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CLINICAL STUDY

Prevalence of dry eye among adult Chinese in the Beijing Eye Study

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Abstract

Purpose To study the prevalence and associations of dry eye symptoms in adult Chinese.
Methods The Beijing Eye Study is a population-based study in northern China, which included 4439 of 5324 subjects invited to participate with an age of 40 + years (response rate: 83.4%). For the present study, a random sample was taken consisting of 1957(44.1%) subjects (1112 women; 56.9%). Dry eye symptoms were evaluated with (1) an interviewer-assisted questionnaire; (2) measurement of the tear-film break-up time; (3) assessment of the fluorescein staining of the cornea; (4) slit-lamp-based examination of a meibomian gland dysfunction; and (5) Schirmer's test.
Results Symptoms of a dry eye felt 'often' or 'at all times' were present in 411 subjects (21.0%). In a multivariate analysis, dry eye symptoms were significantly associated with age (*P* < 0.001), female gender (*P* < 0.001; odds ratio (OR): 1.56; 95% confidence intervals (CI): 1.23, 1.98), urban region (*P* < 0.001;OR: 1.89; 95% CI: 1.46, 2.48), low degree of nuclear cataract (*P* = 0.02), and undercorrection of refractive error (*P* = 0.005; OR: 1.42; 95% CI: 1.11, 1.82). All tests for dry eye did not vary significantly between the dry eye group and the normal group.
Conclusions The dry eye symptoms as evaluated subjectively in a questionnaire occurred in about 21% of the adult population in China, with associations to age, female gender, urban region, and undercorrection of a refractive error. Measurement of the tear-film break-up time, assessment of the corneal fluorescein staining, slit-lamp-based examination of a meibomian gland dysfunction, and Schirmer's test were not significantly associated with dry eye symptoms.

Introduction

Dry eye symptoms belong to the most frequently encountered ocular problems that patients complain about in the daily practice of ophthalmologists.[1–14] Although these symptoms rarely lead to severe problems threatening vision, they may be one of the most common symptoms decreasing the quality of vision. In view of their importance for daily life of patients and ophthalmologists, in practice it was the purpose of the present study to examine the prevalence of dry symptoms and their associations with ocular and general parameters in a population-based study in mainland China. An additional goal of the study was to evaluate which commonly used test of the ocular surface was most suitable to assess a dry eye symptom as reported by the subjects.

Methods

The Beijing Eye Study is a population-based study in northern China performed in 2001. It was carried out in four communities in the urban districts of Xicheng and Haidian, which were in the centre of Beijing, and in three communities in the village area of Yufa of the Daxing district, south of Beijing. The rural communities, the inhabitants of which mainly lived from farming, were located about 50 km from central Beijing and were easily accessible by car in about 1 h via an express autobahn. The mean family income was significantly higher in the urban region (1688 ± 4134 RMB) than in the rural region (393 ± 360 RMB). All people living

in the seven communities were officially registered by name, gender, and age at the local mayor's office. Using this register as the sampling frame, all subjects living in the seven communities and fulfilling the inclusion criterion of an age of 40+ years were eligible for the study. Because of the registration list at the mayor's office, the boundaries of the communities and the size of the population of each of the communities were known before the start of the study. Home visits were performed according to the registration list, and the eligibility criterion for the study, an age of 40+ years, was confirmed by door-to-door enrolment. The door-to-door visitation included all houses in the communities, and the registration list of the inhabitants served to have an overview of who is residing in each of the houses. The eligible subjects were visited up to three times if they did not participate after the first visit in the Beijing Eye Study. The study has been described in detail recently.[15,16] The Medical Ethics Committee of the Beijing Tongren Hospital had approved the study protocol and all participants had given informed consent, according to the Declaration of Helsinki.

At the time of the survey in 2001, there were 5324 individuals aged 40+ years residing in the seven communities. In total, 4439 individuals (2505 women) participated in the eye examination, corresponding to an overall response rate of 83.4%. The study was divided into the rural part (1918 (43.8%) subjects; 3814 eyes) and the urban part (2460 (56.2%) subjects; 4910 eyes). Mean age was 56.2 ± 10.6 years (range: 40–101 years). A detailed ophthalmic examination was carried out including measurement of uncorrected and best-corrected visual acuity, noncontact tonometry (CT-60 computerized tonometer, Topcon Ltd, Japan), frequency doubling perimetry using the screening program C-20-1 (Zeiss-Humphrey, Dublin, CA, USA), slit-lamp examination of the anterior segment, ophthalmoscopy, digital photography of the lens (Neitz CT-R camera; Neitz Instruments Co, Tokyo, Japan), and photography (45°) of the optic disc and macula (fundus camera, type CR6-45NM, Canon Inc. USA) after medical mydriasis. Past history of eye diseases, eye trauma, diabetes mellitus, hypertension, any ophthalmologic care that the participant received, professions, educational level of the participants, habit of smoking, and alcohol intake were recorded.

