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OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

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*Pediatrics* 2008;122:e867-e875

DOI: 10.1542/peds.2008-0286

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://www.pediatrics.org/cgi/content/full/122/4/e867>

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American Academy of Pediatrics

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# A Brief Indicator of Household Energy Security: Associations With Food Security, Child Health, and Child Development in US Infants and Toddlers

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The authors have indicated they have no financial relationships relevant to this article to disclose.

## What's Known on This Subject

Rising energy prices are forcing many low-income families to choose between paying utility bills and other necessities such as food and rent. Both "heat or eat" and "cool or eat" phenomena have been described elsewhere, with energy assistance found to moderate their adverse effects.

## What This Study Adds

Energy security was defined conceptually, and a simple but effective operational measure was developed for use in clinical and other settings. Energy insecurity is independently and positively associated with FI and reports of poor health, history of hospitalization, and developmental concerns.

## ABSTRACT

**OBJECTIVE.** Household energy security has not been measured empirically or related to child health and development but is an emerging concern for clinicians and researchers as energy costs increase. The objectives of this study were to develop a clinical indicator of household energy security and assess associations with food security, health, and developmental risk in children <36 months of age.

**METHODS.** A cross-sectional study that used household survey and surveillance data was conducted. Caregivers were interviewed in emergency departments and primary care clinics from January 2001 through December 2006 on demographics, public assistance, food security, experience with heating/cooling and utilities, Parents Evaluation of Developmental Status, and child health. The household energy security indicator includes energy-secure, no energy problems; moderate energy insecurity, utility shutoff threatened in past year; and severe energy insecurity, heated with cooking stove, utility shutoff, or  $\geq 1$  day without heat/cooling in past year. The main outcome measures were household and child food security, child reported health status, Parents Evaluation of Developmental Status concerns, and hospitalizations.

**RESULTS.** Of 9721 children, 11% ( $n = 1043$ ) and 23% ( $n = 2293$ ) experienced moderate and severe energy insecurity, respectively. Versus children with energy security, children with moderate energy insecurity had greater odds of household food insecurity, child food insecurity, hospitalization since birth, and caregiver report of child fair/poor health, adjusted for research site and mother, child, and household characteristics. Children with severe energy insecurity had greater adjusted odds of household food insecurity, child food insecurity, caregivers reporting significant developmental concerns on the Parents Evaluation of Developmental Status scale, and report of child fair/poor health. No significant association was found between energy security and child weight for age or weight for length.

**CONCLUSIONS.** As household energy insecurity increases, infants and toddlers experienced increased odds of household and child food insecurity and of reported poor health, hospitalizations, and developmental risks. *Pediatrics* 2008;122:e867–e875

[www.pediatrics.org/cgi/doi/10.1542/peds.2008-0286](http://www.pediatrics.org/cgi/doi/10.1542/peds.2008-0286)

doi:10.1542/peds.2008-0286

### Key Words

energy security, food security, child health, development

### Abbreviations

HEAG—household energy affordability gap  
LIHEAP—Low-Income Home Energy Assistance Program  
FI—food insecurity  
ED—emergency department  
RR—relative risk  
HES—household energy security  
C-SNAP—Children's Sentinel Nutrition Assessment Program  
FSS—Food Security Scale  
PEDS—Parents' Evaluation of Developmental Status  
HEI—household energy insecurity  
aOR—adjusted odds ratio  
CI—confidence interval

Accepted for publication Jun 16, 2008

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275). Copyright © 2008 by the American Academy of Pediatrics

**T**HE SPECTER OF imminent peaking of global petroleum production and rapid increases in energy prices raise urgent concerns about the ability of some low- and moderate-income households to sustain safe and healthy environments for their children.<sup>1</sup> Overall, energy prices increased by 58% between 2000 and 2006.<sup>2</sup> Between the winters of

2001–2002 and 2006–2007, the national average expenditures for electricity increased by 24%, propane by 83%, natural gas by 75%, and fuel oil by 134%.<sup>3</sup>

For many low-income families in the United States, heating and cooling their homes while maintaining utilities for lighting, refrigeration, and other appliances are ongoing struggles. The difference between an affordable and an actual energy bill has been defined as the home energy affordability gap (HEAG). In 2002, the average annual HEAG per US household with income below 185% of the poverty threshold was estimated at \$639; by 2006 it had increased to \$1047.<sup>4</sup>

