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RESEARCH ARTICLE

# Racial/Ethnic Disparities in Health and Health Care among U.S. Adolescents

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**Objective.** To examine racial/ethnic disparities in medical and oral health status, access to care, and use of services in U.S. adolescents.

**Data Source.** Secondary data analysis of the 2003 National Survey of Children's Health. The survey focus was children 0–17 years old.

**Study Design.** Bivariate and multivariable analyses were conducted for white, African American, Latino, Asian/Pacific Islander, American Indian/Alaskan Native, and multiracial adolescents 10–17 years old ( $n = 48,742$ ) to identify disparities in 40 measures of health and health care.

**Principal Findings.** Certain disparities were especially marked for specific racial/ethnic groups and multiracial youth. These disparities included suboptimal health status and lack of a personal doctor or nurse for Latinos; suboptimal oral health and not receiving all needed medications in the past year for African Americans; no physician visit or mental health care in the past year for Asian/Pacific Islanders; overweight/obesity, uninsurance, problems getting specialty care, and no routine preventive visit in the past year for American Indian/Alaska Natives; and not receiving all needed dental care in multiracial youth.

**Conclusions.** U.S. adolescents experience many racial/ethnic disparities in health and health care. These findings indicate a need for ongoing identification and monitoring of and interventions for disparities for all five major racial/ethnic groups and multiracial adolescents.

**Key Words.** Race/ethnicity, adolescents, disparities, health

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Most pediatric research examining health and health care disparities has focused on specific indicators, such as obesity, a usual source of care, unmet needs, delayed care, mental health care receipt, and selected oral health measures (Brown, Wall, and Lazar 1999; Wen 2007; Alexandre, Martins, and Richard 2009; Bethell et al. 2009; Hoilette et al. 2009; Huang et al. 2009; Taichman et al. 2009). Only two studies have comprehensively examined racial/ethnic disparities among children of all ages (Flores and Tomany-Korman 2008a; Flores 2010), but no published studies have comprehensively examined racial/ethnic disparities in health status, access to care, and

use of services. A comprehensive examination of adolescent racial/ethnic disparities is crucial for identifying, monitoring, and eliminating disparities.

Adolescents 10–17 years old comprise almost 50 percent of the pediatric population, and approximately half of adolescents are racial/ethnic minorities (U.S. Census Bureau a 2011). Latinos are the largest racial/ethnic group of children after whites, followed by African Americans, Asian/Pacific Islanders (APIs), and American Indian/Alaska Natives (AI/ANs) (U.S. Census Bureau 2011). Available studies suggest that there are unique disparities for adolescents (Wen 2007; Van Wie, Blewett, and Davern 2008; Adams et al. 2009; Alexandre, Martins, and Richard 2009). For example, adolescents had higher odds of poorer parent-rated health relative to younger children in a study of U.S. children (Wen 2007). Poor childhood health is associated with lower educational attainment (Haas and Fosse 2008; Jackson 2009) and poor health in adulthood (Case, Fertig, and Paxson 2005). Two studies have examined adolescent disparities in overall health status and a limited number of access-to-care and use-of-services measures (Fox et al. 2007; Mulye et al. 2009). One study examined disparities only among three racial/ethnic groups (whites, Latinos, and African Americans) for 12 indicators of health and health care access and use in two national datasets, and found minority youth were more likely to have poor or fair health (Fox et al. 2007). The other study (Mulye et al. 2009) was a review of multiple data sources, including electronic databases, articles, and reports, with a limited number of nationally representative measures. Additional studies on overweight/obesity, dental caries, discussion of preventive health topics, or mental health services receipt mainly compared whites with Latinos and African Americans or African Americans only (Brown, Wall, and Lazar 1999; Alexandre, Martins, and Richard 2009; Bethell et al. 2009). Nationally representative studies comprehensively examining adolescent disparities in medical and oral health, access to care, and use of services from other racial/ethnic groups, including API, AI/AN, and multiracial youth, are lacking.

To understand and reduce racial/ethnic health care disparities among adolescents, disparities must first be identified (Kilbourne et al. 2006). The study aim, therefore, was to identify disparities in 40 health and health care

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measures in a nationally representative, racially/ethnically diverse sample of adolescents. The study hypothesis was that multiple disparities in medical and oral health, access to care, and use of services would be identified in this nationally representative, racially/ethnically diverse sample of adolescents.

## METHODS

### *Data Source*

The 2003 National Survey of Children's Health (NSCH) was a cross-sectional, random-digit-dial household telephone survey conducted by the National Center for Health Statistics (NCHS) (Blumberg et al. 2005). The NSCH provides national and state estimates of a variety of physical, emotional, and behavioral health indicators. From January 2003 to July 2004, 102,353 interviews were completed for children 0–17 years old in all 50 states and the District of Columbia. Survey respondents were parents or guardians (hereafter referred to as parents) who were most knowledgeable about the health and health care of the children in the household. The index child for the survey was randomly selected. All interviews were conducted in English or Spanish.

The NSCH Spanish survey was translated from the English version by an experienced Spanish health survey translator and reviewed for accuracy and cultural appropriateness by NSCH telephone interviewers and supervisors. Parents not speaking English or Spanish were excluded from the NSCH.

To obtain nationally representative estimates of health and health care disparities for API and AI/AN adolescents, the nonpublic NSCH dataset was analyzed. Although similar to the public dataset, the nonpublic dataset allows national estimates for APIs and AIs/ANs and contains restricted variables, including geography, detailed race/ethnicity, and specific dates (Blumberg et al. 2005).

The NSCH used computer-assisted telephone interviewing system, which minimizes missing data (Blumberg et al. 2005). Nevertheless, any records with missing data were not included in these analyses.

### *Definitions and Variables*

Sociodemographic characteristics reported by parents included the adolescent's age, gender, race/ethnicity, and primary language spoken at home; the number of adults and children in the household; employment status and highest educational attainment of an adult in the household; and

household poverty status (using the federal poverty threshold [FPT] for a family of four at the time of the survey). A child was considered multiracial if the parent selected more than one race/ethnicity. Body mass index (BMI) was calculated using parental reports of the adolescent's height and weight. The study variables consisted of a subset of 40 health and health care measures (Table 1).

