Eye Care Availability and Access Among Individuals With Diabetes, Diabetic Retinopathy, or Age-Related Macular Degeneration

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IMPORTANCE Understanding whether differences in the local availability of eye care professionals are related to differences in realized access to eye care is important for assessing whether and where public health efforts are needed to increase access to eye care professionals.

OBJECTIVE To examine whether the county-level availability of ophthalmologists and optometrists is associated with measures of realized access to eye care for individuals with diabetes mellitus, diabetic retinopathy, or age-related macular degeneration (ARMD).

DESIGN, SETTING, AND PARTICIPANTS We studied a cross-sectional sample of US adults 40 years and older (1098 individuals with diabetes, 345 with diabetic retinopathy, and 498 with ARMD) from the 2005-2008 National Health and Nutrition Examination Survey.

MAIN OUTCOMES AND MEASURES Outcomes were whether diabetic individuals reported undergoing a dilated eye examination in the past year, whether individuals were unaware they had diabetic retinopathy, whether diabetic individuals had vision-threatening diabetic retinopathy, and whether individuals were unaware they had ARMD.

RESULTS In logistic regression models that also included individual characteristics, individuals who lived in a county in the highest ophthalmologist availability quartile were less likely to be unaware they had diabetic retinopathy (predictive margin [PM], 66.1%; 90% CI, 48.8%-83.4%; vs PM, 84.1%; 90% CI, 78.7%-89.6%) and were less likely to have vision-threatening diabetic retinopathy (PM, 1.4%; 90% CI, 0.9%-1.9%; vs PM, 2.6%; 90% CI, 1.8%-3.4%) than individuals who lived in a county in the lower 3 ophthalmologist availability quartiles. Individuals who lived in a county in the lowest ophthalmologist availability quartile were more likely to be unaware they had ARMD (PM, 93.8%; 90% CI, 90.6%-97.0%; vs PM, 88.3%; 90% CI, 84.7%-91.9%) than individuals who lived in a county in the higher 3 ophthalmologist availability quartiles. Optometrist availability quartiles were not significantly related to any of the outcomes.

CONCLUSIONS AND RELEVANCE The results suggest that efforts to increase access to ophthalmologists to improve outcomes related to diabetic retinopathy or to increase awareness of ARMD should focus on improving access for diabetic individuals who live in counties in the lowest 3 quartiles of ophthalmologist availability and on individuals at risk of ARMD who live in counties in the lowest quartile of ophthalmologist availability.

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Realized access to eye care has been defined as the use of eye care services and the visual health outcomes and patient satisfaction that result from the use of care. Understanding whether differences in the local availability of eye care professionals are related to differences in realized access to eye care is important for assessing whether and where public health efforts are needed to increase access to eye care professionals. This article examines whether the county-level availability of ophthalmologists and optometrists is associated with measures of realized access to eye care for individuals with diabetes mellitus, diabetic retinopathy, or age-related macular degeneration (AMD).

Diabetic retinopathy and AMD are 2 of the most common eye diseases in the United States, and both conditions can progress to cause severe visual impairment. Estimates for US individuals aged 40 years or older are that 28% to 40% of individuals with diabetes have diabetic retinopathy, 6.5% of individuals have ARM, and 73% of individuals with diabetic retinopathy and 84% of individuals with AMD are not aware that they have the condition. Effective treatments exist for some stages of these diseases, making it important that individuals at risk of these conditions or who already have these conditions receive regular eye care.

The conceptual model of access to eye care developed by Zhang et al assumes that the use of eye care services is influenced by an individual’s “predisposing,” “enabling,” and “need” characteristics and by contextual characteristics, such as the local availability of eye care professionals. Knowledge of a vision condition and disease severity may also be related to the local availability of eye care professionals. For example, it may be more difficult to find eye care professionals with expertise in the diagnosis of retinal diseases or to receive expert treatment promptly in areas with a more limited availability of eye care professionals.