The primary federal government program for assisting low-income families in paying their energy bills is the Low Income Home Energy Assistance Program (LIHEAP), administered by the Department of Health and Human Services' Administration for Children and Families. According to the LIHEAP Home Energy Notebook for Fiscal Year 2003, published by Department of Health and Human Services' Administration for Children and Families in 2005, the average home energy burden (proportion of household income required for energy purchases) for the 9.6 million households in 2003 with incomes below 150% of poverty was 13.7% of income, compared with the mean for all households of 6.4% of income.<sup>4–6</sup> This survey of LIHEAP recipients found that 51% of recipient families with children younger than 18 years received an electricity or home heating fuel shutoff notice or threat of shutoff that year.<sup>5</sup> Although updated shutoff data are not yet available, it is noteworthy that overall energy prices increased by an additional 44% between 2003 and 2006.<sup>2</sup>

Health effects of inadequate home heating and cooling on the elderly have been described in some detail,<sup>7–9</sup> but little empirical research literature has addressed the effects of home energy insecurity on infants' and toddlers' health and development. Maintaining a thermally neutral environment through household space heating in the winter and cooling in the summer is important to both health and development of young children.<sup>10</sup> Infants' and toddlers' immature physiologic capacity for thermoregulation makes them more vulnerable than healthy adults to extreme variations in ambient temperature.<sup>10,11</sup> Under extreme temperature conditions, these differences in thermoregulation can contribute to adverse child health outcomes, such as higher rates of hospitalization,<sup>12</sup> and increased incidence of neurodevelopmental and psychological disturbances.<sup>13</sup>

Many poor families have to make difficult choices between paying for energy to heat (or cool) their homes and paying for enough food because household finances do not allow both.<sup>7</sup> Thus, in addition to direct effects of unregulated environmental temperatures on infant and child health, data suggest that household food insecurity (FI) associated with energy insecurity can adversely affect children's nutritional status and health.<sup>14,15</sup> Data from the US Consumer Expenditure Survey and the Third National Health and Nutrition Examination Survey showed a temperature-related decrease in food expenditures and energy intake in low-income families with children.<sup>15</sup> A 1996 study of children 6 to 24 months

of age in Boston, MA, found significantly higher proportions of children with weight-for-age below the fifth percentile in the 3 months after the coldest months, compared with all other months of the year (8.8% vs 6.6% [ $P < .001$ ]).<sup>16</sup> A 2006 multisite study from our research group that examined children who were younger than 3 years and in low-income families showed that energy assistance can buffer the effects of this "heat or eat" phenomenon in infants and toddlers. Children in eligible households that received LIHEAP were less likely to have anthropometric evidence of undernutrition and less likely to require acute hospitalization from an emergency department (ED) visit than children from comparable households that did not receive LIHEAP.<sup>17</sup>

In addition to "heat or eat" decisions, energy insecurity can lead to other undesirable choices. In a 2005 survey of LIHEAP recipients, 35% reported going without medical or dental care as a result of high energy bills, and 32% reported taking less than the prescribed dose or not filling a prescription for medication as a result of high energy bills.<sup>18</sup> When families are unable to pay their gas, electric, or heating-fuel bills, they often resort to improvised unsafe energy sources.<sup>18,19</sup> Alternative heating sources that many poor families use can lead to adverse health consequences in young children, such as increased incidence of burns,<sup>19</sup> carbon monoxide exposure, and respiratory illnesses.<sup>20,21</sup> In 2002, 24% of all fatal home candle fires occurred in homes in which the power had been shut off, and children who were younger than 5 years faced the highest relative risk (RR) for death (2.5) from home candle fires of all age groups.<sup>22</sup> Despite the widespread need for LIHEAP, however, combined state and federal funding for the program enabled only 16% of eligible families to receive energy assistance in 2006.<sup>23</sup>