### *Analyses*

To account for the complex sample design of NSCH and to produce weighted estimates, all analyses were performed using *STATA* 10 (StataCorp 2007). Adolescents were defined as 10–17 years old, consistent with the Society of Adolescent Health and Medicine's definition of adolescence as beginning at 10 years old (Society for Adolescent Medicine 1995). The conceptual framework for this study was the life-course model, which posits that adolescence is a critical or sensitive developmental period in which events can positively or negatively impact future health, underscoring the importance of research focused on identifying racial/ethnic disparities specific to adolescents (U.S. Department of Health and Human Services 2010).

The 40 different health and health care variables examined measures in three domains: medical and oral health status, access to care, and use of services. These domains and variables were selected to provide a comprehensive picture of racial/ethnic disparities. The sociodemographic characteristics of all adolescents and their households were compared, followed by bivariate analyses to identify disparities between white and racial/ethnic minority adolescents in health and health care. Bivariate analyses were done using the chi-square and Wilcoxon nonparametric tests. Statistical significance was considered to be a two-tailed  $p < .05$ .

Multivariable logistic regression analyses were performed to examine adjusted associations between race/ethnicity and health and health care outcomes. Covariates in each model included the adolescent's age, primary language spoken at home, insurance coverage (except when this was the outcome), employment status and highest educational attainment of an adult in the household, number of adults and children in the household, and household poverty status. All multivariable analyses employed stepwise procedures followed by forced entry of significant covariates from the stepwise model to obtain the final weighted odds ratios and 95 percent confidence intervals; the initial alpha-to-enter was 0.15, and the final alpha-to-enter was 0.05. Consistent with prior NSCH analyses (Flores and Tomany-Korman 2008b)

Table 1: Study Variable List from the 2003 National Survey of Children’s Health

<i>Variable</i>	<i>Question</i>
<i>Medical and oral health status</i>	
Health status	In general, how would you describe [CHILD’s NAME] health?
BMI	How tall is [CHILD’s NAME]? How much does [CHILD’s NAME] weigh?
Needs more medical care than others	Does [CHILD’s NAME] need or use more medical care, mental health, or educational services than is usual for most children of the same age?
Has limited abilities	Is [CHILD’s NAME] limited or prevented in any way in his/her ability to do the things most children of the same age can do?
Needs/gets special therapy	Does [CHILD’s NAME] need or get special therapy, such as physical, occupational, or speech therapy?
Difficulty with emotions, concentration, behavior, or interpersonal relations	Overall, do you think that [CHILD’s NAME] has difficulties with one or more of the following areas: emotions, concentration, behavior, or being able to get along with other people?
Emotional, developmental, or behavioral problems needing treatment or counseling	Does [CHILD’s NAME] have any kind of emotional, developmental, or behavioral problem for which he/she needs treatment or counseling?
Learning disability	Has a doctor, health professional, teacher, or school official ever told you [CHILD’s NAME] has a learning disability? Has a doctor or health professional ever told you that [CHILD’s NAME] has any of the following conditions?
Asthma	Asthma
Hearing/vision problems	Hearing or vision problems that cannot be corrected with glasses or contacts?
ADHD	Attention deficit disorder or attention deficit hyperactive disorder
Depression/anxiety	Depression or anxiety problems
Behavior problems	Behavior or conduct problems
Bone/joint/muscle problems	Bone, joint, or muscle problems
Diabetes	Diabetes
Developmental delay	Any developmental delay or physical impairment  During the past 12 months, have you been told by a doctor or other health professional that [CHILD’s NAME] had any of the following conditions?
Allergies	
Respiratory	Hay fever or any kind of respiratory allergy
Digestive	Any kind of food or digestive allergy

*continued*

Table 1. *Continued*

<i>Variable</i>	<i>Question</i>
Skin	Eczema or any kind of skin allergy
Headaches	Frequent or severe headaches, including migraines
Speech problems	Stuttering, stammering, or other speech problems
≥ 3 ear infections in past year	Three or more ear infections
Teeth condition	How would you describe the condition of [CHILD's NAME]'s teeth: excellent, very good, fair, poor?
<i>Access to care</i>	
Insurance coverage at time of survey	Does [CHILD's NAME] have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, or government plans such as Medicaid?
Sporadically insured in past year	During the past 12 months, was there any time when he/she was not covered by ANY health insurance?
Has dental insurance	Does [CHILD's NAME] have insurance that helps pay for any routine dental care including cleanings, X-rays, and examinations?
Has PDN	You have one or more persons you think of as [CHILD's NAME]'s personal doctor or nurse?
Received all needed medical care	During the past 12 months, did [CHILD's NAME] receive all the medical care he/she needed?
Reason for unmet medical needs	Why did [CHILD] not get all medical care that [he/she] needed?
Problems getting specialty care	How much of a problem, if any, was it to get the care from the specialist doctor or doctors?
Did not receive all needed prescription medications in past year	During the past 12 months, did he/she receive all the prescription medication he/she needed?
Received all needed dental care	During the past 12 months, did he/she receive all the routine preventive dental care he/she needed?
Reason for unmet dental care need	Why did [CHILD's NAME] not get all the dental care he/she needed?
<i>Use of medical and dental services</i>	
No. of physician visit in last year	During the past 12 months, how many times did [CHILD's NAME] see a doctor, nurse, or other health care professional for preventive medical care such as a physical exam or well-child check up?
No. of ED visit in past year	During the past 12 months, how many times did [CHILD's NAME] go to a hospital emergency room about his/her health?
Received mental health care in past year	During the past 12 months, did [CHILD's NAME] receive any mental health care or counseling?

*continued*

Table 1. *Continued*

<i>Variable</i>	<i>Question</i>
Never seen dentist	About how long has it been since he/she last saw a dentist?
No preventive dental visit in past year	During the past 12 months, did [CHILD's NAME] see a dentist for any routine preventive dental care, including checkups, screenings, and sealants?
Needs/uses prescription medicine	During the past 12 months, did [CHILD's NAME] use any prescription medication? During the past 12 months, was there any time when [CHILD's NAME] needed prescription medication?
Used prescription medication in past year	During the past 12 months, did [CHILD's NAME] use any prescription medication?