Previous research on the association between the local availability of eye care professionals and realized access to care has used Medicare claims data. Sloan et al found that the combined number of ophthalmologists and optometrists per capita in the metropolitan area or county in which an individual resided was associated with significantly increased odds that an individual with AMD had an eye examination during a 15-month period but was not significantly related to the likelihood an individual with diabetes had an eye examination during a 15-month period. Wang and Javitt found that the number of ophthalmologists per capita but not the number of optometrists per capita in an individual’s county of residence was associated with significantly increased odds that diabetic individuals visited a physician for any kind of eye care during a 2-year period.

This article builds on the previous research by considering the association between the local availability of eye care professionals and a set of outcomes that measure various dimensions of realized access to eye care. These outcomes include the frequency of dilated eye examinations for diabetic individuals with and without retinopathy, the likelihood an individual with diabetic retinopathy or AMD is unaware of the condition, and the severity of diabetic retinopathy. In addition, this article uses a sample of individuals 40 years and older rather than a sample limited to Medicare beneficiaries.

Methods

Sample

The City University of New York institutional review board determined that this investigation was exempt from institutional review board approval. Data from the 2005-2008 National Health and Nutrition Examination Survey (NHANES) on individuals 40 years and older were used in the empirical analyses. The NHANES collects data through interviews, physical examinations, and laboratory tests. The samples are designed to be nationally representative of the US noninstitutionalized civilian population.

The physical examination component of the 2005-2008 NHANES included retinal imaging for individuals 40 years and older. Two nonmydriatic digital images per eye were taken. The images were graded at the University of Wisconsin using standard protocols for diabetic retinopathy and AMD. Of the 5828 individuals who participated in the retinal examination, there was information on the retinopathy status of 5704 individuals and the ARM status of 5604 individuals. Zhang et al and Klein et al describe reasons for missing diabetic retinopathy or ARM status.

Sample of Diabetic Individuals

Individuals were asked in the NHANES interview, “Other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?” Individuals who responded yes to this question or who had a hemoglobin A1c level greater than 6.5% (to convert to proportion of total hemoglobin, multiply by 0.01) were defined as having diabetes.

The sample of diabetic individuals was composed of 1098 individuals with diabetes with information on diabetic retinopathy status.

Samples of Diabetic Individuals and Sample of Individuals With ARM

The sample of individuals with diabetes was divided into 2 subsamples: those with signs of retinopathy in one or both eyes (n = 345) and those without retinopathy (n = 753). Gibson describes the clinical findings used to define diabetic retinopathy and ARM. The stage of diabetic retinopathy was categorized as mild nonproliferative, moderate nonproliferative, or vision-threatening. The ARM sample was composed of 498 individuals who had signs of ARM in one or both eyes. The stage of ARM was categorized as early or late.

Outcomes

Dilated Eye Examination in the Past Year

Annual dilated eye examinations are recommended for all diabetic individuals. Self-reported diabetic individuals were asked, “When was the last time you had an eye exam in which the pupils were dilated? This would have made you temporarily sensitive to bright light.” An indicator variable was created for reporting undergoing a dilated eye examination in the past year. This variable was set equal to zero for respondents who were unaware of their diabetes status.
Unawareness of Diabetic Retinopathy and ARMD
Self-reported diabetic individuals were asked, “Has a doctor ever told you that diabetes has affected your eyes or that you had retinopathy?” Individuals with diabetic retinopathy were defined as being unaware of their diabetic retinopathy if they responded no or don’t know to this question or if they were unaware of their diabetes.

Individuals 40 years and older were asked in the interview, “Have you ever been told by a doctor that you have age-related macular degeneration?” Individuals with ARMD were defined as being unaware of their ARMD if they responded no or don’t know to this question.

Vision-Threatening Diabetic Retinopathy
An indicator variable was created for whether an individual with diabetes had vision-threatening diabetic retinopathy.

