

Prevalence of Diagnosed Dry Eye Disease in the United States Among Adults Aged 18 Years and Older



KIMBERLY F. FARRAND, MOSHE FRIDMAN, IPEK ÖZER STILLMAN, AND DEBRA A. SCHAUMBERG

- **PURPOSE:** To provide current estimates of the prevalence of diagnosed dry eye disease (DED) and associated demographics among US adults aged ≥ 18 years.
- **DESIGN:** Cross-sectional, population-based survey.
- **METHODS:** Data were analyzed from 75 000 participants in the 2013 National Health and Wellness Survey to estimate prevalence/risk of diagnosed DED overall, and by age, sex, insurance, and other demographic factors. We weighted the observed DED prevalence to project estimates to the US adult population and examined associations between demographic factors and DED using multivariable logistic regression.
- **RESULTS:** Based on weighted estimates, 6.8% of the US adult population was projected to have diagnosed DED (~16.4 million people). Prevalence increased with age (18–34 years: 2.7%; ≥ 75 years: 18.6%) and was higher among women (8.8%; ~11.1 million) than men (4.5%; ~5.3 million). After adjustment, there were no substantial differences in prevalence/risk of diagnosed DED by race, education, or US census region. However, there was higher risk of diagnosed DED among those aged 45–54 years (odds ratio [OR]: 1.95; 95% confidence interval [CI]: 1.74–2.20) and ≥ 75 years (OR: 4.95; 95% CI: 4.26–5.74), vs those aged 18–34 years. Risk was also higher among women vs men (OR: 2.00; 95% CI: 1.88–2.13) and insured vs uninsured participants (OR: 2.12; 95% CI: 1.85–2.43 for those on government and private insurance vs none).
- **CONCLUSIONS:** We estimate that >16 million US adults have diagnosed DED. Prevalence is higher among women than men, increases with age, and is notable among those aged 18–34 years. (Am J Ophthalmol 2017;182:90–98. © 2017 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Accepted for publication Jun 30, 2017.

From Shire, Wayne, Pennsylvania (K.F.F.); AMF Consulting, Inc., Los Angeles, California (M.F.); Shire, Lexington, Massachusetts (I.Ö.S., D.A.S.); Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, Massachusetts (D.A.S.); and Department of Ophthalmology & Visual Sciences, University of Utah School of Medicine, Salt Lake City, Utah (D.A.S.).

Inquiries to Ipek Özer Stillman, Shire, 300 Shire Way, Lexington, MA 02421, USA; Tel: 781-482-9228; e-mail: istillman0@shire.com

DRY EYE DISEASE (DED) IS A CHRONIC DISEASE OF the ocular surface that is widely encountered in ophthalmic practice.^{1,2} A summary of a 1998 workshop, cosponsored by the National Eye Institute, concluded that there were insufficient data available on prevalence of DED and how it is affected by demographic factors.³ Since then, several studies have evaluated DED prevalence. In the United States (US), estimates have ranged from 4.3% among men aged ≥ 50 years⁴ to 21.6% in men and women aged 48–91 years⁵ and 14.5% among those aged ≥ 21 years.⁶ Of the recent DED estimates in large populations, the Women's Health Study (WHS)⁷ and the Physicians' Health Studies I and II (PHS I and II)⁴ have employed validated DED questionnaires to estimate the prevalence of DED diagnosis and symptoms. The WHS estimated DED prevalence at 7.8% for women aged ≥ 50 years (1999), and the PHS at 4.3% for men aged ≥ 50 years (2004). Most published estimates of DED prevalence have focused on older age groups, in which prior research has suggested that DED is more prevalent. However, there is an increasing clinical perception that the prevalence of DED is growing and also that it is increasingly occurring at younger ages (Dana R, et al. Poster presented at the Annual Meeting of the American Academy of Ophthalmology. Oct 15–18, 2016; Chicago, Illinois).

This study was designed to provide current estimates of the prevalence of DED among the adult population in the US, based on a large and diverse study population. Our analysis is intended to fill gaps in published data about DED prevalence, specifically to estimate the prevalence of diagnosed DED, and to inform prevalence among younger age groups (18–50 years). This work is also intended to further characterize the US DED population.

METHODS

- **STUDY POPULATION:** The study population was derived from the 2013 National Health and Wellness Survey (NHWS) conducted by Kantar Health, USA. The NHWS is an annual self-administered, internet-based questionnaire with a nationwide sample of 75 000 adults (aged ≥ 18 years) in the US. Individuals self-select into the internet panel by responding to advertisements in e-newsletters and online banners.⁸ A random sample,

stratified for sex, age, race/ethnicity, and education, is then invited to participate in the survey to obtain a nationally diverse sample of the US adult population. The NHWS is a general health survey that queries participants on a wide range of diseases and associated factors. For the purpose of this analysis, we focused on dry eye–related questions in the survey. The NHWS was reviewed and approved by the Essex Institutional Review Board (Lebanon, New Jersey, USA) to ensure that the rights of research participants are protected and that the study is carried out in an ethical manner. All survey respondents confirmed their voluntary participation and consent.