*Source.* National Survey of Childhood Health.

and published guidelines (Perneger 1998), a Bonferroni correction was not performed, given that a specific a priori hypothesis was tested (minority racial/ethnic adolescents and whites significantly differ in medical and oral health, access to care, and use of services, after adjustment for covariates) for each dependent variable, rather than testing a universal null hypothesis or conducting an analysis without any a priori hypothesis. Pearson and deviance residuals, studentized residual, hat matrix diagonal (Hoaglin and Welsh 1978), Cook's distance (Belsley et al. 1980), and the COVRATIO (Cook and Weisberg 1982) from the changes of the covariance matrixes were examined to identify the influential data points and outliers in the regression diagnostics process. No influential data points or outliers were identified using any of these procedures. The  $p$  values for model fit statistics ranged from  $<.01$  to  $.02$ . The log likelihood chi-square tests for all models were significant. After each logistic regression, pseudo  $R$ , Hosmer and Lemeshow goodness-of-fit test, the Akaike Information Criterion, and the Bayesian Information Criterion were used to select the optimally fitted model (Chen et al., n.d.).

## RESULTS

### *Bivariate Analyses*

*Sociodemographics.* A total of 48,742 completed interviews were analyzed for adolescents 10–17 years old. The mean age of adolescents from different racial/ethnic groups slightly differed (Table 2). Latino households had the highest percentages of having no high-school graduate, the primary language

Table 2: Sociodemographic Characteristics of U.S. Adolescents 10–17 Years Old by Race/Ethnicity

Characteristic	Mean or Proportion for Each Racial/Ethnic Group						P
	White (34,767)	Latino (5,181)	African American (4,697)	Asian/ Pacific Islander (808)	American Indian/ Alaska Native (666)	Multiracial (1,609)	
Mean age (years)	13.5	13.2	13.4	13.4	13.5	13.4	<.0001
Male gender (%)	51.3	50.8	49.6	56.8	48.5	49.4	NS
Highest educational attainment in household (%)							
Not a high-school graduate	2.3	28.6	8.0	1.3	9.7	5.1	<.0001
High-school graduate	24.5	33.0	35.4	8.3	33.2	21.8	
At least some college	73.3	38.4	56.6	90.3	57.1	73.1	
Primary language spoken at home not English (%)	0.7	56.9	0.7	39.2	6.6	0.3	<.0001
Number of children in household (%)							
1	25.4	15.6	23.6	28.1	18.2	30.4	<.0001
2	40.4	30.2	33.3	38.6	34.4	41.1	
3	23.3	31.0	24.4	21.5	28.2	20.8	
>3	11.0	23.2	18.6	11.7	19.2	7.7	
Number of adults in household (%)							
1	13.1	15.8	33.3	9.5	20.1	21.7	<.0001
2	65.6	53.5	46.4	61.1	53.3	55.9	
>2	21.3	30.6	20.3	29.4	26.6	22.4	
Adult in household employed ≥ 50 weeks in past year (%)	92.3	86.0	83.6	90.1	82.2	87.4	<.0001
Combined family income: % of federal poverty threshold							
<100%	7.6	33.4	26.2	9.0	29.8	14.2	<.0001
100–199%	17.1	26.4	28.7	17.9	32.9	21.4	
200–299%	18.3	11.7	13.3	12.2	14.5	14.1	
300–399%	17.9	6.3	9.7	17.8	9.3	12.2	
≥ 400%	31.7	9.1	12.5	35.2	8.2	29.3	
Unknown	7.4	13.2	9.8	8.0	5.3	8.8	

Source. National Survey of Childhood Health, 2003.

spoken at home was not English, and >3 children at home. Over 1/4 of Latino, API, and AI/AN households had >2 adults living in the home.

White households were most likely to have an adult employed  $\geq 50$  weeks in the past year (Table 2). Close to 1/3 of Latino and AI/AN households had a family income <100 percent of the FPT.

*Medical and Oral Health Status.* *Medical health status:* White, API, and multiracial adolescents had the highest percentages of optimal (excellent or very good) health (Table 3). Obesity/overweight was identified in approximately 40 percent of AI/AN, African American, and Latino adolescents. AI/AN, African American, and multiracial adolescents had the highest proportions of asthma. AI/AN adolescents had the highest prevalence of hearing/vision problems and bone/joint/muscle problems. Respiratory allergies were most prevalent in multiracial youth and skin allergies in African Americans. AIs/ANs had the highest rates of  $\geq 3$  ear infections in the past year and APIs had the lowest rates. Higher proportions of parents of AI/AN, multiracial, and white adolescents reported needing more medical care than others. AI/AN adolescents were more likely to have limited abilities and need/get special therapy.

*Behavioral, developmental, and emotional health:* African American adolescents had the highest prevalence of behavior problems (Table 3). Attention deficit hyperactivity disorder (ADHD) rates were highest for whites and multiracial adolescents. African American, multiracial, and Latino adolescents had similar percentages for speech problems. AIs/ANs were most likely to have a learning disability. African American, multiracial, and AI/AN adolescents have the highest proportions for difficulty with emotions, concentration, behavior, or interpersonal relations. AI/AN adolescents had the highest prevalence of depression/anxiety.

*Oral health status:* The teeth condition was suboptimal (not excellent/very good) in over half of Latino adolescents (Table 3).

*Access to Medical and Dental Care.* Latino and AI/AN adolescents were significantly more likely to be uninsured than white children, and Latino, African American, and AI/AN adolescents had higher proportions of sporadic insurance coverage (Table 3). Public insurance coverage was greatest among African American, AI/AN, and Latino adolescents. Latino and AI/AN adolescents had the lowest rates of dental insurance.

Table 3: Bivariate Analysis of the Association of Racial/Ethnicity with Medical and Oral Health, Access to Care, and Use of Services among U.S. Adolescents