Explanatory Variables
Measurement of the Local Availability of Eye Care Professionals
Information on the number of ophthalmologists and optometrists in each US county is available from the Area Health Resource Files.29 A respondent’s ophthalmologist availability was defined using the number of “patient care” ophthalmologists in the respondent’s county of residence in the year corresponding to the NHANES survey year. A respondent’s optometrist availability was defined using the number of optometrists in the respondent’s county of residence in 2009, the closest year of optometrist data available in the Area Health Resource Files to the 2005-2008 NHANES survey years. Separate county-level variables were created for the number of ophthalmologists per 100,000 county residents and the number of optometrists per 100,000 county residents. County population was drawn from the 2005-2009 American Community Survey 5-year estimates.

Population-weighted quartiles of county-level ophthalmologist and optometrist availability were defined using data on all of the counties in the United States. To create the quartile definitions, ophthalmologist numbers were drawn from 2008 and optometrist numbers were drawn from 2009. Quartiles were defined so that each quartile contained 25% of the US population. The quartile definitions for ophthalmologists per 100,000 county residents are as follows: low, 3.0 or less; medium-low, greater than 3.0 to 5.4; medium-high, greater than 5.4 to 7.5; and high, greater than 7.5. The quartile definitions for optometrists per 100,000 county residents are as follows: low, 10.8 or less; medium-low, greater than 10.8 to 14.0; medium-high, greater than 14.0 to 17.2; and high, greater than 17.2. Indicator variables were created for each of the ophthalmologist and optometrist quartiles.

Other Explanatory Variables
A large set of variables was used to measure an individual’s predisposing, enabling, and need characteristics, including measures of socioeconomic status and race/ethnicity.1,8 These variables include age (40-64 years, 65-79 years, or ≥80 years), sex, race/ethnicity (white non-Hispanic, black non-Hispanic, Hispanic, or other race/ethnicity), family size, educational attainment (less than high school, high school or general equivalency diploma, or more than high school), marital status (married or unmarried), whether a language other than English was the primary language spoken at home, total family income in the previous calendar year divided by the poverty threshold appropriate to the individual’s family size (lower income, <1.5; middle income, ≥1.5 and <3; higher income, ≥3; or missing), whether the individual had health insurance, and whether the individual received routine health care from a physician or a health maintenance organization.

Statistical Analysis
Descriptive statistics and logistic regression models were estimated taking into account the complex design features of the NHANES. As in previous research using 2005-2008 NHANES retinal examination data, unadjusted NHANES physical examination weights were used in the analyses.4,7,8 Taylor series linearization was used for variance estimation.30

A recent article by Ioannidis et al31 reports that the optimal choice of type I and type II errors varies with sample size and plausible effect size. Taking the sample sizes of the current study and assuming modest effect sizes, Ioannidis et al31 found that the optimal value of a ranges from .072 to .180, with corresponding values of β ranging from .087 to .260 under their additive model. An α value of .10 was used in this article because it falls in the range suggested by Ioannidis et al,31 and it is a commonly used significance level. Accordingly, associations were considered to be significant at P ≤ .10.

Descriptive statistics for the outcome and eye care professional variables were calculated for the 4 samples. Zhang et al4 and Gibson6 report descriptive statistics for each sample for the individual characteristics used in the analyses. Descriptive statistics were calculated within the samples by whether diabetic individuals with and without retinopathy reported undergoing a dilated eye examination in the past year, whether individuals with diabetic retinopathy were aware of the condition, whether diabetic individuals had vision-threatening diabetic retinopathy, and whether individuals with ARMD were aware of the condition. Differences in characteristics among the groups were tested using Pearson design-based F statistics for percentages and t tests for means.

