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RESEARCH ARTICLE

Narrow- and Broad-Spectrum Antibiotic Use among U.S. Children

Eric M. Sarpong and G. Edward Miller

Objectives. To provide updated estimates of narrow- and broad-spectrum antibiotic use among U.S. children.

Data Sources. Linked nationally representative data from the 2004–2010 Medical Expenditure Panel Survey Household Component and the 2000 Decennial Census.

Study Design. Relationships between individual-, family-, and community-level characteristics and the use of antibiotics overall and in the treatment of respiratory tract infections (RTIs) are examined using multinomial choice models.

Principal Findings. More than one quarter (27.3 percent) of children used at least one antibiotic each year with 12.8 percent using broad-spectrum and 18.5 percent using narrow-spectrum antibiotics. Among children with use, more than two-thirds (68.6 percent) used antibiotics to treat RTIs. Multivariate models revealed many differences across groups in antibiotic use, overall and in the treatment of RTIs. Differential use was associated with a broad range of factors related to need (e.g., age, health status), resources (e.g., insurance status, parental income, and education), race-ethnicity, and Census region.

Conclusions. Despite encouraging reports regarding the declining use of antibiotics, large differences in use associated with resources, race-ethnicity, and Census regions suggest a need for further improvement in the judicious and appropriate prescribing of antibiotics for U.S. children.

Key Words. Children, antibiotics, narrow- and broad-spectrum, multinomial choice model

Antibiotics, a class of chemotherapeutic agents that are used to treat the underlying causes of infectious diseases by inhibiting microbial growth and survival, have been instrumental in drastically reducing illness and death from infections since the 1940s. Widespread use of antibiotics, however, has also resulted in drug resistance, therapeutic failure, and adverse drug–drug interactions (Interagency Task Force on Antimicrobial Resistance 2011). Children are a population of particular concern due to their high rates of antibiotic use and infection with antibiotic-resistant pathogens (Perz et al. 2002). These

concerns, especially the increasing prevalence of antibiotic-resistant bacterial infections and the burden they exert on society, prompted the Centers for Disease Control and Prevention (CDC) to launch The National Campaign for Appropriate Use of Antibiotics in the Community in 1995. In 2003, this program was renamed Get Smart: Know When Antibiotics Work in conjunction with the launch of a national media campaign (Centers for Disease Control and Prevention 2013).

A number of previous studies have found that children's use of antibiotics—overall and in the treatment of respiratory tract infections (RTIs)—declined sharply in the mid-1990s following the launch of the initial CDC campaign in 1995 (McCaig, Besser, and Hughes 2002; Finkelstein et al. 2003; Mainous et al. 2003; Steinman et al. 2003; Miller and Hudson 2006). In spite of these encouraging trends, inappropriate use of different types of antibiotics has continued among U.S. children (McCaig, Besser, and Hughes 2002; Centers for Disease Control and Prevention 2011). One of the most concerning findings in the recent literature is increased use of broad-spectrum antibiotics to treat common RTIs (Mainous et al. 2003; Coco, Horst, and Gambler 2009; Grijalva, Nuorti, and Griffin 2009; Coco et al. 2010; Hersh et al. 2011; Kronman et al. 2011; Shapiro et al. 2011).

In this study, we examine antibiotic use in the years following the launch of the CDC media campaign, focusing on differences in use across subgroups of U.S. children (ages 1–17). Our goal was to identify individual-, family-, and community-level characteristics associated with high levels of antibiotic use. This information may be useful in guiding policy makers and health practitioners as they target educational materials and other interventions that promote the appropriate use of antibiotics. We begin by examining all antibiotic use, then focus on antibiotics used to treat common RTIs, which account for the majority of antibiotic use in children (Miller and Hudson 2006). In all of our analyses, we examine the use of narrow-spectrum antibiotics as well as broad-spectrum antibiotics, which have greater implications for the spread of antibiotic-resistant infections.