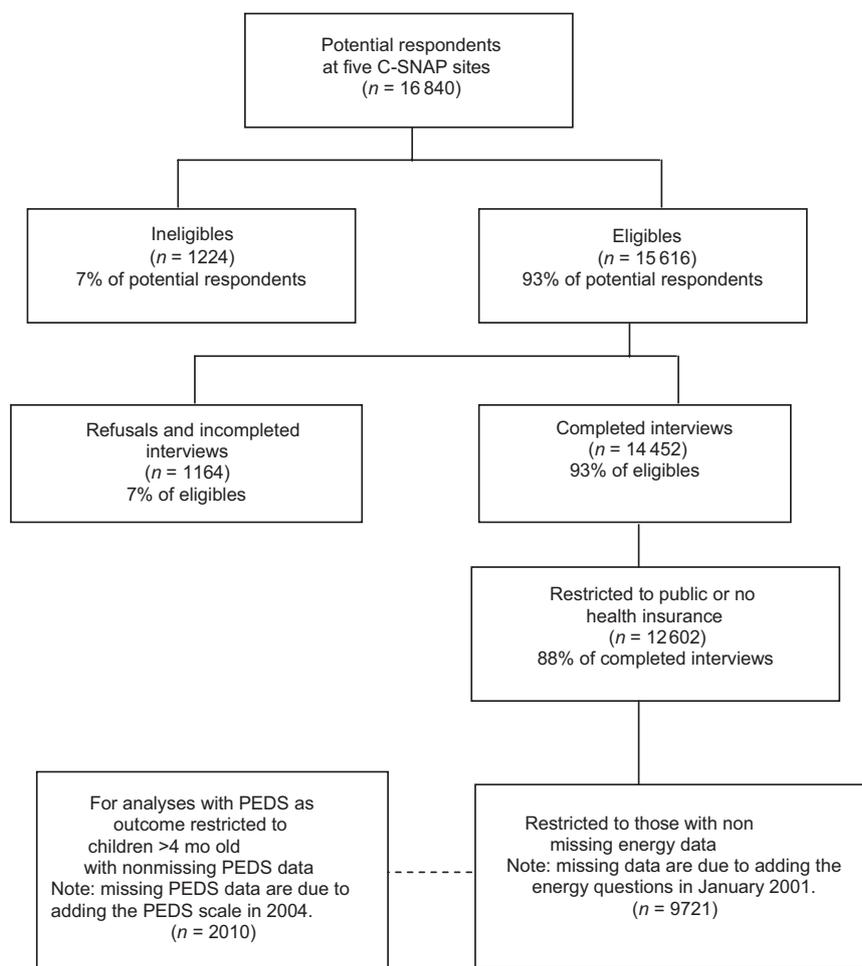
Along with increasing energy prices, poverty rates for children who were younger than 6 years rose from 17.2% in 2000 to 20.3% in 2006.<sup>6</sup> In addition, children's experience of FI during this period was widespread. The prevalence of FI among all children (regardless of age) living in households with at least 1 child who was younger than 6 years averaged 19.5%.<sup>24</sup> With rapidly increasing energy costs accompanied by unremitting levels of child poverty and FI, it is important to understand how energy insecurity affects food security, nutritional risks, and ultimately health and development in young children. The aims of this study were to (1) propose a simple household energy security (HES) indicator that can be adapted to surveys and clinical practice and (2) test hypotheses about relationships between HES as measured by this indicator and FI, poor health, and developmental risks in children who are younger than 36 months.

## METHODS

### Participants and Survey: Children's Sentinel Nutrition Assessment Program

This was a cross-sectional study that used a household survey administered from January 2001 through De-

FIGURE 1  
Description of analytic sample selection.



ember 2006 as part of the ongoing Children's Sentinel Nutrition Assessment Program (C-SNAP).<sup>17</sup> The C-SNAP surveys and medical chart audits were completed at central-city medical centers in Baltimore, Boston, Little Rock, Minneapolis, and Philadelphia. Institutional review board approval was obtained at each site before beginning data collection and has been renewed yearly. Trained interviewers who were scheduled during peak patient flow times interviewed adult caregivers who accompanied children who were younger than 3 years in private settings at acute/primary care clinics and hospital EDs. Caregivers of critically ill or injured children were not approached. Potential respondents were excluded when (1) they did not speak English, Spanish, or (in Minneapolis only) Somali, (2) they were not knowledgeable about the child's household, (3) they had been interviewed within the previous 6 months, (4) they lived out of state, or (5) they refused consent for any reason (Fig 1).

Since initiation in 1998, the C-SNAP survey instrument included questions on household characteristics, children's health and hospitalization history, maternal health, participation in federal assistance programs, changes in benefit levels, and the US Food Security Scale (FSS).<sup>24-27</sup> Questions about energy insecurity were added to the initial survey in 2001,<sup>28-30</sup> and the Parents' Eval-

uation of Developmental Status (PEDS; a well-validated and reliable standardized instrument that meets the American Academy of Pediatrics' standards for developmental screening) was added in 2004.<sup>31-33</sup>

Study staff members also collected anthropometric data. Each child's weight was obtained either by project staff members or from medical chart reviews conducted on the same day as the caregiver interview. Each child's length or height (referred to hereafter as height) was also obtained when possible. To ensure that weights and heights were recorded in the same manner at all sites, standard equipment was purchased and regular periodic training sessions conducted at each site.