Characteristic	Mean or Proportion						P
	White	Latino	African American	Asian/Pacific Islander	American Indian/Alaska Native	Multiracial	
<i>Medical and oral health status</i>							
Health status (%)*							
Excellent	66.1	37.9	47.3	65.2	54.1	58.3	<.0001
Very good	23.4	23.0	28.6	22.2	26.1	28.9	
Good	8.8	28.6	19.6	11.5	17.5	10.5	
Fair	1.5	9.9	3.9	0.8	1.9	2.1	
Poor	0.3	0.7	0.6	0.3	0.4	0.3	
BMI class (%)†							
Underweight	4.9	4.0	4.6	10.8	2.7	4.8	<.0001
Normal	68.5	58.4	54.3	62.6	55.3	64.4	
Overweight	14.7	18.7	17.7	13.0	21.7	15.6	
Obese	12.0	18.9	23.4	13.6	20.3	15.3	
Asthma (%)	14.0	12.7	18.6	11.7	20.0	16.8	.0001
Diabetes (%)	0.6	0.5	0.3	0.0	1.0	0.5	.0423
Headaches (%)	7.8	8.9	10.1	5.2	12.3	10.7	.0476
Hearing/vision problems (%)	3.3	3.5	2.1	1.0	7.7	2.7	<.0001
Bone/joint/muscle problems (%)	5.2	3.4	4.4	1.5	8.7	6.8	.0001
Allergies (%)							
Respiratory	18.8	11.5	17.4	13.3	20.0	22.7	.0001
Digestive	3.1	3.0	3.3	2.7	3.2	4.4	.75
Skin	7.5	6.9	12.7	5.6	11.9	9.9	.0001
≥ 3 ear infections in past year (%)	2.6	3.3	2.2	0.2	6.3	4.1	.0002
Needs more medical care than others (%)	13.4	11.4	11.8	3.8	19.2	15.5	<.0001
Has limited abilities (%)	6.3	5.4	9.3	6.9	17.2	7.8	.0002
Needs/gets special therapy (%)‡	4.8	5.4	5.1	1.7	7.2	6.6	.01
Difficulty with emotions, concentration, behavior, or interpersonal relations (%)	19.5	17.5	26.2	8.3	23.8	25.5	<.0001
Behavior problems (%)	5.9	5.7	9.6	2.6	7.2	6.8	.0001

*continued*

Table 3. Continued

Characteristic	Mean or Proportion						P
	White	Latino	African American	Asian/Pacific Islander	American Indian/Alaska Native	Multiracial	
Developmental delay (%)	4.1	1.9	2.8	1.6	3.8	3.3	.0001
Speech problems (%)	1.8	2.6	3.3	0.8	1.5	2.7	.0006
Emotional, developmental, or behavioral problems needing treatment or counseling (%)	8.7	9.1	9.2	4.7	11.1	10.1	.13
Depression/anxiety (%)	7.4	5.4	5.0	2.2	10.0	7.5	.0001
Learning disability (%)	13.1	13.0	13.6	4.2	16.9	14.7	.0001
Teeth condition (%) <sup>§</sup>							
Excellent	44.3	22.3	28.6	37.7	33.9	37.5	<.0001
Very good	29.1	21.1	27.1	33.3	29.5	30.3	
Good	20.3	33.4	32.3	22.2	25.8	23.1	
Fair	5.0	18.4	10.0	4.3	6.0	6.8	
Poor	1.3	4.9	2.0	2.5	4.8	2.3	
<i>Access to medical and dental care</i>							
Insurance coverage at time of survey (%)							
None	6.4	23.8	9.2	8.1	13.4	8.2	<.0001
Public	15.7	37.3	46.0	13.0	45.2	22.8	
Private	77.2	37.5	43.5	76.2	38.8	67.7	
Insured, type unknown	0.7	1.4	1.3	2.7	2.7	1.4	
Sporadically insured in past year (%)	8.7	16.0	14.1	12.8	16.0	11.1	<.0001
Has dental insurance (%)	79.2	65.1	81.5	78.7	68.5	81.9	<.0001
Has PDN (%)	88.0	65.0	74.6	85.4	68.4	81.1	<.0001
Received all needed medical care (%) <sup>¶</sup>	99.1	98.2	97.7	99.6	93.4	96.6	<.0001
Reason for unmet medical care need (%)**							
Transportation barrier	2.4	4.3	4.2	0	9.1	2.0	.7665
No insurance	43.1	59.8	47.8	49.4	20.9	12.6	.07
No one accepts child's insurance	3.3	3.5	4.2	0	1.8	4.5	.98
Treatment is ongoing	2.6	3.8	0.7	0	11.3	4.1	.21
Doctor did not know how to provide care	5.3	0.3	0.5	0	1.8	8.5	.03
Health-plan problem	16.0	8.7	24.9	50.6	42.9	43.6	.12
Problems getting specialty care (%)	20.8	36.1	25.1	48.0	48.4	23.8	<.0001

continued

Table 3. Continued

Characteristic	Mean or Proportion						P
	White	Latino	African American	Asian/Pacific Islander	American Indian/Alaska Native	Multiracial	
Did not receive all needed prescription medications in past year (%)	2.3	3.4	5.3	0.9	2.6	1.8	<.0001
Received all needed dental care (%) <sup>§</sup>	97.5	95.4	94.6	98.7	97.0	95.3	.0001
Reason for unmet dental care need (%)**							
Dentist did not know how to provide care	0.9	0.5	2.4	0	0	1.1	.0001
No insurance	32.6	39.9	27.1	17.2	15.4	23.1	.08
Did not know where to go for treatment	3.9	7.2	2.3	0	1.5	5.5	.53
Health-plan problem	8.9	17.6	6.6	7.3	1.3	10.3	.02
<i>Use of medical and dental services</i>							
No physician visit in past year (%)	25.7	36.3	24.2	36.1	34.1	26.0	<.0001
No. of ED visits in past year (%)							
0	84.0	87.7	81.8	93.7	79.5	81.3	<.0001
1–2	14.3	10.9	15.4	5.7	17.4	16.7	
≥ 3	1.7	1.4	2.8	0.7	3.1	2.0	
Received mental health care in past year (%)	10.7	7.7	7.3	4.0	12.3	12.4	<.0001
Never seen dentist (%)	0.6	4.1	1.5	0.6	0.8	1.5	<.0001
No preventative dental visit in past year (%) <sup>††</sup>	4.4	12.4	12.5	9.9	15.2	6.4	<.0001
Needs/uses prescription medication (%)	26.1	16.0	21.4	14.4	23.0	26.9	<.0001
Used prescription medication in past year (%)							
Yes	52.6	60.9	64.8	75.7	61.5	59.7	<.0001
No, did not need to	45.1	35.7	29.9	23.4	35.9	38.5	
No, but needed to	2.3	3.4	5.3	2.6	2.6	1.8	

\*By parental report.

<sup>†</sup>BMI, body mass index; overweight was defined as a BMI = 85–94 percent for age and gender, and obese was defined as a BMI ≥ 95 percent for age and gender.

<sup>‡</sup>Includes physical, occupational, or speech therapy.

<sup>§</sup>Only if made a dental visit in past 12 months.

<sup>¶</sup>Only if made a physician visit in past 12 months.

\*\*Only access barriers with significant racial/ethnic disparities listed; see text for other barriers.