- **DRY EYE DISEASE ASCERTAINMENT:** Participants were asked whether they had ever experienced dry eye. Possible responses were **Yes** or **No**. Those who answered “**No**” to ever experiencing dry eye were classified as Non-DED and were not asked any other DED-related questions. All participants who said “**Yes**” were asked a series of dry eye–related questions. The first question in the series was whether their dry eye had ever been diagnosed by a physician. Possible responses were **Yes** or **No**. Those who answered “**yes**” to experiencing dry eye but “**No**” to being diagnosed by a physician were classified as Symptomatic-Undiagnosed. Those who confirmed both experiencing dry eye and physician diagnosis were classified as Diagnosed-DED and were given a list of symptoms (pain, light sensitivity, a gritty sensation, a feeling of a foreign body or sand in the eye, itching, redness, and blurring of vision) and asked to select all that applied. Diagnosed respondents were also asked to specify year of diagnosis, provide details about the physician who made the diagnosis (Primary Care Physician/GP/Internist, Ophthalmologist, Optometrist, Other), and asked about dry eye severity (select 1 of mild, moderate, or severe). In this analysis, we focused on the prevalence of Diagnosed-DED; the Symptomatic-Undiagnosed DED group were excluded from the main analysis. Owing to the limitations of the symptom questionnaire used in the NHWS, this group was likely to have a higher proportion of misclassified subjects and thus our confidence in classifying them as having DED was far lower. However, for completeness, we did use data from the Symptomatic-Undiagnosed group to estimate prevalence of undiagnosed DED.

- **STATISTICAL ANALYSIS:** Prevalence of Diagnosed-DED was calculated overall and stratified by various demographic and lifestyle factors. We also calculated unadjusted prevalence of Diagnosed-DED by self-reported severity and selected symptoms of DED. We compared categorical variables across groups using the χ^2 test and continuous variables using the 1-way analysis of variance (ANOVA) *F* test and the Kruskal-Wallis rank sum test. Observed DED prevalence estimates were adjusted using the Horvitz-Thompson estimator and inverse probability weighting on joint strata of sex, age, race, and education to project

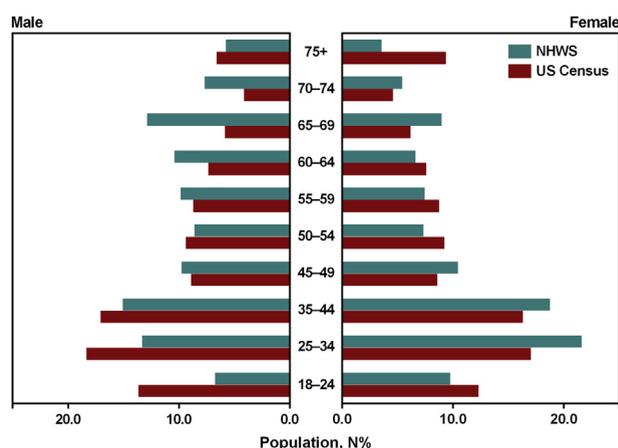


FIGURE 1. Comparison of age and sex distribution in the 2013 National Health and Wellness Survey (NHWS) with the US adult population in the 2013 census.

estimates to the US adult population (US census data for 2013⁹ [a total of 242 542 967 adults]). We report prevalence estimates as percentages with 95% confidence intervals (CIs), calculated using Taylor Series linearization. We used multivariate models to estimate and test differences across groups in age, sex, insurance type, and other significant covariates. Odds ratios (ORs), along with Wald χ^2 tests and 95% CIs, are reported for each predictor. The multivariate model’s accuracy of classification was measured by the C-statistic value.

RESULTS

- **STUDY POPULATION:** Of the 75 000 survey participants, 5051 reported a diagnosis of DED and 68 160 reported no experience of DED or diagnosis (Non-DED). The remaining 1789 participants reported experience of DED, but no DED diagnosis (Symptomatic-Undiagnosed); this group was excluded from the main analysis, but data were used to estimate the prevalence of undiagnosed DED.

Compared with the US population, the NHWS has more women in the younger age groups (18–49 years) and more men in the older age groups (≥ 55 years). The NHWS age and sex distribution in relation to US census data is shown in [Figure 1](#).

The Diagnosed-DED group was older, with 72% of participants aged ≥ 50 years compared with 45% in the Non-DED group ([Table 1](#)). There was a higher proportion of women (62%) and white race (76%) in the Diagnosed-DED group vs the Non-DED group (51% women and 72% white). Differences between the 2 groups by census region were small but statistically significant ($P = .002$) due to the large sample size. In the unadjusted data, there was a higher proportion of divorced, separated, or widowed respondents and a lower proportion of single respondents in