We use nationally representative data from the 2004–2010 Medical Expenditure Panel Survey Household Component (MEPS-HC), which

Address correspondence to Eric M. Sarpong, Ph.D., Economist, Division of Modeling and Simulation, Center for Financing, Access and Cost Trends, Agency for Healthcare Research and Quality, 540 Gaither Road, Rockville, MD 20850; e-mail: eric.sarpong@ahrq.hhs.gov. G. Edward Miller, Ph.D., is with the Division of Modeling and Simulation, Center for Financing, Access and Cost Trends, Agency for Healthcare Research and Quality, Rockville, MD.

contains a rich set of information on individual- and family-level characteristics. We further enhance our analyses by linking the MEPS-HC to Census tract-level information to get information on community-level characteristics that may influence differential use of antibiotics. We use these linked data to estimate multinomial choice models of the relationships between individual-, family-, and community-level characteristics and three mutually exclusive outcomes: no antibiotic use, any broad-spectrum antibiotic use, and narrow-spectrum antibiotic use only.

DATA AND METHODS

Data

The data for the study were primarily drawn from the 2004–2010 MEPS-HC, an ongoing, overlapping panel survey sponsored by the Agency for Healthcare Research and Quality (AHRQ). The MEPS-HC collects detailed and nationally representative information on health care utilization and expenditures, insurance coverage, sources of payment, health status, and sociodemographic variables for the U.S. civilian, noninstitutionalized population (Cohen 1997; Ezzati-Rice, Rohde, and Greenblatt 2008). Previous studies suggest that community-level characteristics such as average household income, the percent of persons who own their homes, and the percent of persons with incomes below the Federal poverty level affect the prevalence of bacterial infections (Huang et al. 2004). We therefore linked individuals in the MEPS-HC to tract-level information from the 2000 Decennial Census to obtain information on the communities where children live.¹ Generally, Census tracts have between 2,500 and 8,000 people and are constructed to be as homogeneous as possible with respect to population characteristics, economic status, and living conditions (Census Bureau 1994). We included the following tract-level variables in our multivariate models: the median value of homes, the percent of persons renting their homes, the percent of persons receiving public assistance, and the percent of persons living in poverty.

Sample

We limited our sample to children ages 1–17 who were in the MEPS survey for all 12 months in a given year. We conducted analyses for all children in our sample and for children who were reported to have at least one RTI. We used the International Classification of Diseases, Ninth Revision (ICD-9-CM)

three-digit codes to identify children with the following RTIs: otitis media (381.x, 382.x), pharyngitis (034.x, 462.x, 463.x), sinusitis (461.x, 473.x) bronchitis (465.x, 466.x), pneumonia (481.x, 482.x, 483.x, 484.x, 485.x, 486.x), and upper RTIs (460.x, 465.x, 478.x). Our unweighted samples comprised 61,992 person-years for all children and 23,558 for children with RTIs.

Antibiotic Medications

We used the MEPS Prescribed Medicines files linked to the Multum Lexicon database, a product of Cerner Multum, Inc., to assess children's acquisitions of antibiotics during the year. We used Multum information on active ingredients to assign prescription drug purchases reported by respondents to the therapeutic subclasses of antibiotics that are commonly available via oral or intramuscular routes of administration, excluding antimalarial, antiviral, and antifungal medications. Next, we grouped antibiotic therapeutic subclasses by their spectrum of activities. Antibiotic agents that act against a limited subset of bacteria were classified as narrow spectrum, while antibiotic agents that act against a wider range of bacteria (gram-positive and gram-negative) were classified as broad spectrum.

It is important to note that the terms “narrow” and “broad” are somewhat arbitrary—among narrow-spectrum antibiotics, some are narrower than others and among broad-spectrum antibiotics some are broader than others (Acar 1997). Furthermore, some subclasses of antibiotics contain both narrow-spectrum and broad-spectrum antibiotics. As a result, the classification of antibiotics into “narrow” and “broad” spectrum categories is not entirely consistent in the published domain. We started with the classifications presented in the most recent studies on children's antibiotic use (Grijalva, Nuorti, and Griffin 2009; Hersh et al. 2011). Then, we consulted two pediatricians to get their expert opinion on the classification of antibiotics.² Finally, we used this information to place all major subclasses of oral and intramuscular antibiotics into mutually exclusive “narrow” and “broad” spectrum categories. The details of our narrow- and broad-spectrum classifications are presented in Appendix SA2.