Logistic regression models of undergoing an eye examination in the past year were estimated using the diabetic retinopathy sample and separately using the sample of diabetic individuals without retinopathy. Logistic regression models of unawareness of diabetic retinopathy and unawareness of ARMD were estimated using the diabetic retinopathy sample and the ARMD sample, respectively. Logistic regression models of having vision-threatening diabetic retinopathy were estimated using the sample of diabetic individuals. Three main models were estimated for each outcome. Model 1 included the number of ophthalmologists and the number of optometrists per capita in the respondent’s county. To test for nonlinearities in the association between eye care professional availability and the outcomes, model 2 included indicator variables for the highest ophthalmologist availability quartile and the highest optometrist availability quartile, and model 3 included indicator variables for the lowest ophthalmologist availability quartile and the lowest optometrist availability quartile. All the models included the individual predisposing, enabling, and
need variables described above. Indicator variables for moderate nonproliferative diabetic retinopathy and vision-threatening diabetic retinopathy were included in the models of dilated eye examination receipt for the diabetic retinopathy sample and unawareness of diabetic retinopathy. An indicator variable for late ARMD was included in the model of unawareness of ARMD. Measures of diabetes duration and current insulin use were also included in the models of diabetic retinopathy-related outcomes. Predictive margins (PMs), odds ratios (ORs), and 90% CIs were calculated.

Results

Descriptive Statistics

Table 1 presents descriptive statistics for the outcome and eye care professional variables for the 4 samples. A total of 61.8% of individuals with diabetic retinopathy and 47.0% of diabetic individuals without retinopathy reported undergoing a dilated eye examination in the past year. A total of 73.1% of the diabetic retinopathy sample was unaware of their diabetic retinopathy, and 83.8% of the ARMD sample was unaware of their ARMD. A total of 4.9% of the sample of diabetic individuals had vision-threatening diabetic retinopathy. Across the 4 samples, the mean number of ophthalmologists per 100,000 county residents ranged from 4.0 to 4.3, and the mean number of optometrists per 100,000 county residents ranged from 13.7 to 13.9.

The only significant differences in eye care professional variables by differences in outcome variables were for the sample of diabetic individuals (results not shown). Differences were found by vision-threatening diabetic retinopathy status (yes or no) in the percentage of the subsample who lived in a county in the lowest optometrist availability quartile (38.0% vs. 25.4% for diabetic individuals with and without retinopathy, respectively).

Table 1. Measures of Realized Access to Eye Care and Eye Care Professional Availability for Diabetic Individuals With and Without Diabetic Retinopathy and Individuals With ARMD, NHANES, 2005-2008

<table>
<thead>
<tr>
<th>Measure</th>
<th>Weighted Percentage or Mean (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetic Individuals (n = 1098)</td>
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<tr>
<td>Self-reported dilated eye examination in past year</td>
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<tr>
<td>Yes</td>
<td>51.2 (16.3-21.4)</td>
</tr>
<tr>
<td>No</td>
<td>48.8 (45.4-52.2)</td>
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<tr>
<td>Diabetic retinopathy stage</td>
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</tr>
<tr>
<td>Mild nonproliferative</td>
<td>18.7 (16.3-21.4)</td>
</tr>
<tr>
<td>Moderate nonproliferative</td>
<td>4.8 (3.7-6.3)</td>
</tr>
<tr>
<td>Vision-threatening</td>
<td>4.9 (4.1-5.9)</td>
</tr>
<tr>
<td>Awareness of diabetic retinopathy</td>
<td></td>
</tr>
<tr>
<td>Aware</td>
<td>7.6 (6.4-9.1)</td>
</tr>
<tr>
<td>Unaware</td>
<td>20.8 (18.0-23.9)</td>
</tr>
<tr>
<td>Diabetic retinopathy stage</td>
<td></td>
</tr>
<tr>
<td>Mild nonproliferative</td>
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<td>4.9 (4.1-5.9)</td>
</tr>
<tr>
<td>Awareness of ARMD</td>
<td></td>
</tr>
<tr>
<td>Aware</td>
<td>NA</td>
</tr>
<tr>
<td>Unaware</td>
<td>NA</td>
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<tr>
<td>ARMD stage</td>
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<tr>
<td>Late</td>
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<tr>
<td>Awareness of ARMD</td>
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<tr>
<td>Aware</td>
<td>NA</td>
</tr>
<tr>
<td>Unaware</td>
<td>NA</td>
</tr>
<tr>
<td>County-level eye care professional availability</td>
<td></td>
</tr>
<tr>
<td>Ophthalmologists per 100 000 residents</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>4.1 (3.1-5.1)</td>
</tr>
<tr>
<td>Medium-low</td>
<td>17.6 (10.7-27.4)</td>
</tr>
<tr>
<td>Medium-high</td>
<td>21.1 (13.2-32.2)</td>
</tr>
<tr>
<td>High</td>
<td>16.4 (9.8-26.2)</td>
</tr>
<tr>
<td>Optometrists per 100 000 residents</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>4.3 (3.3-5.3)</td>
</tr>
<tr>
<td>Medium-low</td>
<td>18.9 (10.4-31.8)</td>
</tr>
<tr>
<td>Medium-high</td>
<td>22.6 (13.6-35.3)</td>
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<tr>
<td>High</td>
<td>18.1 (11.1-28.3)</td>
</tr>
<tr>
<td>County-level ophthalmologist availability quartile</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>40.4 (27.6-54.6)</td>
</tr>
<tr>
<td>Medium-low</td>
<td>18.9 (10.4-31.8)</td>
</tr>
<tr>
<td>Medium-high</td>
<td>20.6 (12.8-31.4)</td>
</tr>
<tr>
<td>High</td>
<td>15.7 (9.1-25.8)</td>
</tr>
<tr>
<td>County-level optometrist availability quartile</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>24.7 (14.6-38.6)</td>
</tr>
<tr>
<td>Medium-low</td>
<td>27.7 (19.0-38.4)</td>
</tr>
<tr>
<td>Medium-high</td>
<td>28.3 (20.0-38.4)</td>
</tr>
<tr>
<td>High</td>
<td>16.0 (9.2-26.4)</td>
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</tbody>
</table>
| Abbreviations: ARMD, age-related macular degeneration; NA, not applicable; NHANES, National Health and Nutrition Examination Survey.