TABLE 1. Demographic Characteristics by Dry Eye Disease Status

Characteristic, n (%)	Non-DED n = 68 160	Diagnosed-DED n = 5051	P Value
Age (y)			<.001
18–49	37 260 (55)	1419 (28)	
≥50	30 900 (45)	3632 (72)	
Sex			<.001
Male	33 533 (49)	1895 (38)	
Female	34 627 (51)	3156 (62)	
Race			<.001
White	49 122 (72)	3851 (76)	
African American	7899 (12)	493 (10)	
Hispanic	5660 (8)	363 (7)	
Asian	3479 (5)	165 (3)	
Other	2000 (3)	179 (4)	
Census region			.002
Northeast	13 167 (19)	904 (18)	
Midwest	16 451 (24)	1162 (23)	
South	24 014 (35)	1887 (37)	
West	14 528 (21)	1098 (22)	
Education			.24
<4 years of college	39 652 (58)	2949 (58)	
College degree or higher	28 508 (42)	2102 (42)	
Marital status			<.001
Married or living with partner	39 517 (58)	2984 (59)	
Single	17 528 (26)	736 (15)	
Divorced/separated/widowed	11 115 (16)	1331 (26)	
Insurance type for age <65 years			<.001
None	11 820 (22)	417 (15)	
Private	32 096 (59)	1619 (57)	
Government	7378 (14)	611 (21)	
Both ^a	1063 (2)	150 (5)	
Other	1812 (3)	45 (2)	
Insurance type for age ≥65 years			<.001
None	393 (3)	36 (2)	
Private	1640 (12)	192 (9)	
Government	6642 (47)	1107 (50)	
Both ^a	5293 (38)	870 (39)	
Other	23 (0)	4 (0)	

DED = dry eye disease.

^aBoth = private as well as government insurance.

the Diagnosed-DED group compared with the Non-DED group. Insurance data have been split by age to account for Medicare coverage in the age ≥65 years group. As would be expected, compared with the age ≥65 years group, there were more participants aged 18–64 years on private insurance, and fewer on government insurance, in both the Diagnosed-DED and Non-DED groups. The proportion with no insurance was higher in the Non-DED group (22% and 3% in the age 18–64 and ≥65 years groups,

respectively) compared with the Diagnosed-DED group (15% and 2% in the age 18–64 and ≥65 years groups, respectively; [Table 1](#)).

• **DRY EYE DISEASE PREVALENCE BY AGE AND SEX:** The overall prevalence of Diagnosed-DED among US adults in 2013 was estimated at 6.8% (95% CI: 6.55%–6.98%), corresponding to ~16.4 million people in the US population. An additional 2.5% (95% CI: 2.34%–2.59%) of participants (corresponding to ~6 million people in the US population) reported having experienced DED but had not been diagnosed with DED (Symptomatic-Undiagnosed). Prevalence of Diagnosed-DED was higher among women (8.8%) than men (4.5%). These proportions would correspond to ~11.1 million women and ~5.3 million men aged ≥18 years in the US. Prevalence of Diagnosed-DED increased with age, ranging from 2.7% among those aged 18–34 years to 18.6% among those aged ≥75 years ([Figure 2](#)). Among those aged 18–34 years, 2.9% of women and 2.6% of men had a DED diagnosis; among those aged ≥75 years, 22.8% of women and 12.6% of men had a DED diagnosis. Prevalence was 3.4% (women, 4.1%; men, 2.7%) among those aged 18–49 years and 11.3% (women, 15.2%; men, 7.0%) in the age ≥50 years group ([Figure 2](#)).

• **DRY EYE DISEASE PREVALENCE BY DEMOGRAPHIC FACTORS:** After adjustment for age and sex, the prevalence of Diagnosed-DED was highest among white participants (7.03%; 95% CI: 6.79%–7.27%) and lowest among Asian participants (4.25%; 95% CI: 3.57%–4.93%; [Table 2](#)). Prevalence among African American (6.29%; 95% CI: 5.49%–7.09%) and Hispanic participants (6.23%; 95% CI: 5.50%–6.96%) was not significantly different from that among white participants. Participants who self-identified as “other” races had a significantly higher prevalence (8.74%; 95% CI: 7.33%–10.16%) than any of the racial groups.

Prevalence of Diagnosed-DED was higher among insured participants. Those with both private and government insurance reported the highest prevalence in all age groups: 11.72% (95% CI: 9.84%–13.61%) among the age <65 years group and 16.59% (95% CI: 15.11%–18.07%) in the age ≥65 years group. This was followed by prevalence among those reporting government or private health insurance coverage for all age groups ([Table 2](#)). Participants on government insurance reported a prevalence of 7.33% (95% CI: 6.73%–7.93%) among the age <65 years group and 15.78% (95% CI: 14.57%–17.00%) in the age ≥65 years group, while those on private insurance reported a prevalence of 4.80% (95% CI: 4.55%–5.04%) and 14.53% (95% CI: 11.58%–17.48%) in the age <65 and ≥65 years groups, respectively. Those reporting “none” or “other” insurance had significantly lower prevalence of Diagnosed-DED in all age groups ([Table 2](#)).