In addition, in a random sample of study participants, dry eye symptoms were evaluated with (1) an interviewer-assisted questionnaire (Table 1), (2) measurement of the tear-film break-up time, (3) assessment of fluorescein staining of the cornea, (4) examination of a meibomian gland dysfunction, and (5) Schirmer's test. For each study participant, both eyes were tested, and the data of the worse eyes were taken

Table 1 Dry eye questionnaire in the Beijing Eye Study

1. Do your eyes ever feel dry?
2. Do you ever feel a gritty or sandy sensation in your eye?
3. Do your dyes ever have a burning sensation?
4. Are your eyes ever red?
5. Do you notice much crusting on your lashes?
6. Do your eyes ever get stuck shut in the morning?

Possible answers to the questions were 'none', 'rarely or sometimes', and 'often or all the time'. Subjectively dry eye was defined as having one or more symptoms 'often or all the time'.

for statistical analysis. The tear-film break-up time test was performed before the other dry eye tests to avoid any interference between the tests. The tear-film break-up test was repeated three times for each eye, and the average time was recorded. Fluorescein staining of the cornea was observed through a slit lamp with a cobalt blue filter and was graded as '0' for 'no staining', as '1' for 'mild staining with a few disseminated stains, and limited to less than one-third of the cornea', as '2' for 'moderate staining with a severity between grades 1 and 3', or as '3' for 'severe staining with confluent stains, and occupying half or more of the cornea'. The condition of the meibomian glands was determined by examining the lid margin with a slit lamp. As there has not been any generally accepted grading system for meibomian gland dysfunction, we defined meibomian gland dysfunction as the presence of a plugging of the meibomian gland orifices or as telangiectasias at the lid margin. The presence of lid margin telangiectasia was recorded, and the meibomian gland orifices were graded using a scale of '0' for 'no obstruction', grade 1 for 'plugged with translucent serous secretion when the lid margin was compressed', grade 2 as 'plugged with viscous or waxy white secretion when the lid margin was compressed', and as grade 3 for 'plugged with no secretion when the lid margin was compressed'. The Schirmer's test was performed at the end of the examination, so that ocular irritation by the test strip would not interfere with the other examinations. One minute after instillation of a drop of 0.5% proparacaine, any visible fluid in the inferior fornix or lid margin was gently dried with a cotton swab. A precalibrated filter strip was then placed into the temporal inferior fornix and left in place for 5 min. The patient was allowed to either blink normally or to close the eyes. After 5 min, the strip was removed, and the amount of wetting (in millimetres) was recorded from the precalibrated strip.

For the diagnosis of an objectively diagnosed dry eye several definitions were used. Definition 1 was made if one of the following conditions was fulfilled: a tear-film break-up time ⩽10 s; a Schirmer test score ⩽5 mm; a fluorescein score ⩾1; telangiectasia at the lid margin; or if plugging of the gland orifices was present. Definition 2

was made if all parameters mentioned above were positive, that is, a tear-film break-up time ≤10 s, a Schirmer test score ≤5 mm, a fluorescein score ≥1 telangiectasia at the lid margin, and plugging of the gland orifices. Definition 3 was made if the tear-film break-up time ≤4 s or a Schirmer test score ≤4 mm, or a fluorescein score ≥2. Telangiectasia at the lid margin and plugging of the gland orifices were not considered for this definition. Definition 4 was made if the tear-film break-up time ≤4 s and a Schirmer test score ≤4 mm and a fluorescein score ≥2. Definition 5 was made if the tear-film break-up time ≤4 s or a Schirmer test score ≤4 mm, without taking the fluorescein score into account, and the appearance of the lid margin and the meibomian glands. Definition 6 was made if the tear-film break-up time ≤4 s and a Schirmer test score ≤4 mm, again without taking the fluorescein score into account, and the appearance of the lid margin and the meibomian glands.