Independent Variables

We included the following characteristics in all multivariate models: age (1–5, 6–10, 11–14, and 15–17), sex, race-ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other non-Hispanic), household income as a

percentage of the Federal poverty line or FPL (<200 percent of FPL and ≥ 200 percent of FPL), parental education ($\leq$ high school or GED and $>$ high school or GED), insurance coverage (any private, public only, and uninsured), perceived health status (“excellent,” “very good” or “good,” and “fair” or “poor”), number of parents (single-parent or two-parent household), number of siblings (none, one, two, and three or more), parental perception of child’s health compared to peers (child less healthy than other children?: “definitely/mostly true,” and “don’t know” or “definitely/mostly false”), Metropolitan statistical area (non-MSA and MSA), Census region (Northeast, Midwest, South, and West), and the community-level variables described above. Our multivariate models also included dummy variables for data years to capture time-specific unobservables that are common to all children. Information on individual-, family-, and community-level characteristics of our sample is provided in Appendix SA3.

Analytic Approach

We used both descriptive and multivariate analyses to examine three mutually exclusive outcomes that capture children’s antibiotic use during the year: no antibiotic use, any broad-spectrum antibiotic use, and use of narrow-spectrum antibiotics only. As our outcomes are unordered, limited dependent variables, they can be modeled via multinomial regressions (Wooldridge 2002; Greene 2012). The multinomial specifications are natural extensions of latent variable models (McFadden 1974), which simultaneously estimate binary logit (or probit) models among all pairs of our dependent categories.

Our preferred specification is the multinomial logit (MNL) model, which is computationally tractable due to its globally concave likelihood function that makes maximum likelihood estimation straightforward. However, the MNL model imposes the assumption of independence of irrelevant alternatives (IIA), which requires that the ratio of any two choice probabilities cannot depend on any other choice probabilities and the determinants of the probability ratios of the initial choices must remain unaffected with the inclusion or exclusion of any other alternative (Davidson and MacKinnon 1993). Results from Hausman tests (Hausman and McFadden 1984) suggested that the IIA assumption may be untenable in our MNL models.

We tested the sensitivity of our MNL estimates to alternative specifications in two ways. First, we reestimated our models via multinomial probit (MNP). The MNP model shares desirable statistical properties of estimators

with the MNL model (e.g., consistency, normality, and efficiency), but it offers a potential advantage because it does not require imposition of the IIA assumption. We found few qualitative differences between our MNL and MNP models. Second, we assessed the overall fit of our MNL model specification using both McFadden's pseudo R-squared and the likelihood ratio chi-square test. Results from both tests showed that the model fit was better in our preferred model specification than in models with a more limited set of covariates (i.e., restricted models).

Estimation of MNL and MNP model parameters was accomplished using the iterative maximum likelihood algorithm in STATA 12. We present results from all models as average marginal effects which reflect the discrete first-differences from the reference category of a covariate, on the probability of selecting a given alternative, holding all other covariates constant. There were few qualitative differences between our MNL and MNP models, so we focus on the estimates from our MNL models and present the MNP estimates in Appendix SA4. All analyses incorporated sampling weights that take disproportionate sampling and nonresponse into account. Standard errors were adjusted for the complex sampling design of the MEPS-HC using the Taylor Series approach. The survey design-adjusted standard errors also adjust for the nonindependence between multiple observations for the same respondent (Williams 2000).

RESULTS

Descriptive Statistics

Table 1 presents pooled estimates, for the years 2004–2010, of the percentages of U.S. children who used each of the major subclasses of antibiotics. Results show that more than a quarter (27.3 percent) of children used antibiotics with 12.8 percent using broad-spectrum antibiotics and 18.5 percent using narrow-spectrum antibiotics.³ Penicillins were the most commonly prescribed class of antibiotics as 16.9 percent of children used any penicillin and 15.1 percent used a narrow-spectrum penicillin. The proportion of children with at least one prescription from the macrolide class was 8.5 percent, overall, with broad-spectrum macrolides (8.2 percent) comprising nearly all of this use. Cephalosporins were the third most commonly prescribed antibiotic with 4.7 percent of children using these medications and a majority of this use (3.0 percent) coming from the broad-spectrum category. The percentages of children using the remaining classes of antibiotics were lower: sulfonamides and

Table 1: Percent of U.S. Children (Ages 1–17) Using Major Subclasses of Oral Antibiotics, 2004–2010