No substantial differences in prevalence by census region or education status were observed ([Table 2](#)), although

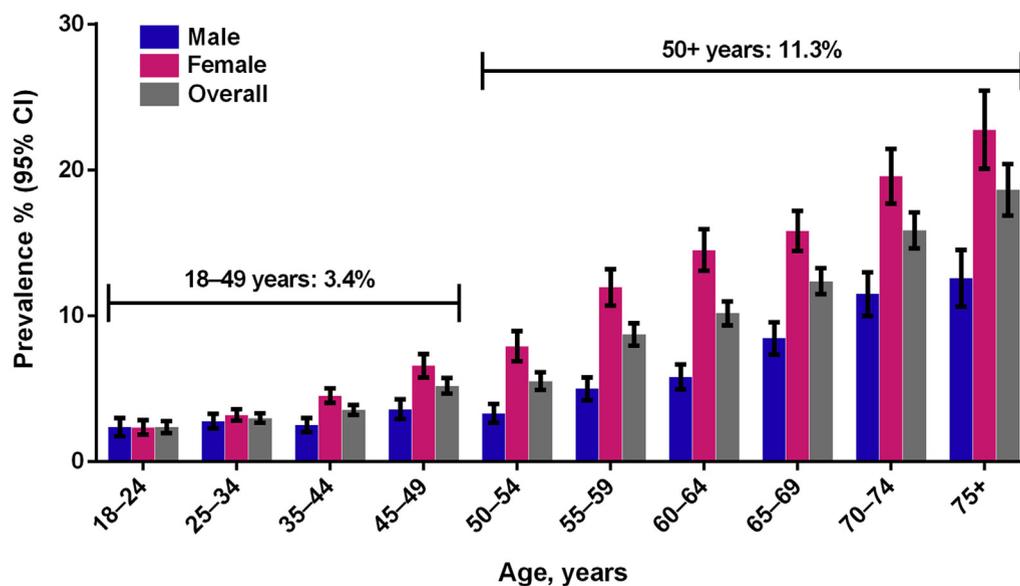


FIGURE 2. Estimates of diagnosed dry eye disease (Diagnosed-DED) prevalence by age and sex. CI = confidence interval.

participants in the southern US had a marginally higher prevalence (7.04%; 95% CI: 6.66%–7.41%) compared with participants in the northeastern (6.69%; 95% CI: 6.14%–7.24%), midwestern (6.40%; 95% CI: 5.98%–6.82%), and western (6.78%; 95% CI: 6.30%–7.25%) regions of the US.

• **ASSOCIATION OF DRY EYE DISEASE WITH AGE, SEX, AND OTHER DEMOGRAPHIC FACTORS:** In estimates based on multivariable logistic regression models, we again observed the trend of increasing Diagnosed-DED with age and female sex (Figure 3). Adjusted for other factors, participants aged 45–54 years were twice as likely to have Diagnosed-DED as those in the age 18–34 years group. The risk of Diagnosed-DED was 5-fold higher among participants aged ≥ 75 years than among participants aged 18–34 years. The risk of Diagnosed-DED was 2-fold higher among women than men.

There were significant differences across racial groups. Hispanic (OR: 1.34; 95% CI: 1.19–1.51) and “other” participants (OR: 1.44; 95% CI: 1.22–1.69) had a slightly higher risk of Diagnosed-DED (Figure 3) compared with their white counterparts. There were no substantial differences in the prevalence of Diagnosed-DED by census region, although participants from the southern region of the US had a slightly higher adjusted risk (OR: 1.14; 95% CI: 1.05–1.24) than those from other regions. Participants on government (OR: 2.06; 95% CI: 1.83–2.32) or both private and government insurance (OR: 2.12; 95% CI: 1.85–2.43) were twice as likely to be diagnosed compared with uninsured participants. Participants with a college degree or higher education level had a slightly higher risk of Diagnosed-DED (OR: 1.08; 95% CI: 1.01–1.14) compared with participants with < 4 years of college.

Divorced, separated, or widowed participants had a slightly higher risk of diagnosed DED (OR: 1.11; 95% CI: 1.03–1.19) compared with participants who were single (OR: 0.97; 95% CI: 0.88–1.06), married, or living with partners (reference: OR: 1.00).

• **DRY EYE DISEASE SEVERITY AND DIAGNOSIS CHARACTERISTICS:** One half of all Diagnosed-DED participants self-reported mild DED severity; 42% and 8% reported moderate or severe DED, respectively. The percentage of Diagnosed-DED participants who reported experiencing symptoms were as follows: itching (60%), gritty sensation (48%), feeling of foreign body in eye (46%), blurred vision (44%), redness (42%), light sensitivity (32%), and pain (19%); symptom descriptors of dryness and irritation were not included in the NHWS questionnaire.

The majority of Diagnosed-DED participants had received both their DED diagnosis and DED prescriptions from an eye doctor (ophthalmologist or optometrist; Table 3). Of the 4746 Diagnosed-DED participants who reported valid treatment options for DED, 81% noted treatments including artificial tears, ophthalmic cyclosporine, topical steroids, topical allergy medications, topical antibiotics, doxycycline, or omega-3 fatty acids.