#### Energy Security Defined

There is no officially sanctioned definition of HES of which we are aware. For the research reported here, drawing on our experience with the construct of food security, we defined energy security conceptually as follows: HES is consistent access to enough of the kinds of energy needed for a healthy and safe life in the geographic area where a household is located. An energy-secure household's members are able to obtain the energy needed to heat/cool their home and operate lighting, refrigeration, and appliances while maintaining expenditures for other necessities (eg, rent, food, cloth-

ing, transportation, child care, medical care). A household experiences energy insecurity (HEI) when it lacks consistent access to the amount or the kind of energy needed for a healthy and safe life for its members.

### **Predictor Variable: HES Indicator**

The definitions in the previous section were operationalized by using a 3-category HES indicator as the primary predictor variable. This indicator was created from responses to a set of 4 questions about the household's energy situation asked in the C-SNAP survey questionnaire since 2001:

1. Since [current month] of last year, has the [gas/electric] company sent [you/the primary caregiver] a letter threatening to shut off the [gas/electricity] in the house for not paying bills?
2. In the last 12 months since last [current month], [have you/has the primary caregiver] ever used a cooking stove to heat the [house/apartment]?
3. Since [current month] of last year, were there any days that the home was not [heated/cooled] because [you/the primary caregiver] could not pay the bills?
4. Since [current month] of last year, has the [gas/electric/oil] company [shut off/refused to deliver] the [gas/electricity/oil] for not paying bills?

When a respondent affirmed none of these 4 questions, her or his household was categorized as "energy secure." Preliminary bivariate associations between each of these questions and proposed outcome measures were examined to determine how affirmative responses to the questions correlated individually and in combinations with the study outcomes. When only the first question was affirmed, indicating the household received a letter from a utility company threatening to shut off a supply of energy, the household was categorized as "moderately energy insecure." When any 1 or more of questions 2 to 4 were also affirmed by a respondent, their household was categorized as "severely energy insecure." Pediatric colleagues who specialize in housing issues reviewed this categorization scheme for face validity. In multivariate analyses, statistical significance of differences in magnitude of associations between successively more severe categories of energy insecurity indicated by the energy security indicator and outcomes was also tested.

### **Outcome Variables**

Outcome variables included household and child food security status, categorized in the standard manner. Food security was measured by the 18-item FSS, which classifies households as food-insecure when adult respondents report conditions indicating that they cannot afford enough nutritious food for all household members to lead active, healthy lives.<sup>24–26</sup> Child FI was measured using 8 child-referenced items in the FSS and has been shown elsewhere to indicate a more severe pediatric condition than household FI measured by using the 18-item scale.<sup>27–29</sup> Other outcomes used are caregiver reports of the child's health status as "fair/poor" versus

"excellent/good" (from the Third National Health and Nutrition Examination Survey health status question), caregivers' reports of whether the child had been hospitalized since birth, the child's weight for age (in z-score form), whether the child was at risk for underweight (weight/age z score < 5th percentile or weight/height z score < 10th percentile), whether the child was overweight or at risk for overweight (age- and gender-standardized weight for length > 85th percentile), whether the child was admitted on the day of the interview (for interviews conducted in EDs at Boston and Little Rock only), and whether the caregiver reported significant developmental concerns on the PEDS.

The FSS uses 18 survey questions to categorize households with children as food-secure (no scale items affirmed), food-insecure without hunger or "low food security" (3–7 scale items affirmed), and food-insecure with hunger or "very low food security" ( $\geq 8$  scale items affirmed). For these analyses, the 2 most severe categories (food-insecure without hunger and food-insecure with hunger) were collapsed to form a dichotomous (food-secure versus food-insecure) variable. Similarly, the 8-item child FSS was used to form a dichotomous child food security variable in accordance with procedures described elsewhere.<sup>27,29</sup> In this study, we examined associations of HES with household and child food security separately.

The PEDS, standardized for children birth to 8 years of age, includes 10 questions and is largely unaffected by sociodemographic variables, geographic location, parental education or employment, and parent or child gender.<sup>31,32</sup> Caregivers were asked to report any concerns (responding no, yes, or a little) about the child's development in 8 areas: expressive and receptive language, fine and gross motor, behavior, socioemotional, self-help, and, for older children, school. In addition, caregivers were asked 2 open-ended questions about concerns in the global/cognitive area and "other concerns." On the basis of standard scoring of the PEDS, endorsed items (yes or a little) were classified as significant or nonsignificant concerns depending on the age of the child. Children who had  $\geq 2$  significant concerns were considered to be at developmental risk.<sup>31,32</sup> The sensitivity and specificity of the PEDS are better for children who are older than 4 months than for infants; therefore, PEDS data were analyzed for children who were older than 4 months and younger than 36 months.<sup>33</sup>