<i>Type of Antibiotic</i>	<i>Any Antibiotic</i>	<i>Spectrum</i>	
		<i>Broad</i>	<i>Narrow</i>
All antibiotics	27.3 (0.3)	12.8 (0.3)	18.5 (0.3)
Penicillin	16.9 (0.3)	2.7 (0.1)	15.1 (0.3)
Macrolides	8.5 (0.2)	8.2 (0.2)	0.4 (0.0)
Cephalosporins	4.7 (0.2)	3.0 (0.1)	1.8 (0.1)
Sulfonamides and trimethoprim	1.3 (0.1)	n/a	1.3 (0.1)
Tetracyclines	0.9 (0.1)	n/a	0.9 (0.1)
Lincosamides	0.3 (0.0)	0.3 (0.0)	n/a
Others*	0.8 (0.1)	0.4 (0.0)	0.1 (0.0)

Note. Authors’ calculations using data from the 2004–2010 Medical Expenditure Panel Survey Household Component. All analyses incorporated sampling weights that take disproportionate sampling and nonresponse into account.

*Among the “Other” antibiotics category, there are some that cannot be classified as either broad or narrow. Standard errors are in parentheses.

trimethoprim (1.3 percent), tetracyclines (0.9 percent), lincosamides (0.3 percent), and all others (0.8 percent).

Table 2 presents information on the conditions that antibiotics were intended to treat for U.S. children from 2004 through 2010. Results show that among children with antibiotic use, more than two-thirds (68.6 percent) used antibiotics to treat an RTI. More than one quarter (28.5 percent) used antibiotics to treat otitis media, while pharyngitis, which includes strep throat, accounted for the second highest proportion of children with use (20.0 percent). The four remaining conditions accounted for smaller percentages of antibiotic use: upper RTIs (13.1 percent), sinusitis (9.8 percent), bronchitis (5.6 percent), and pneumonia (3.7 percent). Although the distributions were somewhat different, the rank order of these conditions was the same among children with any broad-spectrum use and among children with narrow-spectrum use only.

Multivariate Models

For any individual, the predicted probabilities of our three dependent variables (no antibiotic use, any broad-spectrum use, and narrow-spectrum-only use) sum to one (i.e., $P_{i1} = 1 - [P_{i2} + P_{i3}]$) and the marginal effects of any variable on these probabilities, therefore, must sum to zero (i.e., $ME_{i1} + ME_{i2} + ME_{i3} = 0$). That is, for any increase (decrease) in no antibiotic

Table 2: Percent of U.S. Children (Ages 1–17) Using Antibiotics to Treat Any RTI, Specific RTIs: among U.S. Children with Antibiotic Use, 2004–2010

<i>Condition*</i>	<i>All Antibiotics</i>	<i>Spectrum</i>	
		<i>Broad</i>	<i>Narrow</i>
Any respiratory tract infection	68.6 (0.5)	68.6 (0.8)	66.7 (0.6)
Otitis media	28.5 (0.6)	26.3 (0.8)	29.1 (0.7)
Pharyngitis	20.0 (0.5)	14.3 (0.6)	21.5 (0.6)
Sinusitis	9.8 (0.4)	12.4 (0.6)	7.3 (0.4)
Bronchitis	5.6 (0.3)	7.6 (0.5)	3.5 (0.3)
Pneumonia	3.7 (0.2)	5.5 (0.4)	1.9 (0.2)
Upper respiratory tract infection	13.1 (0.4)	12.9 (0.6)	11.5 (0.5)

Note. Authors' calculations using linked data from the 2004–2010 Medical Expenditure Panel Survey Household Component (MEPS-HC). All analyses incorporated sampling weights that take disproportionate sampling and nonresponse into account.

*MEPS-HC respondents may report one or multiple conditions that each drug fill was intended to treat and respondents may report using both a broad- and a narrow-spectrum antibiotic to treat the same condition. Standard errors are in parentheses.

use, there must be a compensating decrease (increase) in the probability of any broad-spectrum antibiotic use and/or narrow-spectrum-only antibiotic use. Also, in interpreting the results, it is important to note that a negative (positive) marginal effect for the outcome “No Antibiotic” corresponds to a positive (negative) marginal effect on the use of any antibiotics.