DISCUSSION

BASED ON AN ANALYSIS OF PARTICIPANT-REPORTED DATA from the 2013 NHWS, we estimate that 6.8% of the US adult population has a diagnosis of DED, corresponding to 16.4 million men and women. An additional 2.5% of Americans are estimated to have experienced dry eye,

TABLE 2. Prevalence of Dry Eye Disease by Demographic Strata, Adjusted for Age and Sex

Characteristic	Diagnosed-DED n = 5051		
	%	95% CI	
Race			
White	7.03	6.79	7.27
African American	6.29	5.49	7.09
Hispanic	6.23	5.50	6.96
Asian	4.25	3.57	4.93
Other	8.74	7.33	10.16
Census region			
Northeast	6.69	6.14	7.24
Midwest	6.40	5.98	6.82
South	7.04	6.66	7.41
West	6.78	6.30	7.25
Education			
<4 years of college	6.86	6.58	7.14
College degree or higher	6.52	6.23	6.81
Insurance for age <65 years^a			
None	3.16	2.83	3.48
Private	4.80	4.55	5.04
Government	7.33	6.73	7.93
Both	11.72	9.84	13.61
Other	2.15	1.47	2.82
Insurance for age ≥65 years^b			
None	10.85	5.35	16.35
Private	14.53	11.58	17.48
Government	15.78	14.57	17.00
Both	16.59	15.11	18.07
Other	9.60	0	20.54

CI = confidence interval; DED = dry eye disease.

^aThe total number of respondents aged <65 years is 58 500.

^bThe total number of respondents aged ≥65 years is 16 500.

although it is not possible to verify the DED status of this population from the NHWS questions. This additional group of people who report having experienced dry eye does, however, allow us to put an upper limit on the estimate of DED prevalence, suggesting that up to 9.3% of adult Americans may suffer from DED. Female sex and increased age, as suggested by previous research, continue to be significant risk factors for Diagnosed-DED. Prevalence is nearly 2 times higher in women than in men. For both sexes, prevalence increases with age and is >3 times higher in individuals aged ≥50 years vs those aged 18–49 years.

This study encompasses the most recent data available on prevalence and epidemiology of DED in the US adult population. Of note are the large sample size leading to narrow CIs and the comprehensive evaluation of DED across demographic groups, including younger ages. Many previous studies have either been carried out in small geographic regions^{5,6,10} or derived study populations from selective

databases (eg, claims or veteran databases),^{11,12} or were limited to older individuals.^{4,7}

The NHWS is an annual questionnaire developed and administered by Kantar Health that seeks a variety of health care responses from a broad population. We accessed data from the 2013 survey and analyzed the responses for epidemiologic information pertaining to DED and its symptoms. Differences in methodologies and DED definitions (there is still no gold standard) make direct comparisons between studies difficult; however, our results are broadly consistent with previous studies showing higher DED prevalence and symptoms among women than men, and increasing prevalence with age.^{4,5,7,11–13} Estimates in large populations (N >25 000) have come from the WHS⁷ and PHS I and II.⁴ Both of these studies used a validated DED-specific questionnaire to query health professionals about their DED diagnosis and symptoms. Our diagnosed DED prevalence estimate of 11.3% among individuals aged ≥50 years is higher than the estimates from these studies (women in WHS, 7.8%; men in PHS I and II, 4.3%). We note that the WHS and PHS estimates were derived from questionnaires administered in the late 1990s,^{4,7} whereas the NHWS is more current, having been conducted in 2013. We believe it is unlikely that the different survey methodologies in WHS and PHS relative to the NHWS would have contributed to a higher estimate in the NHWS since the WHS and PHS also ascertained diagnosed DED. The difference could then potentially be attributed to a true increase in the disease over time due to changes in environmental and lifestyle factors, an increase in awareness and likelihood of diagnosis, or aging of the population over time.

Other studies have estimated a range of DED prevalence. However, these have been based on either symptom-based definitions that maximize sensitivity (at the cost of specificity), or participant-reported diagnosis that may be partially confounded by participants who had other conditions with overlapping symptoms (eg, allergies and other common ocular surface conditions). The Salisbury Eye Study, for example, defined DED as having 1 or more of 6 selected dry eye symptoms often or all of the time and estimated DED prevalence at 14.6% among individuals aged 65–84 years.¹⁰ The Beaver Dam estimates were based on patient-reported sensations of dry eyes or dry eye symptoms and produced an estimate of 21.6% among those aged 48–91 years.⁵ Neither of those studies distinguished dry eye symptoms from diagnosed DED. Among other DED prevalence estimates, the Beaver Dam Offspring Study and the US Veterans Affairs database study are notable for including younger age groups in their estimates. The Beaver Dam Offspring Study estimated the prevalence of DED symptoms at 14.5% among individuals aged 21–84 years, but the specificity of the classification was not evaluated.⁶ The Veterans Affairs researchers analyzed patient records and based DED prevalence on indicators of dry

