HCUP, 2008).

However, we also note that the follow-up medical costs we estimated may be underestimates as they are based on HMO costs rather than charges. Furthermore, we do not account for precursor costs incurred before the hospitalization events, nor do we include out-of-pocket medical expenses such as the costs of in-hospital doctors' fees, prescriptions, equipment and other medical services. According to survey results from Thayer *et al*. (2003) for HMO patients, out-of-pocket costs are relatively minor compared to hospital charges.

We applied results from Thayer and coworkers' survey to estimate the 5 cost categories for hospitalizations outside of hospital charges. Since the survey respondents were HMO patients with a higher average wage rate than the general CA population, it is possible that the average heat wave patient may have valued impacts differently. For example, non-HMO heat wave patients may place a comparatively higher WTP value

on avoiding hospitalizations, and although we did not estimate out-of-pocket costs, these would likely be more expensive for non-HMO patients. Of course, applying Thayer *et al*.'s estimates (derived for cardiovascular and acute and chronic respiratory hospitalizations) to all of the heat wave diagnosis categories is an approximation. However, Thayer *et al.* did not observe significant differences among patients' responses for the three types of hospitalizations they studied, so it is possible that the parameters we used are fairly constant for hospitalizations in general.

With regard to our application of Thayer and coworkers' WTP estimates, our linear fit of their WTP values for avoiding 1- and 5-day hospitalizations may slightly overestimate the costs. Thayer *et al.* observed significant nonlinearity in the WTP responses, with payment to avoid additional hospital days after 1 day adding successively smaller values. By approximating a curve with a line, our WTP values for hospital stays of duration $d$, where $1 < d < 5$, would be underestimated, but overestimated for $d > 5$. The average length of hospital stays, weighted by diagnosis group, is 5.15 days, so the overestimate should be minimal. In addition, we did not estimate WTP values for avoiding ED visits, nor did we consider the other 4 non-hospital charge categories for ED events. The latter costs per visit would be much lower than those for hospitalizations due to the short duration of ED visits, but still significant given ~16,000 excess ED cases.

**Summary**

Using COI and WTP measures, we have estimated the total societal cost of the 2006 California heat wave as ~$132 million. The bulk of the cost consists of in-hospital expenses.

**References**

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