474 JAMA Ophthalmology April 2014 Volume 132, Number 4 jamaophthalmology.com

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vs 25.0, \( P = .048 \)) and the percentage who lived in a county in the medium-high optometrist availability quartile (18.0 vs 30.0, \( P = .07 \)).

Regression Analyses

Table 2 presents the results of model 1. The number of ophthalmologists per 100 000 county residents was associated with significantly higher odds of undergoing a dilated eye examination in the past year for diabetic individuals without retinopathy (OR, 1.05; 90% CI, 1.00-1.10), significantly lower odds of unawareness of diabetic retinopathy (OR, 0.94; 90% CI, 0.89-0.99), and significantly lower odds of unawareness of ARMD (OR, 0.94; 90% CI, 0.88-0.99). The number of ophthalmologists was not significantly related to the likelihood of having vision-threatening diabetic retinopathy. The number of optometrists per 100 000 county residents was not significantly related to the likelihood of having ARMD (OR, 0.94; 90% CI, 0.88-0.99). The number of ophthalmologists per 100 000 county residents was significantly more likely to be unaware they had diabetic retinopathy (PM, 66.1%; 90% CI, 48.8%-83.4%; vs PM, 84.1%; 90% CI, 78.7%-89.6%) and were significantly less likely to have vision-threatening diabetic retinopathy (PM, 1.4%; 90% CI, 0.9%-1.9%; vs PM, 2.6%; 90% CI, 1.8%-3.4%) than individuals who lived in a county in the lower 3 optometrist availability quartiles. Individuals who lived in a county in the lowest optometrist availability quartile were significantly more likely to be unaware they had ARM (PM, 93.8%; 90% CI, 90.6%-97.0%; vs PM, 88.3%; 90% CI, 84.7%-91.9%) than individuals who lived in a county in the
higher 3 ophthalmologist availability quartiles. Optometrist availability quartiles were not significantly related to any of the outcomes.

Discussion

This study found that the local availability of ophthalmologists was positively associated with measures of realized access to eye care for individuals with diabetes, diabetic retinopathy, and ARMD. These associations were significant in models that included a large set of individual characteristics, including measures of socioeconomic status and race/ethnicity. No significant associations were found between the local availability of optometrists and the measures of realized access to eye care. Similarly, Wang and Javitts found that the county-level availability of ophthalmologists but not optometrists was associated with increased odds of needing care among diabetic individuals.