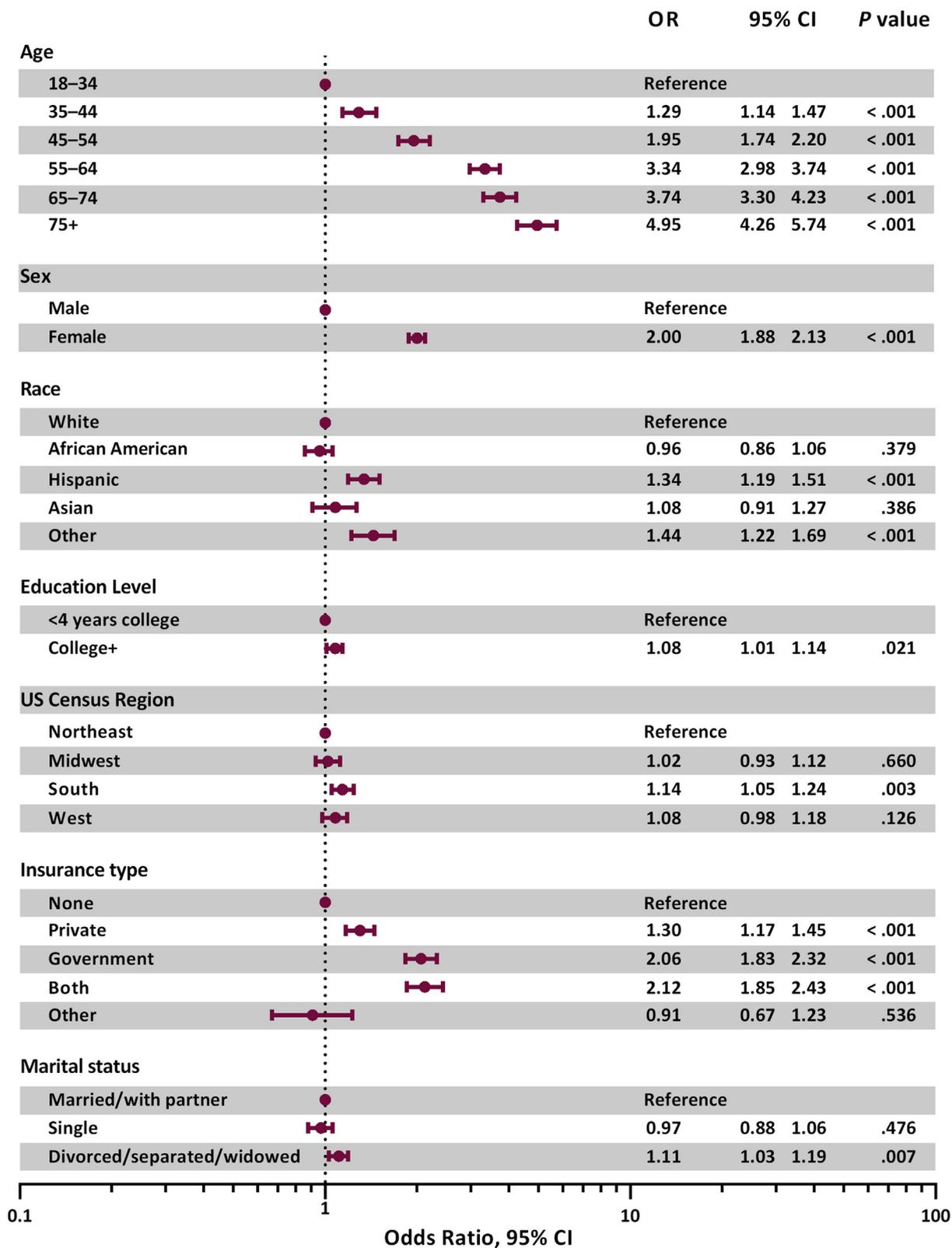


FIGURE 3. Significant association of dry eye disease with demographic factors. Results of multivariate logistic regression model for diagnosed dry eye disease (Diagnosed-DED) vs no dry eye disease (Non-DED). The model's accuracy of classification was measured by the C-statistic value (C = 0.71). CI = confidence interval; OR = odds ratio.

TABLE 3. Diagnosis Characteristics of the Diagnosed Dry Eye Disease Group

Characteristic	Diagnosed-DED n = 5051
Time since diagnosis, mean (SD), y	7.1 (8.0)
Age at DED diagnosis, mean (SD), y	51.3 (16.4)
Provider who diagnosed, n (%)	
Eye doctor ^a	4401 (89)
Primary care provider ^b	424 (9)
Other	122 (2)

DED = dry eye disease; SD = standard deviation.
^aEye doctor includes both ophthalmologists and optometrists.
^bPrimary care provider could be either of the following: primary care physician, general physician, or internist.

eye diagnosis and therapy and estimated prevalence at 18.8% among those aged 21–100 years.¹²

After adjusting our NHWS data for age and sex, we found no difference in Diagnosed-DED prevalence between Asian and white participants. This observation contrasts with high estimates for the prevalence of DED symptoms in Asian population-based surveys. In the Taiwanese Shihpai study, 33.7% of individuals aged ≥ 65 years reported experiencing 1 or more symptom(s) of dry eye often or all the time.¹⁴ Among individuals aged ≥ 40 years in the Japanese Koumi study, prevalence of clinically diagnosed DED was estimated at 2% for men and 7.9% for women, but 11.5% of men and 18.7% of women reported severe DED symptoms.¹⁵ A similar trend was noted in the WHS that found that Asian women were more likely to report severe DED symptoms, but not a clinical diagnosis of DED.⁷ In a recently reported New Zealand study, Craig and associates¹⁶ observed that the Asian population has higher meibomian gland dropout and poorer blinking compared with the white population, suggesting a possible morphologic predisposition to DED among Asian patients. Together, these observations suggest that DED may be underdiagnosed among Asian patients in the US, but further research is needed. Another possibility is that the population distribution of other DED risk factors may differ among people of Asian descent in the US vs countries in Asia.