<sup>††</sup>Only among those who have ever made a dental visit.

Source. National Survey of Childhood Health.

Latino and AI/AN adolescents had the lowest proportions of having a personal doctor or nurse (PDN), and AI/AN adolescents had the lowest proportion of receiving all needed medical care (Table 3). Multiracial and white adolescents had the highest percentages of unmet medical needs due to the doctor not knowing how to provide care. About half of APIs and AIs/ANs had problems getting specialty care. African American adolescents had the highest prevalence of not receiving all needed prescription medications in the past year.

African American, multiracial, and Latino youth were least likely to receive all needed dental care (Table 3). Unmet dental care needs due to the dentist not knowing how to provide care were seen most often in African American youth, and due to a health-plan problem most often among Latino and multiracial youth.

*Use of Medical and Dental Care.* Over 1/3 of Latino, API, and AI/AN adolescents did not have a physician visit in the past year (Table 3). Higher percentages of AI/AN, African American, and multiracial adolescents had  $\geq 3$  visits to the emergency department (ED). Greater numbers of African American and Latino adolescents did not receive needed prescription medications in the past year.

Latino adolescents had the highest risk of never seeing a dentist (Table 3). Among adolescents who ever made a dental visit, AI/ANs were most likely to have not made a preventive dental visit in the past year.

### *Multivariable Analyses*

*Medical and Oral Health Status. Medical health:* Compared with white adolescents, Latino and African American adolescents had significantly greater odds of suboptimal health status (Table 4). AI/AN, African American, and Latino adolescents had higher odds of overweight/obesity and having asthma. AI/ANs had higher odds of having hearing/vision problems, and African Americans and APIs had lower odds. API adolescents had lower odds of bone/joint/muscle problems and diabetes, whereas African American adolescents had lower odds of diabetes. African American, AI/AN, and multiracial adolescents had greater odds of having skin allergies. African American and API adolescents had lower odds of having  $>3$  ear infections in a year. African Americans and APIs had lower odds of needing more medical care than others. AI/ANs had higher odds of having limited

Table 4: Multivariable Analysis of Racial/Ethnic Disparities in Medical and Oral Health Status, Access to Care, and Use of Services among U.S. Adolescents

Outcome	Odds Ratio (95% Confidence Interval) versus White Adolescents					
	Latino	African American	Asian/ Pacific Islander	American Indian/ Alaska Native	Multiracial	
Medical and oral health status						
Health not excellent/very good	2.12 (1.78, 2.52)	2.08 (1.80, 2.39)	NS	NS	NS	NS
Overweight or obese	1.36 (1.16, 1.59)	1.74 (1.56, 1.94)	NS	1.83 (1.27, 2.64)	NS	NS
Asthma	1.33 (1.10, 1.60)	1.40 (1.22, 1.61)	NS	1.62 (1.09, 2.40)	NS	NS
Diabetes	NS	0.42 (0.23, 0.75)	0.03 (0.00, 0.22)	NS	NS	NS
Hearing/vision problems	NS	0.51 (0.37, 0.71)	0.31 (0.13, 0.70)	2.10 (1.18, 3.71)	NS	NS
Bone/joint/muscle problems	NS	NS	0.32 (0.16, 0.66)	NS	NS	NS
Digestive allergies	NS	NS	NS	NS	NS	NS
Skin allergies	NS	1.89 (1.62, 2.22)	NS	1.77 (1.10, 2.86)	1.36 (1.04, 1.78)	
≥ 3 ear infections in past year	NS	0.64 (0.45, 0.91)	0.10 (0.03, 0.35)	NS	NS	NS
Needs more medical care than others	NS	0.74 (0.64, 0.87)	0.32 (0.19, 0.56)	NS	NS	NS
Has limited abilities	NS	NS	NS	2.50 (1.55, 4.03)	NS	NS
Needs/gets special therapy	NS	NS	0.41 (0.19, 0.88)	NS	NS	NS
Behavior problems	NS	NS	NS	NS	NS	NS
Developmental delay	NS	0.58 (0.43, 0.78)	NS	NS	NS	NS
Speech problems	NS	NS	NS	NS	NS	NS
Difficulty with emotions, concentration, behavior, or interpersonal relations	NS	1.21 (1.07, 1.37)	0.49 (0.29, 0.83)	NS	1.32 (1.06, 1.65)	
Emotional, developmental, or behavioral problems needing treatment or counseling	NS	0.80 (0.65, 0.97)	NS	NS	NS	NS
Depression/anxiety	NS	0.52 (0.41, 0.67)	0.36 (0.15, 0.84)	NS	NS	NS
Learning disability	NS	0.85 (0.72, 1.00)	0.38 (0.22, 0.65)	NS	NS	NS
ADHD	0.69 (0.54, 0.89)	0.67 (0.56, 0.81)	NS	NS	NS	NS

continued

Table 4. Continued

Outcome	Odds Ratio (95% Confidence Interval) versus White Adolescents					
	Latino	African American	Asian/ Pacific Islander	American Indian/ Alaska Native	Multiracial	
Teeth condition not excellent/very good*	1.59 (1.37, 1.85)	1.75 (1.56, 1.95)	NS	NS	1.23 (1.01, 1.50)	
Access to medical and dental care						
No health insurance <sup>†</sup>	1.47 (1.18, 1.83)	1.30 (1.04, 1.63)	NS	1.74 (1.14, 2.66)	NS	
Sporadically insured in past year <sup>†</sup>	1.36 (1.07, 1.73)	1.47 (1.23, 1.75)	NS	1.67 (1.17, 2.38)	NS	
No dental insurance <sup>†</sup>	NS	0.78 (0.68, 0.91)	NS	1.49 (1.10, 2.02)	NS	
No PDN	1.65 (1.38, 1.98)	2.00 (1.75, 2.29)	NS	2.52 (1.77, 3.58)	1.62 (1.28, 2.06)	
Did not receive all needed medical care <sup>‡</sup>	NS	2.15 (1.14, 4.07)	NS	5.36 (2.00, 14.41)	3.72 (1.93, 7.19)	
Reason for unmet medical care need						
Health-plan problem	NS	NS	26.61 (2.47, 286.47)	NS	8.40 (2.39, 29.56)	
No one accepts child's insurance	NS	NS	NE	NS	NS	
No insurance	NS	NS	NS	0.18 (0.04, 0.91)	0.15 (0.05, 0.44)	
Cost	NS	0.36 (0.15, 0.86)	NS	NS	NS	
Transportation	NS	NS	NS	8.38 (1.28, 54.82)	NS	
Treatment is ongoing	11.58 (1.96, 68.34)	NS	NE	11.92 (1.24, 115.07)	NS	
Problems getting specialty care	1.57 (1.12, 2.20)	NS	3.17 (1.72, 5.82)	3.19 (1.39, 7.34)	NS	
Did not receive all needed prescription medications in past year	NS	1.88 (1.26, 2.78)	NS	NS	NS	
Did not receive all needed dental care <sup>§</sup>	NS	1.70 (1.23, 2.35)	NS	NS	1.89 (1.14, 3.12)	
Reason for unmet dental care need <sup>d</sup>						
Transportation	NS	NS	16.09 (1.58, 163.51)	7.99 (2.24, 28.52)	0.18 (0.04, 0.95)	
Dentist did not know how to provide care	NS	NS	NE	NE	NS	
No one accepts child's insurance	NS	NS	NE	NS	0.12 (0.02, 0.66)	
Inconvenient times/could not get an appointment	NS	NS	13.20 (1.34, 129.49)	6.72 (2.12, 21.26)	NS	