In a survey of primary care physicians in Indiana, Lazardis et al found that 89.8% of the physicians referred their patients with diabetes mainly to ophthalmologists rather than optometrists. Guidelines for primary care physicians focus on referring patients with signs of ARMD to ophthalmologists. Data from a workforce survey conducted in 1999 indicated that approximately 10% of optometric visits (11 million visits) were devoted to disease management or treatment. These findings suggest that most optometrists devote a small fraction of their practice to the care of patients with diabetes or ARMD, which may explain the lack of an association between optometrist availability and the outcomes considered in this article.

The results suggest that public health efforts to increase access to ophthalmologists to improve outcomes related to diabetic retinopathy or to increase awareness of ARMD should focus on improving access for diabetic individuals who live in counties in the lowest 3 quartiles of ophthalmologist availability and on individuals at risk of ARMD who live in counties in the lowest quartile of ophthalmologist availability. The next issue to discuss is how access to ophthalmologists could be increased in target areas. Lee et al conclude that increasing the number of ophthalmology training positions is not an effective short-term solution for increasing the supply of ophthalmologists. They estimate that it would take more than 20 years for a 20% increase in ophthalmology training positions to result in a 10% increase in the number of ophthalmologists in practice. In addition, this approach would not address the uneven distribution of ophthalmologists across the country.

Finding new ways to use existing excess ophthalmologist capacity is likely to be a more promising approach. Lee et al reported that 52% of ophthalmologists in a representative sample of US ophthalmologists indicated that they were interested in increasing their patient volume by 33% or more. Telemedicine could be used to connect potential patients in underserved areas with ophthalmologists. Telemedicine using digital retinal images that are evaluated remotely by ophthalmologists has been found to be an effective tool for screening for both diabetic retinopathy and ARMD. Screening for diabetic retinopathy via telemedicine has also been found to be cost-effective. The cost-effectiveness of screening for ARMD via telemedicine has not been evaluated. Whether telemedicine could be used successfully as a tool in the management of these conditions has not been investigated extensively, although early research suggests that it holds promise.

The mean county-level density of optometrists was greater than that of ophthalmologists, and previous research indicates that many optometrists have excess capacity. Increasing the use of a “shared care” model where chronic eye diseases are managed jointly by ophthalmologists and optometrists in at-risk areas could potentially take advantage of excess optometrist capacity and relieve some of the need for ophthalmologists.

This study is subject to several limitations. First, it was not possible to obtain information on the number of ophthalmologists and optometrists located in a geographic area smaller than a county. The county-level density of eye care professionals may not represent accurately a given individual’s experience of the availability of eye care professionals. Second, data on optometrist availability were drawn from 2009. This means that the optometrist availability of NHANES respondents could be measured with error. Third, although appropriately weighted NHANES data are demographically nationally representative of the US noninstitutionalized civilian population, the sample is not geographically representative of the entire country. It is possible that the associations found between eye care professional availability and visual health outcomes would differ with a geographically representative sample.

Conclusions

It has been estimated that in the United States there are 25.6 million individuals 20 years and older with diabetes, 4.2 million individuals 40 years and older with diabetic retinopathy, and 7.2 million individuals 40 years and older with ARMD. Adequate access to ophthalmologists is necessary to ensure that this large number of individuals at high risk of and already affected by diabetic retinopathy or ARMD have the best visual health outcomes possible. Using telemedicine to take advantage of existing excess ophthalmologist capacity and increasing shared-care partnerships between ophthalmologists and optometrists may provide a way to improve realized access to eye care in areas with limited local availability of ophthalmologists.
Conflict of Interest Disclosures: None reported.

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Disclaimer: The findings and conclusions in this article are those of the author and do not necessarily represent the views of the NCHS, Centers for Disease Control and Prevention.

Additional Information: The use of restricted-access data for this project was approved by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention. All results presented in the article have been cleared for release by the NCHS Research Data Center.

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REFERENCES