We did observe a higher risk of Diagnosed-DED among Hispanic participants compared with non-Hispanic white participants in the NHWS. A similar observation was noted in the US Veterans Affairs study.¹² Previous studies have also noted a higher risk of DED symptoms among Hispanic women⁷ and higher prevalence of DED symptoms among Hispanic patients.¹⁷ We also found that NHWS participants who live in the southern US have a small but significantly higher risk of Diagnosed-DED compared with those who live in other regions of the US. This finding is consistent with the WHS data that showed that women

in the southern US had a slightly higher risk of DED compared with those in the Midwest and Northeast.⁷ Interestingly, education and marital status of NHWS participants had a small but significant impact on their likelihood of having Diagnosed-DED. NHWS participants with higher education were more likely to have Diagnosed-DED. In the WHS, however, higher education was associated with lower risk of DED.⁷ Associations of education with DED are most likely driven by a number of factors, which could include health knowledge, access to care, and working environments, which may have contributed to this discrepancy. The higher risk of Diagnosed-DED among NHWS participants who were divorced, widowed, or separated compared with those who were either married, living with a partner, or single suggests the possibility that emotional well-being may be a significant factor in Diagnosed-DED, although most likely through indirect mechanisms.

Health insurance was another factor found to be a significant indicator of Diagnosed-DED in the present study, with insured participants most likely to have a DED diagnosis. This raises the possibility that among the total population of people with DED symptoms in the US (diagnosed and undiagnosed), only those with better access to health care are able to obtain help with diagnosis of this chronic disease. Given the public health significance of DED, based on its high prevalence and impact on quality of life, this finding warrants consideration, with an aim toward maximizing appropriate diagnosis and management of DED in all segments of the population.

One half of all Diagnosed-DED participants in NHWS reported at least mild DED. Given the prevalent nature of the DED cases, however, it is unknown whether this reflects the underlying disease severity, or perhaps may point to beneficial effects of DED therapies. In the WHS, 4.7% of the surveyed women reported a clinical diagnosis of DED, but more than 30% reported mild symptoms (eye dryness and irritation at least some of the time).⁷ The corresponding numbers in the PHS were 3.0% and 21.8%, respectively.⁴ With increased contemporary awareness of DED, people with mild symptoms may now be more likely to seek medical help and/or receive a diagnosis of DED. As expected, the majority of the Diagnosed-DED participants received their diagnosis from either an ophthalmologist or an optometrist.

Although our study was based on survey responses from a large nationwide population sample, it had some limitations. Broadly, demographic characteristics of NHWS respondents approximate those in the Current Population Survey of the US Census Bureau.^{18,19} However, ethnic minority groups are known to be underrepresented in the NHWS, as are those without a college degree.^{18,19} To the extent that these factors were associated with the prevalence of DED, this may have had an impact on our extrapolated numbers, though the magnitude of such an impact is likely to be modest. The main limitation of the

study relates to patient self-reporting of diagnosis of DED: the presence of DED was not confirmed outside of the NHWS for this study. However, prior research over the past 2 decades has demonstrated the value of patient-reported findings in this highly symptomatic disease.¹ Data derived from a web-based panel also introduce other limitations, such as possible sampling bias due to access or availability of internet access, as well as financial incentives given to responders.

The formulation of questions for the NHWS was done by the NHWS investigators at the time of the survey, and the authors of the present analysis were not involved in that aspect of the study. Although the NHWS did not use a previously validated DED questionnaire or a standardized questionnaire to assess symptoms (such as the one developed for the WHS and PHS),^{4,7} it did include questions that were relevant to estimating the prevalence of DED in the US. The NHWS questionnaire had other advantages (eg, an updated time frame so that more current estimates could be obtained, a very large sample size, and a more geographically and demographically representative sample than those upon which other estimates of DED prevalence have been based). While other published data inform on the prevalence of DED in the US, most estimates are now dated and have other limitations, such as most commonly excluding subjects

under the age of 50 and, in many cases, being performed in relatively small populations from a narrow geographic region (eg, the Beaver Dam Eye Study only includes subjects from a single small town in Wisconsin⁵ that is unlikely to be representative of the US as a whole). The estimates provided by the present analysis have additional value insofar as they are based on self-reports of having received a diagnosis of DED.

In conclusion, this large nationally representative study, based on data from 2013, estimates that more than 16 million US adults aged ≥ 18 years have Diagnosed-DED. Consistent with prior research, the prevalence of Diagnosed-DED in the US is higher among women and increases with age. However, adding substantially to the limited data on DED in the younger adult population, the present study demonstrates a notable 2.7% prevalence of Diagnosed-DED among younger adults aged 18–34 years. Combined with prior research on the prevalence of DED in the US, these data reinforce clinical impressions of an expansion of the DED patient population both overall and among younger adults, and the continued public health significance of this common condition. The study also points to areas for further research, including possible differences in the likelihood of a DED diagnosis based on factors such as geography, race/ethnicity, and insurance coverage.