### **Analytic Plan**

Separate multivariate logistic regression models were estimated for each of the outcome variables described in the previous section. Covariates included in each model (Table 1) varied and were selected on the basis of previous research results<sup>16,17,28–30,33</sup> and bivariate correlation with both the outcome and predictor variables. All children in the study were US citizens; however, mother's race/ethnicity was included as a covariate on the basis of previous research using these data and differences in national prevalence of poverty and FI across race/ethnicity subgroups.<sup>6,17,24,28–30,33,34</sup> Separate sets of logistic regression models were estimated to test whether asso-

**TABLE 1 Demographic Characteristics of the C-SNAP Sample**

Characteristic	Energy Security ( <i>n</i> = 6385 [66%])	Moderate Energy Insecurity: Shutoff Threatened ( <i>n</i> = 1043 [11%])	Severe Energy Insecurity: Heat With Cooking Stove/Shutoff/ Unheated ( <i>n</i> = 2293 [23%])	Overall <i>P</i>
Site, % <sup>a</sup>				
Baltimore	67	15	18	
Boston	64	9	27	
Little Rock	61	14	25	<.01
Minneapolis	70	7	23	
Philadelphia	69	15	15	
Child's gender, %				
Male	53	54	54	.74
Female	47	46	46	
Race/ethnicity, % <sup>a</sup>				
Asian	82	3	15	
Black	62	12	26	
Latino	73	7	20	<.01
White	67	13	20	
Native American	62	13	25	
Mother				
US born, %	66	76	69	<.01
Married, %	33	30	29	<.01
Employed, %	40	49	40	<.01
Education, %				
Some high school	35	29	35	
High school graduate	41	40	39	<.01
College graduate	25	31	25	
Maternal depressive symptoms, %	29	40	49	<.01
Age, y	26.0	27.4	26.9	<.01
Child				
Age, mo	12.1	13.4	12.8	<.01
Breastfed, %	59	51	56	<.01
Low birth weight (<2500 g), %	13	15	14	.29
Insurance, %				
Public	96	96	95	.16
None	4	4	5	
Receives, %				
Food stamps	40	55	50	<.01
TANF	27	30	35	<.01
WIC	82	78	82	.01
Housing subsidy	27	35	38	<.01
LIHEAP	13	30	22	<.01
Receives TANF or food stamps, %	43	58	54	<.01
TANF sanctioned, %	25	30	33	<.01
FSP sanctioned, %	5	7	8	<.01

Some percentages do not sum to 100% because of rounding. TANF indicates Temporary Assistance for Needy Families; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; FSP, Food Stamp Program.

<sup>a</sup> Row percentage instead of column percentage.

ciations between energy security status and outcomes might have been mediated by food security status. These tests involved including household food security status and child food security status in the multivariate models (separately) as covariates. Interaction models with energy security by food security interactions were also estimated to test whether food security was a modifier of the effects of energy security on the outcomes.

## RESULTS

Sixty-six percent of children in the analytic sample lived in energy-secure households, whereas 11% lived in

moderately energy-insecure households and 23% in severely energy-insecure households (Table 2). Compared with infants and toddlers in households that were energy secure, those in households with moderate energy insecurity had odds of household FI >2.33 times as great (adjusted odds ratio [aOR]: 2.37 [95% confidence interval (CI): 1.78–3.16]), whereas those in households with severe energy insecurity had odds of household FI >3 times as great (aOR: 3.06 [95% CI: 2.46–3.81]) after adjusting for covariates (Table 1). Similarly, compared with infants and toddlers in energy-secure households, those in moderately energy-insecure households had

**TABLE 2 Adjusted Logistic Regression Results**

Outcomes	Energy Security (n = 6385 [66%])	Moderate Energy Insecurity: Shutoff Threatened (n = 1043 [11%])		Severe Energy Insecurity: Heat With Cooking Stove/Shutoff/Unheated (n = 2293 [23%])		P
		aOR (95% CI)	P	aOR (95% CI)	P	
Household FI (yes/no) <sup>a</sup>	1.00	2.37 (1.78–3.16)	<.01	3.06 (2.46–3.81)	<.01	<.01
Child FI (yes/no) <sup>a</sup>	1.00	1.79 (1.18–2.72)	<.01	3.46 (2.56–4.67)	<.01	<.01
Child health fair/poor <sup>b</sup>	1.00	1.34 (1.08–1.68)	.01	1.36 (1.15–1.61)	<.01	<.01
Hospitalized since birth (yes/no) <sup>b</sup>	1.00	1.22 (1.03–1.45)	.02	1.02 (0.89–1.17)	.74	.07
PEDS, significant concerns <sup>c</sup>	1.00	1.00 (0.71–1.41)	.99	1.82 (1.38–2.39)	<.01	<.01

Covariates were included when significantly related to outcome and predictor. Education is forced into PEDS concern model, and birth weight is forced into underweight and z weight models.