Table 3 presents marginal effects from our MNL model of overall antibiotic use. After controlling for individual-, family-, and community-level characteristics, results indicate that children ages 1–5 (15.9 percentage points), ages 6–10 (7.3 percentage points), in fair or poor health (13.5 percentage points), considered to be less healthy than their peers (6.8 percentage points), and those living in the South (2.6 percentage points) were more likely than others to use any antibiotics during the year. Results also indicate that non-Hispanic black (17.0 percentage points), Hispanic (6.2 percentage points), and non-Hispanic other (11.3 percentage points) children were less likely than non-Hispanic white children to use any antibiotics. Children in families with low levels of income (3.0 percentage points) and parents with no more than a high-school education (4.1 percentage points), uninsured children (8.5 percentage points), children with one (1.8 percentage points), two (4.5 percentage points), or three or more (7.8 percentage points) siblings, those living in MSAs (2.4 percentage points) and those living in the West (3.5 percentage points) were also less likely than others to use any antibiotics during the year.

Table 3: Marginal Effects from Multinomial Logit Models of Antibiotic Use among All U.S. Children (Ages 1–17), 2004–2010

		Spectrum	
	No Antibiotic	Any Broad	Narrow Only
Individual- and family-level characteristics			
Age in years (reference: 15–17)			
1–5	–0.159*** (0.008)	0.078*** (0.006)	0.081*** (0.006)
6–10	–0.073*** (0.008)	0.024*** (0.006)	0.049*** (0.007)
11–14	0.012 (0.008)	–0.006 (0.006)	–0.006 (0.007)
Sex			
Female	–0.009* (0.01)	0.002 (0.00)	0.007* (0.00)
Race-ethnicity (reference: non-Hispanic white)			
Non-Hispanic black	0.170*** (0.01)	–0.108*** (0.01)	–0.062*** (0.01)
Hispanic	0.062*** (0.009)	–0.041*** (0.007)	–0.021*** (0.006)
Non-Hispanic other	0.113*** (0.012)	–0.049*** (0.008)	–0.064*** (0.009)
Family income (reference: Middle/high income)			
Poor/low income	0.030*** (0.007)	–0.020*** (0.005)	–0.010* (0.006)
Parent's education (max) (reference: >high school)			
≤High school	0.041*** (0.01)	–0.024*** (0.01)	–0.016*** (0.01)
Health insurance status (reference: private)			
Public	0.010 (0.01)	–0.022*** (0.01)	0.012** (0.01)
Uninsured	0.085*** (0.012)	–0.050*** (0.011)	–0.035*** (0.010)
Number of parents (reference: one-parent)			
Two-parent	–0.003 (0.01)	0.001 (0.01)	0.002 (0.01)
Number of siblings (reference: none)			
One	0.018*** (0.01)	–0.009* (0.01)	–0.009 (0.01)
Two	0.045*** (0.01)	–0.026*** (0.01)	–0.019*** (0.01)
Three or more	0.078*** (0.012)	–0.044*** (0.009)	–0.033*** (0.009)
Perceived health status (reference: excellent/very good/good)			
Fair/poor	–0.135*** (0.01)	0.081*** (0.01)	0.053*** (0.01)
Child less healthy than peers (reference: No)			
Yes	–0.068*** (0.01)	0.052*** (0.01)	0.016** (0.01)
Community-level characteristics			
At least 10% of persons			
Receiving public assistance [†] (reference: No)			
Yes	0.003 (0.02)	0.007 (0.02)	–0.010 (0.01)
Living below the poverty line [‡] (reference: No)			
Yes	0.022*** (0.01)	–0.013** (0.01)	–0.009 (0.01)
Renting their homes [§] (reference: No)			
Yes	–0.001 (0.011)	0.002 (0.008)	–0.001 (0.008)
Log of median value of homes in Census tract	0.026*** (0.01)	–0.013** (0.01)	–0.013** (0.01)
Geographic variables			
Metropolitan statistical area (reference: non-MSA)			
MSA	0.024** (0.01)	–0.022*** (0.01)	–0.002 (0.01)

Continued

Table 3. *Continued*

	<i>No Antibiotic</i>	<i>Spectrum</i>	
		<i>Any Broad</i>	<i>Narrow Only</i>
Census region (reference: Northeast)			
Midwest	−0.021* (0.01)	−0.006 (0.01)	0.027*** (0.01)
South	−0.026** (0.01)	0.028*** (0.01)	−0.002 (0.01)
West	0.035*** (0.011)	−0.042*** (0.009)	0.007 (0.007)

Note. Authors' calculations using linked data from the 2004–2010 Medical Expenditure Panel Survey Household Component and the 2000 Decennial Census. All analyses incorporated sampling weights that take disproportionate sampling and nonresponse into account.