continued

Table 4. Continued

Outcome	Odds Ratio (95% Confidence Interval) versus White Adolescents					
	Latino	African American	Asian/ Pacific Islander	American Indian/ Alaska Native	Multiracial	
No dental insurance	NS	NS	NS	NS	NS	NS
Cost	NS	0.50 (0.32, 0.80)	0.11 (0.02, 0.67)	0.19 (0.06, 0.65)	NS	NS
Treatment is ongoing	NS	NS	NE	5.49 (1.27, 23.76)	NS	NS
Use of medical and dental services						
No physician visit in past year	NS	1.28 (1.11, 1.46)	2.32 (1.54, 3.51)	1.77 (1.16, 2.69)	NS	NS
One or more ED visits in past year	NS	NS	0.45 (0.28, 0.73)	NS	NS	NS
Received no mental health care in past year	NS	1.90 (1.57, 2.30)	2.36 (1.21, 4.61)	NS	NS	NS
No routine preventive dental visit in past year <sup>§</sup>	NS	2.42 (1.97, 2.96)	2.43 (1.19, 4.97)	2.67 (1.68, 4.27)	NS	1.57 (1.07, 2.30)
Received no mental health care in past year	NS	1.90 (1.57, 2.30)	2.36 (1.21, 4.61)	NS	NS	NS
Needs/uses prescription medication	NS	0.78 (0.69, 0.88)	0.61 (0.39, 0.94)	NS	NS	NS
Not given prescription medication in past year	1.35 (1.15, 1.59)	1.85 (1.63, 2.10)	3.06 (2.08, 4.50)	NS	NS	1.33 (1.07, 1.66)

Note. Adjusted for primary language spoken at home, child's age and medical insurance coverage, highest educational attainment and employment status of adult in household, number of children in the household, number of adults in the household, and poverty level.

\*Adjusted for dental, rather than medical, insurance coverage, as well as child's age, highest educational attainment and employment status of adult in household, number of children and adults in the household, and poverty status.

†Adjusted for primary language spoken at home, child's age, highest educational attainment and employment status of adult in household, number of children in the household, and poverty level.

‡Only if made a physician visit in past 12 months.

§Only for those making a dental visit in past 12 months; adjusted for primary language spoken at home, child's age and dental insurance coverage, educational attainment and employment status of an adult in household, number of children in the household, number of adults in the household, and poverty level.

NS, nonsignificant; NE, nonestimable.

Source. National Survey of Childhood Health.

abilities. API adolescents had lower odds of needing/getting special therapy.

*Behavioral, developmental, and emotional health:* Latino and African American adolescents had lower odds of ADHD (Table 4). African American and API adolescents had lower odds than whites of having a learning disability. African American and multiracial adolescents had greater odds than whites of having difficulty with emotions, concentrations, behavior, or interpersonal relations. African American adolescents had lower odds of developmental delay and emotional, developmental, or behavioral problems needing treatment or counseling. African Americans and APIs had lower odds of depression and anxiety.

*Oral health status:* Compared with white adolescents, Latino, African American, and multiracial adolescents had significantly greater odds of suboptimal teeth condition (Table 4).

*Access to Medical and Dental Care.* AI/AN, Latino, and African American adolescents had significantly greater odds than white adolescents of being uninsured and sporadically insured (Table 4). AIs/ANs had greater odds and African Americans lower odds of having no dental insurance.

All minority racial/ethnic groups except for APIs had higher odds than whites of having no PDN (Table 4). AI/AN, African American, and multiracial youth had greater odds of not receiving all needed medical care. API adolescents had over 26 times the odds and multiracial adolescents had over eight times the odds of an unmet medical care need due to a health-plan problem. Parents of AI/AN and multiracial youth had lower odds of citing uninsurance as a reason for unmet needs, whereas African American parents had lower odds of identifying cost as a reason for unmet medical needs. AI/AN parents had higher odds of citing transportation as a reason for unmet medical needs. Latino and AI/AN parents had over 11 times the odds of reporting treatment is ongoing as reason for unmet medical needs.

AI/AN, API, and Latino adolescents had greater odds than whites of problems getting specialty care (Table 4). Only African American adolescents had greater odds of not receiving all needed prescription medications in the past year.

Multiracial and African American adolescents had greater odds than whites of not receiving all needed dental care (Table 4). APIs and AI/ANs had higher odds of unmet dental needs due to transportation problems and inconvenient times/not being able to get an appointment. African American, API,

and AI/AN adolescents had lower odds of cost as a reason for unmet dental needs. AI/AN adolescents had higher odds for unmet dental needs due to ongoing treatment.

*Use of Medical Care, Dental Care, and Prescription Medications.* African American, API, and AI/AN adolescents had greater odds than white adolescents of no physician visit in the past year and all three groups plus multiracial adolescents had greater odds of no routine preventive dental visit in the past year (Table 4). API adolescents had lower odds of having  $\geq 1$  ED visit in past year. African American and API adolescents had double the odds of no mental health care in the past year but lower odds of needing/using prescription medications. All minority groups except for AI/ANs had higher odds of not being given a prescription medication in the past year.