<sup>a</sup> Adjusted for site, mother's race, US birth, marital status, employment, education, maternal depressive symptoms, age, age of child, being breastfed, food stamps, receiving Temporary Assistance for Needy Families, receiving Special Supplemental Nutrition Program for Women, Infants, and Children benefits, Temporary Assistance for Needy Families sanction, and Food Stamp Program sanction.

<sup>b</sup> Adjusted for site, mother's race, maternal education, maternal depressive symptoms, age of child, being breastfed, receiving Special Supplemental Nutrition Program for Women, Infants, and Children benefits, and receiving housing subsidy.

<sup>c</sup> Limited to those older than 4 months. Adjusted for site, US birth, maternal education, maternal depressive symptoms, age, age of child, being breastfed, receiving Special Supplemental Nutrition Program for Women, Infants, and Children benefits, and receiving housing subsidy.

adjusted odds of experiencing child FI 79% greater (aOR: 1.79 [95% CI: 1.18–2.72]), whereas those in severely energy-insecure households had odds of child FI nearly 3.5 times as great (aOR: 3.46 [95% CI: 2.56–4.67]).

Children in households with moderate or severe energy insecurity had adjusted odds of being reported in “fair/poor” health more than one third greater than those in energy-secure households (aOR: 1.34 [95% CI: 1.08–1.68] and 1.36 [95% CI: 1.15–1.61], respectively). Children in moderately energy-insecure households also had adjusted odds of having been hospitalized since birth 22% greater than children in energy-secure households (aOR: 1.22 [95% CI: 1.03–1.45]); however, no significant association was found between lifetime hospitalizations and severe energy insecurity. Also, no significant association was found between energy security status and children's being admitted to the hospital on the day of interview in the 2 ED study sites.

Significant associations between energy insecurity and growth status did not emerge for any of the 3 growth outcome measures used in the study (weight for age, risk for underweight, and risk for overweight); however, a significant association did appear between energy insecurity and caregivers' report of developmental concerns on the PEDS. Infants and toddlers who were between 4 and 36 months of age and in households with severe energy insecurity had adjusted odds of significant PEDS concerns being reported 82% greater than those in energy-secure households (aOR: 1.82 [95% CI: 1.38–2.39]), although no significant association was found between moderate energy insecurity and caregivers' reports of PEDS concerns.

### Secondary Analyses of the HES Indicator

To test whether the effect of severe energy insecurity on the odds of being food-insecure was statistically significantly greater than the effect of moderate energy insecurity, we changed the reference categories for the energy security variable in multivariate logistic regressions from energy security to moderate energy insecurity. In

models with household food security and child food security as outcomes, children in households with severe energy insecurity had significantly greater odds of being food-insecure than children in moderately energy-insecure households.

Because previous studies had shown household and child FI independently associated with children's health status, hospitalizations, and developmental risk,<sup>28–30,33</sup> we tested whether the effects of HEI were mediated by FI and whether food security modified the effects of energy security on study outcomes. When household or child food security status was entered as a covariate in the multivariate logistic regression models, none of the associations between levels of HES and other outcomes changed notably. In addition, no significant interactions were found when energy security × food security interaction terms were included in the multivariate models.

### DISCUSSION

The concept of HES, although recognized implicitly in the past, has not been extensively developed empirically or previously analyzed in relation to children's health and development. In this study, we introduced, defined, and measured HES and empirically examined hypotheses regarding its associations with household and child food security, child health, and reported developmental issues.

Household FI has been shown to be positively associated with adverse health outcomes in infants and toddlers<sup>28–30,33</sup> and with negative outcomes on health, social functioning, problem behaviors, academic achievement, and school performance in children in other age ranges.<sup>34–39</sup> The results reported here indicate that energy insecurity is positively and strongly associated with both household and child FI, even after controlling for a number of covariates that are associated with both energy security and food security. Moreover, statistically significant increments in the odds that children who were younger than 3 years experienced either household or child FI when comparing associations of moderate versus severe energy insecurity with food security in

these data are noteworthy. These results indicate that HES is ordinal associated with household and child FI in these data and suggest that additional research to examine this relationship by using data from other contexts would be useful.