[†]Percent of Census tracts where at least 10% of the population receive food stamps.

[‡]Percent of Census tracts where at least 10% of the population have family income below the Federal poverty line.

[§]Percent of Census tracts where at least 10% of the population rent their homes.

All multivariate models include a set of time dummy variables for survey years. Standard errors are in parentheses. Significance level: *** $p < .01$, ** $p < .05$, * $p < .10$.

In most cases, broad- and narrow-spectrum antibiotics both contributed to overall differences in antibiotic use across groups defined by individual- and family-level characteristics. For example, the overall difference in antibiotic use between uninsured and privately insured children (8.5 percentage points) is comprised of a 5.0 percentage point difference in broad-spectrum use and a 3.5 percentage point difference in narrow-spectrum use. For community-level and geographic (e.g., MSA and region) variables, however, differences were almost always driven by broad-spectrum antibiotics. For example, children living in the West were 3.5 percentage points less likely than those in the Northeast to use any antibiotics and were 4.2 percentage points less likely to use any broad-spectrum antibiotics.

Table 4 presents marginal effects from our MNL model of antibiotics used to treat RTIs among children who were reported to have an RTI. In most cases, results were qualitatively similar to the results for all antibiotic use. Children who were younger, in fair or poor health, less healthy than their peers, or living in the South were more likely than others to use any antibiotics to treat their RTIs, while minority children, children in families with low levels of income and parental education, uninsured children, children with three or more siblings, and those living in the West were less likely than others to use any antibiotics during the year. There were also qualitative differences. Publicly insured children were more likely to have no antibiotic use (2.3 percentage points) and less likely to use broad-spectrum antibiotics (4.2 percentage points) to treat their RTIs. The magnitudes of some marginal effects

Table 4: Marginal Effects from Multinomial Logit Models of Antibiotic Use among U.S. Children (ages 1–17) with Respiratory Tract Infections, 2004–2010

		<i>Spectrum</i>	
	<i>No Antibiotic</i>	<i>Any Broad</i>	<i>Narrow Only</i>
Individual- and family-level characteristics			
Age in years (reference: 15–17)			
1–5	−0.229*** (0.014)	0.073*** (0.011)	0.156*** (0.013)
6–10	−0.133*** (0.015)	0.002 (0.012)	0.132*** (0.013)
11–14	−0.038** (0.015)	−0.013 (0.012)	0.050*** (0.015)
Sex			
Female	0.006 (0.008)	−0.012* (0.007)	0.006 (0.007)
Race-ethnicity (reference: non-Hispanic white)			
Non-Hispanic black	0.160*** (0.015)	−0.129*** (0.014)	−0.032** (0.013)
Hispanic	0.048*** (0.012)	−0.046*** (0.011)	−0.002 (0.011)
Non-Hispanic other	0.123*** (0.017)	−0.060*** (0.015)	−0.063*** (0.016)
Family income (reference: middle/high income)			
Poor/low income	0.033** (0.013)	−0.015 (0.010)	−0.018* (0.010)
Parent's education (max) (reference: >high school)			
≤high school	0.029** (0.01)	−0.028*** (0.01)	−0.001 (0.01)
Health insurance status (reference: private)			
Public	0.023* (0.01)	−0.042*** (0.01)	0.019* (0.01)
Uninsured	0.085*** (0.024)	−0.056** (0.022)	−0.029 (0.021)
Number of parents (reference: one-parent)			
Two-parent	−0.014 (0.01)	0.016 (0.01)	−0.002 (0.01)
Number of siblings (reference: none)			
One	−0.004 (0.01)	−0.001 (0.01)	0.006 (0.01)
Two	0.010 (0.01)	−0.020* (0.01)	0.011 (0.01)
Three or more	0.041** (0.019)	−0.047*** (0.016)	0.006 (0.016)
Perceived health status (reference: excellent/very good/good)			
Fair/poor	−0.067*** (0.02)	0.053*** (0.01)	0.014 (0.01)
Child less healthy than peers (reference: No)			
Yes	−0.063*** (0.02)	0.063*** (0.01)	0.001 (0.02)
Community-level characteristics			
<i>At least than 10% of persons</i>			
Receiving public assistance [†] (reference: No)			
Yes	0.004 (0.02)	−0.011 (0.02)	0.007 (0.02)
Living below the poverty line [‡] (reference: No)			
Yes	0.034*** (0.01)	−0.021** (0.01)	−0.013 (0.01)
Renting their homes [§] (reference: No)			
Yes	0.019 (0.015)	−0.014 (0.013)	−0.005 (0.014)
Log of median value of homes in Census tract	0.059*** (0.01)	−0.031*** (0.01)	−0.028*** (0.01)
Geographic variables			
Metropolitan statistical area (ref: non-MSA)			
MSA	0.029** (0.01)	−0.030** (0.01)	0.001 (0.01)