FUNDING/SUPPORT: THIS ANALYSIS OF DATA FROM THE 2013 US NATIONAL HEALTH AND WELLNESS SURVEY WAS FUNDED BY Shire Development, LLC. Financial Disclosures: Kimberly F. Farrand was an employee of Shire PLC at the time of the study; Moshe Fridman has been, in the past year, a consultant for CSL Behring, Novo Nordisk, Shire PLC, and Vertex; Ipek Özer Stillman is an employee of Shire PLC; and Debra A. Schaumberg was an employee of Shire PLC at the time of the study and has been, in the past year, a consultant for Kala Pharmaceuticals, a scientific advisory board member at Mimetogen Pharmaceuticals, and a stockholder at Mimetogen Pharmaceuticals and Shire PLC. All authors attest that they meet the current ICMJE criteria for authorship.

The authors thank Ira Probohd, PhD, of Excel Scientific Solutions, Southport, Connecticut, who provided medical writing assistance funded by SARcode Bioscience, a fully owned company of Shire PLC.

REFERENCES

1. The epidemiology of dry eye disease: report of the Epidemiology Subcommittee of the International Dry Eye WorkShop (2007). *Ocul Surf* 2007;5(2):93–107.
2. American Academy of Ophthalmology Cornea/External Disease PPP Panel Hoskins Center for Quality Eye Care. Preferred Practice Pattern[®] guidelines. Dry eye syndrome. Available at, <http://www.aao.org/preferred-practice-pattern/dry-eye-syndrome-ppp-2013#CAREPROCESS>. Accessed February 23, 2016.
3. Lemp MA. Epidemiology and classification of dry eye. *Adv Exp Med Biol* 1998;438:791–803.
4. Schaumberg DA, Dana R, Buring JE, Sullivan DA. Prevalence of dry eye disease among US men: estimates from the Physicians' Health Studies. *Arch Ophthalmol* 2009;127(6):763–768.
5. Moss SE, Klein R, Klein BE. Long-term incidence of dry eye in an older population. *Optom Vis Sci* 2008;85(8):668–674.
6. Paulsen AJ, Cruickshanks KJ, Fischer ME, et al. Dry eye in the Beaver Dam Offspring Study: prevalence, risk factors, and health-related quality of life. *Am J Ophthalmol* 2014;157(4):799–806.
7. Schaumberg DA, Sullivan DA, Buring JE, Dana MR. Prevalence of dry eye syndrome among US women. *Am J Ophthalmol* 2003;136(2):318–326.
8. Marrett E, DiBonaventura MD, Zhang Q. Burden of peripheral arterial disease in Europe and the United States: a patient survey. *Health Qual Life Outcomes* 2013;11:175.
9. Census US. Annual estimates of the resident population by single year of age and sex for the United States: April 1, 2010 to July 1, 2013 (2013 population estimates). Available at, <http://www.census.gov/programs-surveys/popest/data/tables.html>. Accessed April 18, 2016.
10. Schein OD, Muñoz B, Tielsch JM, Bandeen-Roche K, West S. Prevalence of dry eye among the elderly. *Am J Ophthalmol* 1997;124(6):723–728.
11. Yazdani C, McLaughlin T, Smeeding JE, Walt J. Prevalence of treated dry eye disease in a managed care population. *Clin Ther* 2001;23(10):1672–1682.
12. Galor A, Feuer W, Lee DJ, et al. Depression, post-traumatic stress disorder, and dry eye syndrome: a study utilizing the

- national United States Veterans Affairs administrative database. *Am J Ophthalmol* 2012;154(2):340–346.e2.
13. Schaumberg DA, Uchino M, Christen WG, Semba RD, Buring JE, Li JZ. Patient reported differences in dry eye disease between men and women: impact, management, and patient satisfaction. *PLoS One* 2013;8(9):e76121.
 14. Lin PY, Tsai SY, Cheng CY, Liu JH, Chou P, Hsu WM. Prevalence of dry eye among an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Ophthalmology* 2003;110(6):1096–1101.
 15. Uchino M, Nishiwaki Y, Michikawa T, et al. Prevalence and risk factors of dry eye disease in Japan: Koumi study. *Ophthalmology* 2011;118(12):2361–2367.
 16. Craig JP, Wang MT, Kim D, Lee JM. Exploring the predisposition of the Asian eye to development of dry eye. *Ocul Surf* 2016;14(3):385–392.
 17. Hom M, De Land P. Prevalence and severity of symptomatic dry eyes in Hispanics. *Optom Vis Sci* 2005;82(3):206–208.
 18. Bolge SC, Doan JF, Kannan H, Baran RW. Association of insomnia with quality of life, work productivity, and activity impairment. *Qual Life Res* 2009;18(4):415–422.
 19. DiBonaventura MD, Wagner JS, Yuan Y, L'Italien G, Langley P, Ray Kim W. Humanistic and economic impacts of hepatitis C infection in the United States. *J Med Econ* 2010;13(4):709–718.