We examined the possibility that associations found in this study between HES and child health and development outcomes might be mediated by food security and that the effects of HES on those outcomes might be modified by food security. Results indicate that neither the direction nor the magnitude of associations between HES and study outcomes changed; neither was statistical significance of these associations affected. These tests confirm that although household and child food security are associated with HES, neither acts as a mediator or an effect modifier in the associations of HES with child health and developmental risk in these analyses; however these results do not necessarily indicate that the effects of energy insecurity on the child health outcomes are completely independent from those of FI or other correlates of poverty.

Although results of this study indicate that energy security/insecurity seems to be a clinically meaningful construct and that the HES scale seems to be ordinal across the categories of household and child food security, it does not seem to be ordinal with respect to the other outcomes examined in these data. The odds of children in moderately energy-insecure households having their health status reported as "fair/poor" versus "excellent/good" are essentially the same as those for children in severely energy-insecure households. This finding suggests a low "threshold effect" of energy insecurity on parents' reports of child health status that, once passed, does not increase significantly at more severe levels of energy insecurity. Conversely, parental concerns about their children's development seem to appear only at more severe levels of energy insecurity, suggesting a higher threshold for this effect.

Interpretation of the association of HES with lifetime hospitalization is more complex. In that case, the absence of significant association between severe energy insecurity and the odds of having been hospitalized since birth appears together with significantly greater odds of having been hospitalized for children in moderately energy-insecure households. One possible explanation for this is that fewer children in the most severely energy-insecure households are taken to clinics or EDs for care, and, thus, fewer experience hospitalizations. In addition, because HES was measured for the 12 months before the interview only, whereas hospitalizations were reported for the child's entire lifetime (<36 months), the 2 measures are not fully congruent in the time periods covered. These relationships could also be clarified by additional research.

Additional research is also needed to clarify the nature of HES and the mechanisms through which it influences children's health. For practical reasons, we defined HES operationally in terms of threatened or actual utility shutoff or refusal to deliver fuel and coping strategies to avoid or accommodate these conditions. Although it may be considered a correlate of poverty, HES

can also be viewed as a special form of household deprivation because it involves resources and services that are widely viewed as necessities for safe and healthful homes. Heating and cooling homes require large amounts of energy in forms specific to structures and geographic locations. Lighting, water heating, cleaning appliances, and refrigeration for food are practical necessities for safety and prevention of asthma, diarrhea, and infectious disease. Appliances such as computers and, to some extent, radio and television are widely thought to be part of healthy, enriched home environments. Absence or shortages of appropriate forms and amounts of energy to provide these services and amenities can expose children to unsafe and unhealthy conditions.

In addition to effects on household and child food security, other suggested pathways of direct influence of HES on child health include exposure to extreme temperatures (low and high), unsafe conditions as a result of insufficient lighting and use of dangerous alternative heating and lighting sources, and carbon monoxide and other air contaminants from alternative lighting and heating sources. Possible indirect pathways can include exposures that result from financial trade-offs necessitated by high energy costs. These can include unhealthy housing conditions such as water leaks and mold, cockroach and rodent infestations, peeling paint and lead paint, and, in the extreme, homelessness after eviction from rental housing subsequent to utility shutoff.<sup>40</sup>

We note that the indicator of HES reported here excludes additional important forms of energy required for transportation. Gasoline, motor oil, and other forms of energy used in transportation also compose a large proportion of an average household's total expenditures. Transportation energy was not included in the HES indicator developed in this study mainly because of a lack of data. Future research that incorporates transportation energy into the concept of HES is also needed.

Identification of solutions to the problem of HEI is beyond the scope of this study; however, it seems to us that multiple approaches are needed. The largest federally funded energy assistance program is LIHEAP. Although LIHEAP can be effective for households that receive it, it is available only for a small proportion of households that need assistance. Improving efficiency of household energy use by people at all income levels is desirable, and innovative approaches are emerging. These include designing and building more energy-efficient housing and retrofitting existing structures to improve their energy efficiency. Advocates for affordable housing, energy assistance, and other policies to address the needs of low-income populations have forged partnerships with local and regional government agencies and utility companies to obtain support for weatherization, winterization, energy efficiency education, shutoff protections, and supports for purchase of energy-efficient appliances. All of these efforts are laudable, and many more are needed.

There are limitations in this research that need to be noted. First, the C-SNAP sample is a large sentinel convenience sample selected over a long period of time by

well-trained interviewers who recruited participants during peak patient-flow times in clinics and EDs at 5 urban medical centers in 5 states; however it is neither a random nor a probability sample, thereby limiting the extent to which these findings can be generalized. Second, although the time-series cross-sectional nature of the data can support tests of association, they cannot be used to determine causality. Although the sentinel sample was of poor and near-poor caregivers and their children who were at a high baseline of risk for negative health and developmental outcomes, the caregivers of the most severely ill and injured children were not included because of their need for immediate medical care. We controlled statistically for important covariate and confounding factors, but unmeasured confounders also may have influenced the findings. Although we sampled caregivers from poor and near-poor families and adjusted for variables related to poverty, such as caregiver education and employment and type of health insurance, we did not have a measure of family income per se or of the quality of home environments. Quality of the home environment related to poverty may be the most important unmeasured confounder in the relation between HES and developmental risk.