Continued

Table 4. *Continued*

	<i>No Antibiotic</i>	<i>Spectrum</i>	
		<i>Any Broad</i>	<i>Narrow Only</i>
Census region (reference: Northeast)			
Midwest	−0.011 (0.02)	−0.017 (0.01)	0.028** (0.01)
South	−0.032** (0.02)	0.048*** (0.01)	−0.016 (0.01)
West	0.074*** (0.016)	−0.074*** (0.015)	0.00 (0.013)

Note. Authors' calculations using linked data from the 2004–2010 Medical Expenditure Panel Survey and the 2000 Decennial Census. All analyses incorporated sampling weights that take disproportionate sampling and nonresponse into account.

[†]Percent of Census tracts where at least 10% of the population receive food stamps.

[‡]Percent of Census tracts where at least 10% of the population have family income below the Federal poverty line.

[§]Percent of Census tracts where at least 10% of the population rent their homes.

All multivariate models include a set of time dummy variables for survey years. Standard errors are in parentheses. Significance level: *** $p < .01$, ** $p < .05$, * $p < .10$.

were also larger in the RTI model than in the overall model. For example, children ages 1–5 (22.9 percentage points) and ages 6–10 (13.3 percentage points) were both substantially more likely than those ages 15–17 to use any antibiotics primarily due to greater use of narrow-spectrum antibiotics among the younger age groups.

As in the models for all antibiotic use, differences in the use of antibiotics to treat RTIs across groups defined by community-level and geographic variables were primarily driven by broad-spectrum antibiotics. For example, children living in the South were 3.2 percentage points more likely and those living in the West were 7.4 percentage points less likely to use any antibiotics than children living in the Northeast, and these differences were entirely driven by differences in broad-spectrum use of 4.8 and −7.4 percentage points, respectively. In a number of cases, overall differences in antibiotic use across groups defined by individual- and family-level characteristics such as ages 6–10, Hispanic race-ethnicity, parental income, parental education, and health status were driven entirely by narrow- or broad-spectrum antibiotics.

DISCUSSION

Previous studies documented significant declines in children's use of antibiotics—overall and in the treatment of RTIs—in the years immediately following

the launch, in 1995, of the initial CDC campaign to promote the appropriate use of antibiotics (McCaig, Besser, and Hughes 2002; Finkelstein et al. 2003; Mainous et al. 2003; Steinman et al. 2003; Miller and Hudson 2006). In spite of these encouraging trends, however, concern about overuse and misuse of antibiotics continued to be a major issue in public health. In 2003, the Institute of Medicine identified misuse of antibiotics as a key microbial threat to health in the United States and recommended promoting appropriate antibiotic use as an important strategy to address this threat. At the same time, the CDC launched a national media campaign to promote the appropriate use of antibiotics (Centers for Disease Control and Prevention 2013).