## DISCUSSION

This study comprehensively documents multiple disparities among racial/ethnic minority U.S. adolescents in three domains: medical and oral health status, access to care, and use of services. Compared with white adolescents, Latino, African American, and multiracial youth were less likely to have excellent/very good teeth condition; all minority racial/ethnic groups, including multiracial youth, were less likely to have health insurance and a preventive dental visit in the past year; Latino, African American, and AI/AN youth were less likely to have a PDN; and Latinos, APIs, and AI/ANs were less likely to have no physician visit in the past year. Latinos, African Americans, and AIs/ANs had greater odds than whites of being overweight/obese and having asthma; African American, AI/AN, and multiracial youth had greater odds of having skin allergies and not receiving all needed medical care; and Latino, API, and AI/AN youth had greater odds of problems getting specialty care.

Specific racial/ethnic groups had noteworthy disparities. Latino adolescents had the highest proportions of any group of having no health insurance. Despite improvement in insurance-coverage rates of children through the Children's Health Insurance Program and Medicaid, Latino children continue to experience greater odds of uninsurance than whites (Flores and Tomany-Korman 2008a; Van Wie, Blewett, and Davern 2008). Research suggests that older age of the child, parental immigrant status, both parents working, and certain lower income categories are associated with uninsurance in Latino

children, indicating that uninsurance is likely due to the prevalence of sociodemographic factors, not Latino ethnicity (Flores, Abreu, and Tomany-Korman 2006). Over 1/3 of Latino adolescents do not have a usual source of care, the highest prevalence of any racial/ethnic group, consistent with prior work (Wen 2007; Flores and Tomany-Korman 2008a; Hoilette 2009), and likely reflects the high rates of uninsurance.

African American adolescents had the highest number of medical and oral health status disparities of any racial/ethnic group, with significantly higher adjusted odds than white adolescents for six measures. Dental health and dental care disparities were noted in African American children of all ages in a nationally representative study (Flores and Tomany-Korman 2008a). Our study identified analogous dental issues, with African American adolescents having the highest proportions of not receiving all needed dental care and the highest adjusted odds of suboptimal teeth condition. Other research shows African American children having lower odds of receiving needed specialty dental care and higher odds than white children of untreated dental caries (Brown, Wall, and Lazar 1999; Taichman et al. 2009). Geography may account for African American adolescents' high number of health status disparities; African American children are more likely to be poorer, live in more disadvantaged neighborhoods, and more likely to experience double jeopardy (to be poor and live in a high-poverty neighborhood) compared with white children (Acevedo-Garcia et al. 2008).

African American and API adolescents had lower adjusted odds than whites for certain health and health care indicators, including depression/anxiety, diabetes, and >3 ear infections. These disparities were one to three times lower odds for African Americans and 2 to over 30 times lower odds for APIs compared with whites. Previous research has documented African American children to be less likely to be diagnosed with frequent ear infections (Vakharia, Shapiro, and Bhattacharyya 2010) and African American and API children of all ages to have lower odds of several health and health care indicators (Flores and Tomany-Korman 2008a), but this is the first study (to our knowledge) to report these findings in African American and API adolescents. Lower odds of physician-diagnosed conditions may reflect access-to-care barriers, which have been previously documented (Huang et al. 2009; Bhattacharyya, Shapiro, and Vakharia 2010), but the NSCH data do not provide possible reasons for these findings.

Conversely, APIs had substantially higher adjusted odds than whites of citing transportation and inconvenient times/could not get an appointment as reasons for unmet dental needs. Reasons for unmet dental needs for API

youth have not been previously documented in the literature, although adult cultural beliefs (preventive habits controlling dental disease and the importance of secondary teeth over primary teeth) have been shown to be associated with preventive dental care access in young Chinese children (Wong, Perez-Spiess, and Julliard 2005; Hilton, Barker, and Weintraub 2007). API adolescents had substantially higher adjusted odds for no physician visit, not receiving mental health care, and needing but not given prescription medications in the past year. Employment responsibilities, long physician waiting times, and cultural beliefs have been cited as reasons for delayed health care (Huang et al. 2009) and may contribute to low physician visit rates and possibly unmet dental needs for API adolescents. Lack of receipt of mental health care only has been demonstrated in high-risk API youth (Garland et al. 2005).

American Indian/Alaska Native adolescents had the highest number of disparities of any minority group at 18. AI/AN adolescents had the highest adjusted odds of overweight/obesity and asthma. These study findings are consistent with previous research indicating a higher obesity and asthma prevalence in AI/AN children (Zephier et al. 2006; Meng et al. 2007; Brim et al. 2008; Flores and Tomany-Korman 2008a; Singh, Siahpush, and Kogan 2010). AI/AN adolescents also had the highest adjusted odds for eight other indicators, including no health and dental insurance, no PDN, not receiving all needed medical care, treatment is ongoing as a reason for unmet medical care and dental care needs, problems getting specialty care, and no preventive dental visit in the past year. Although these findings were previously noted in AI/AN children of all ages (Flores and Tomany-Korman 2008a), to our knowledge, this is the first report of these disparities in AI/AN adolescents. Previous research has documented higher rates of uninsurance, problems accessing health care, and health care use for AIs/ANs (Zuckerman et al. 2004). Most AIs live in urban areas, not on a reservation, or do not belong to one of the federally recognized tribes, limiting access to the Indian Health Service and may account for the high number of AI adolescent health disparities (Brown et al. 2000; Zuckerman et al. 2004).

Very little published information exists on disparities in multiracial adolescents (Kogan et al. 2007; Lewis et al. 2007a,b), probably due to the smaller sample sizes available in national databases. Multiracial adolescents had particularly high odds of difficulty with emotions, concentration, behavior, or interpersonal relations, and not receiving all needed dental care. This is the first study, to our knowledge, detailing multiracial adolescent health and health care disparities in a national sample. Research has documented multiracial children having a lower likelihood of autism-spectrum disorder and a

preventive dental visit in the past year (Kogan et al. 2007; Lewis et al. 2007a). Without the inclusion of multiracial adolescents, unique and important disparities would have been overlooked and not documented. A possible reason for newly identified multiracial youth disparities is providing multiracial race/ethnicity as a choice, rather than grouping an individual into a self-reported “best race category” (Bratter and Gorman 2011).