Shared method bias (ie, energy security, food security, and child health and developmental concerns all were reported by a single respondent during the same interview) could have influenced the results. That is, it is possible that caregivers who are concerned about energy and food access might report concerns about child health and development because they are more generally concerned about the overall family situation. Finally, we caution that the HES indicator was developed in a sample of largely urban, low-income families with children younger than 3 years and needs additional evaluation in other populations.

## CONCLUSIONS

The research reported here indicates that HES can be measured effectively using a straightforward indicator that is based on a small number of survey questions. Energy insecurity is strongly positively associated with household and child FI in households with children who are younger than 36 months, with significantly greater effects at more severe levels of energy insecurity. As we and others have shown, FI in turn is associated with adverse health and developmental outcomes in children. Above the already established effects of household and child FI, this study suggests that energy insecurity is independently associated with poor health status, lifetime hospitalizations, and parents' report of developmental concerns among infants and toddlers.

Persistently high rates of poverty among families with children in the United States, coupled with increasingly pessimistic projections for energy supplies and prices in the next decade,<sup>41</sup> raise serious concerns about the future health, growth, and development of US children. Pediatric health care providers need to be aware of the energy security status of their patients' households and use this information to inform decisions regarding both treatment and referrals for other services. Additional

research is needed to replicate these findings in other samples and to evaluate whether the relationships pertain to families with older children and households with no children; however, the current findings suggest that policies that reduce HEI may also reduce household FI and may exert additional direct protective effects on the health and development of infants and toddlers.

## ACKNOWLEDGMENTS

This research was supported by unrestricted funding from the following sources (no one working for or representing any of these sources of support had anything to do with or played any role in any aspect of this research and article, including study concept or design; acquisition or interpretation of data; statistical analysis; drafting; review or revision of the manuscript; administrative, technical, or material support; or study supervision): W.K. Kellogg Foundation; MAZON: A Jewish Response to Hunger; Gold Foundation; Minneapolis Foundation; Project Bread: The Walk for Hunger; Sandpiper Foundation; Anthony Spinazzola Foundation; Daniel Pitino Foundation; Candle Foundation; Wilson Foundation; Abell Foundation; Claneil Foundation; Beatrix Fox Auerbach donor-advised fund of the Hartford Foundation (on the advice of Jean Schiro Zavela and Vance Zavela); Susan Schiro and Peter Manus; Eos Foundation; Endurance Fund; Gryphon Fund; Shoffer Foundation; and anonymous donors.

We are very grateful to the families who participated in this study. We also gratefully acknowledge Dr Alan Meyers for careful review of and comments on draft manuscripts; Zhaoyan Yang for excellent management of surveillance and interview data and SAS programming; and Gabriela Santamaria, MA, Nicole Neault, MPH, Joni Geppert, MPH, Tu Quan, Susan Goolsby, Anna Quigg, MA, Jodi Marani, MEd, and Jennifer Breaux, MPH, for excellent training, scheduling, and supervising of interview staff members and for diligence in coding, cleaning, and preparing questionnaires for data entry.

## AUTHOR CONTRIBUTIONS

Dr Cook had full access to all of the data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis; Drs Cook, Frank, Casey, Rose-Jacobs, Black, Chilton, Heeren, Berkowitz, and Cutts were responsible for study concept and design; Drs Cook, Frank, Casey, Black, Chilton, Heeren, Berkowitz, and Cutts, and Ms Ettinger de Cuba, Appugliese, and Coleman were responsible for acquisition and interpretation of data; Drs Cook and Frank were responsible for drafting of the manuscript; Drs Cook, Frank, Casey, Rose-Jacobs, Black, Chilton, Berkowitz, and Cutts and Ms Ettinger de Cuba were responsible for critical revision of the manuscript for important intellectual content; Dr Cook, Frank, and Heeren and Ms Ettinger de Cuba, Appugliese, and Coleman were responsible for statistical analysis; Ms Ettinger de Cuba, Appugliese, and Coleman were responsible for administrative, technical, or material support; and Drs Cook and Frank were responsible for study supervision.

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*Pediatrics* 2008;122:e867-e875  
DOI: 10.1542/peds.2008-0286

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