In this study, we used nationally representative data from the MEPS-HC to examine differences in antibiotic use by U.S. children in the years following the launch of the CDC media campaign in 2003. We examined children's use of narrow- and broad-spectrum antibiotics overall and in the treatment of RTIs. We found that, on average, more than one quarter (27.3 percent) of children used at least one major class of antibiotics each year with 12.8 percent using a broad-spectrum antibiotic and 18.5 percent using a narrow-spectrum antibiotic. The most commonly prescribed class of antibiotics, penicillins (16.9 percent), was primarily comprised of narrow-spectrum antibiotics. The second and third most commonly prescribed classes of antibiotics were macrolides (8.5 percent) and cephalosporins (4.7 percent). Both of these classes were primarily comprised of broad-spectrum antibiotics.

In the MEPS-HC data, we cannot directly determine the degree of appropriate versus inappropriate antibiotic use, but the conditions associated with antibiotic purchases provide some evidence. About two-thirds (68.6 percent) of children who used antibiotics during our study period used them to treat common RTIs—otitis media, pharyngitis, bronchitis, sinusitis, upper RTIs (common cold), and pneumonia. Furthermore, significant proportions of children used antibiotics to treat three conditions—bronchitis (5.6 percent), sinusitis (9.8 percent), and the common cold (13.1 percent)—for which antibiotics are rarely, or never, indicated (O'Brien et al. 1998a,b; Rosenstein et al. 1998).

Our multivariate models revealed many differences across groups in antibiotic use, suggesting that the reasons for differential use may have multiple dimensions. Greater use of antibiotics by younger children, those in fair or poor health and those considered to be less healthy than their peers may reflect real, or perceived, differences in the need for medication. Differences in antibiotic use by insurance status, parental income and education, number of siblings, and the percent of the community living below the poverty line

may reflect differences in resources, including financial resources, time, and information. Controlling for all of these factors, we find large differences in antibiotic use across racial-ethnic groups and Census regions. Racial-ethnic differences suggest that non-Hispanic white children may be overusing antibiotics, relative to other groups, and/or that minority children may actually be underusing antibiotics. Previous researchers have found that non-Hispanic black children were less likely than non-Hispanic white children to receive a diagnosis that justified an antibiotic and, conditional on receipt of an antibiotic, non-Hispanic black children were less likely to receive a broad-spectrum antibiotic (Gerber et al. 2013). Large differences across Census regions (e.g., children living in the South were 12.2 percentage points more likely to use broad-spectrum antibiotics to treat RTIs than children living in the West) may reflect regional differences in parental expectations, physician practice patterns, and other factors unrelated to the need for antibiotics.

Limitations

Our study relies on self-reported conditions that are subsequently coded using ICD-9-CM 3-digit codes, so we cannot rule out misclassification of reported diagnoses. A related limitation is that we lack sufficient clinical data to differentiate between appropriate and inappropriate antibiotic use. Finally, our analysis is based on household survey data and may, therefore, suffer from some degree of underreporting of health services use.

Conclusion

Public health experts remain concerned about the long-term effects of overuse of antibiotics. Recent national campaigns to promote effective use of health care resources and improve health care quality such as “Choosing Wisely”—an initiative led by the American Board of Internal Medicine Foundation—may help providers and parents make informed and effective health care choices (Cassel and Guest 2012). Our findings reveal large differences in antibiotic use across groups of children. These differences in antibiotic use are also associated with a broad range of factors related to the need for antibiotics and the resources to acquire them. Controlling for these factors, we find large differences across race-ethnicity and Census regions—suggesting an opportunity, as well as a need, exists for further improvement in the judicious and appropriate prescribing of antibiotics for children in the United States.

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NOTES

1. To link the MEPS-HC to Census data, we used geocoded MEPS-HC data that are not released on MEPS public use files but that can be accessed in the AHRQ Data Center.
2. Personal communications with Iris R. Mabry-Hernandez, M.D., M.P.H., and William B. Baine, M.D., F.A.C.P.
3. About 4 percent of children used both broad- and narrow-spectrum antibiotics during the year.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Appendix SA2: Classification of Narrow-Spectrum and Broad-Spectrum Antibiotics.

Appendix SA3: Individual-, Family-, and Community-Level Characteristics of Children (Ages 1–17) in the United States, 2004–2010.

Appendix SA4: Marginal Effects from Multinomial Probit Models of Antibiotic Use among U.S. Children (Ages 1–17), 2004–2010: Overall and among Children with Respiratory Tract Infections.