Our study findings documented several unique adolescent racial/ethnic disparities, when compared with a recent study of racial/ethnic disparities among children of all ages (Flores and Tomany-Korman 2008a). In contrast to nonsignificant findings in children of all ages, significantly higher odds versus whites were seen in African American adolescents for no health insurance and not receiving all needed medical care; in API adolescents for unmet medical needs due to a health-plan problem and no preventive dental visit in the past year; and in AI/AN adolescents for having limited abilities, asthma, hearing/vision problems, skin allergies, problems getting specialty care, and no preventive dental visit in the past year. Multiple disparities for minority children of all ages were not observed in minority adolescents. These findings highlight that racial/ethnic disparities among children of all ages do not necessarily pertain to adolescents and support studies on disparities examining adolescents separately from younger children.

Certain study limitations should be noted. Health and health care disparities in racial/ethnic subgroups and AI/AN tribal groups could not be examined, given that this information is not available in the NSCH. All information was obtained via parental report, not medical records, so the prevalence of medical conditions may not be accurate. The NSCH records the primary language spoken at home, but not parental English proficiency, even though research demonstrates the latter to be more useful for examining health and health care measures (Flores, Abreu, and Tomany-Korman 2005). An unknown number of households with parents who had limited proficiency in English and Spanish were not included, given that the NSCH was only conducted in English or Spanish. As a result, it is likely that a larger proportion of parents with limited English proficiency (LEP) of Latino adolescents were included in the NSCH, compared with LEP parents of API adolescents. Immigration status was not examined in the NSCH, but it has been associated with medical and oral health status, obesity, health insurance coverage, mental health care, and a usual source of care (Huang, Yu, and Ledsky 2006; Maserejian et al. 2008; Weathers et al. 2008; Singh, Kogan, and Yu 2009). Adjustment for gender was not done in multivariable analyses, because published research is conflicting regarding the association of gender with access-to-care

and use-of-services outcomes (Ford, Bearman, and Moody 1999; Shenkman, Youngblade, and Nackashi 2003; Sarmiento et al. 2004; Lehrer et al. 2007). Disparities were not separately examined in younger and older adolescents. Health and health care disparities were identified by analyzing the NSCH database, but such a cross-sectional study cannot provide insights on why specific race/ethnicities experience certain disparities.

Specific study strengths should be noted. The analyses examined all five major U.S. racial/ethnic groups and multiracial adolescents. This was a nationally representative sample of over 48,742 adolescents, with analyses of 40 measures in three domains: medical and oral health status, access to care, and use of services. This study provides a comprehensive examination of racial/ethnic disparities, focusing solely on adolescents 10–17 years old. Previous research has concentrated on a single disparity or defined adolescence as starting at 12 years old (Deitrich et al. 2008; Singh, Siahpush, and Kogan 2010).

The 2003 NSCH dataset was the most up-to-date dataset available at the time of this analysis. To gain access to the 2003 NSCH nonpublic dataset, NCHS approval was needed, and analyses need to be performed at the NCHS Research Data Center. Analyses of the 2007 NSCH will be reported in a separate paper by our team as part of a trend analysis of adolescent racial/ethnic disparities in the United States comparing the 2007 and 2003 NSCH databases. Initial analyses of the nonpublic 2007 NSCH database were conducted in the third quarter of 2010, in collaboration with the NCHS.

The study findings have several research, practice, and policy implications. Unique adolescent racial/ethnic disparities have been identified; these disparities would have been missed if adolescents were not examined separately from younger children, possibly affecting future research, practice, and policy. Newly identified disparities in AI/AN, API, and multiracial adolescents underscore the need for data collection, analysis, and monitoring of disparities for all five major racial/ethnic groups and multiracial adolescents. Toolkits have been developed to educate hospital staff on the importance and collection of race/ethnicity data (Health Research and Educational Trust). Along with race/ethnicity, immigration status, immigration generational status, the primary language spoken at home, and LEP are variables for which data could be collected nationally to identify and monitor disparities. Many racial/ethnic disparity studies continue to combine minority children into a single nonwhite category or do not include a comparison group of white children (Flores 2010). Disparity studies primarily have focused on African American and Latino children; few studies exist on API and AI/AN children (Flores 2010) and no studies exist on multiracial youth. Inclusion of APIs in health

disparities research, however, is supported by a recent study of a nationally representative sample of racially/ethnically diverse children of all ages demonstrating Latino and Asian children as the two groups with the worst health care quality (Berdahl et al. 2010). Multiracial individuals need to be examined separately from other racial/ethnic groups, given that recent work demonstrates that placing multiracial individuals into a single racial/ethnic group masks disparities (Bratter and Gorman 2011).

The study findings might prove useful for practitioners, hospitals, and policy makers in developing and evaluating interventions to reduce disparities in minority youth. Practitioners could use these study findings to identify disparities within their practice and develop effective interventions (Chin, Alexander-Young, and Burnet 2009). The American Academy of Pediatrics provides grants to practitioners to develop community-based initiatives that can involve schools and social service agencies; these grants are aimed at improving children's health and reducing/eliminating disparities (American Academy of Pediatrics 2011). Hospitals also can implement interventions to reduce adolescent disparities. Although many hospitals collect race/ethnicity data, hospitals are not always aware of how to use the data and develop effective interventions (Regenstein and Sickler 2006). The American Hospital Association has developed a guide for hospital leaders to improve collection of race/ethnicity data, identify and track disparities, and develop effective interventions (Health Research and Educational Trust 2011). Racial/ethnic minority adolescents have increased to 43 percent in 2009 from 39 percent in 2003, according to the latest available data (U.S. Census Bureau n.d.a, b, c, d), so federal and state policy makers can use these findings, in conjunction with an upcoming trend analysis by our team on U.S. adolescent racial/ethnic disparities, to inform, target, and enact policy at schools, social agencies, and other sites to address specific adolescent disparities. High rates of uninsurance, especially for foreign-born children (Pati and Danagoulian 2008), and the multiple identified nonfinancial barriers to care suggest an urgent need to improve access to care for minority youth by policy makers. Recent health care reform legislation targeted increasing the pediatric work force, establishing quality-of-care priorities, enhancing preventive pediatric services to include oral and vision services, expanding Medicaid, increasing Medicaid payments to physicians, and ensuring insurance security regardless of employment status (The Commonwealth Fund 2010a,b; The White House, n.d.). The study findings suggest that these measures could help reduce or eliminate many racial/ethnic disparities in the health and health care of adolescents.

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## NOTE

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## SUPPORTING INFORMATION

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

Appendix SA1: Author Matrix.

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