Statistical analysis was performed using a commercially available statistical software package (SPSS for Windows, version 15.0, SPSS, Chicago, IL, USA). χ^2 tests were used to compare the proportions. Logistic regression was used to investigate the associations of the binary dependent variable 'presence of dry eye' with the continuous or categorical independent variables, such as age and gender. Confidence intervals were presented. The statistical analysis was performed on the basis of subjects and not of eyes. All *P*-values were two-sided and were considered statistically significant when the values were less than 0.05.

Results

Of the 4439 subjects participating in the Beijing Eye Study 2001, a random sample of 1957 (44. 1%) subjects (1112 (56.8%) women) was drawn to assess dry eye symptoms and their associations. The mean age was 56.5 ± 9.3 years (median: 57 years; range: 40–84 years), and the mean refractive error was −0.34 ± 2.29 D. The study group did not vary significantly from the total study population of the Beijing Eye Survey in age (56.5 ± 9.3 years *vs* 56.0 ± 10.7 years; *P* = 0.14), gender (*P* = 0.64), refractive error (*P* = 0.59), rural *vs* urban region (*P* = 0.06), family income (*P* = 0.97), intraocular pressure (*P* = 0.25), prevalence of glaucoma (*P* = 0.10), and prevalence of age-related maculopathy (*P* = 0.39).

Table 2 Ocular and general parameters in subjects with subjective dry eye symptoms in the Beijing Eye Study 2001

	Asymptomatic group	Dry eye group	P-value	95% CI
	1546	411		
Age (Years)	55.6 ± 9.3	58.4 ± 9.1	<0.001	−3.46, −1.46
Male/Female	700/846	145/266	<0.001	OR: 1.52 (1.21, 1.90)
Rural/Urban region	718/828	121/290	<0.001	OR: 2.08 (1.64, 2.63)
Refractive error (D)	−0.32 ± 2.20	−0.45 ± 2.59	0.37 (n.s.)	−0.15, 0.41
Corneal astigmatism (D)	0.57 ± 0.88	0.72 ± 0.89	0.003	−0.25, −0.05
Best-corrected visual acuity	0.93 ± 0.18	0.91 ± 0.20	0.03	0.002, 0.045
Snellen lines' improvement by best correcting glasses *vs* habitual glasses	1.20 ± 2.22	1.58 ± 2.29	0.003	−0.63, −0.13
Undercorrection of refractive error	26.4 ± 1.1%	36.6 ± 2.4%	<0.001	OR: 1.61 (1.28, 2.03)
Nuclear cataract	2.48 ± 1.00	2.62 ± 0.94	0.007	−0.25, −0.04
Cortical cataract	1.4 ± 7.2	1.8 ± 7.7	0.40 ((NS)	−0.01, 0.01
Subcapsular. cataract	0.3 ± 4.0	0.3 ± 2.6	0.82 (NS)	−0.002, 0.004
Intraoccular pressure	16.0 ± 3.3	16.0 ± 3.0	0.80 (NS)	−0.38, 0.29
Prevalence glaucoma	37 (2.4%)	13 (3.2%)	0.38 (NS)	OR: 1.33 (0.70, 2.53)
Prevalence of age-related maculopathy	24 (1, 5%)	2 (0.5%)	0.14 (NS)	OR: 0.31 (0.07, 1.32)
Diabetes mellitus	12.4 ± 0.9%	17.9 ± 2.0%	0.007	OR: 1.54 (1.14, 2.10)
Arterial hypertension	57.8 ± 1.3%	53.2 ± 2.5%	0.11 (NS)	OR: 0.83 (0.67, 1.04)
Present smokers	22.9 ± 1.1%	15.8 ± 1.9%	0.003	OR: 0.63 (0.47, 0.85)
Former smokers	28.3 ± 1.2%	21.1 ± 2.1%	0.005	OR: 0.68 (0.52, 0.89)
Alcohol drinker	3.7 ± 0.5%	3.1 ± 0.9%	0.65 (NS)	OR: 0.65 (0.43, 1.55)
Level of education	3.94 ± 1.06	4.03 ± 1.14	0.16 (NS)	−0.21, 0.04
Family income	1078 ± 840	1247 ± 866	0.001	−262.5, −72.9
Corneal fluorescein test (0–3)	0.68 ± 0.54	0.68 ± 0.54	0.91 (NS)	−0.06, 0.06
Plugging of orifices of meibomian glands	1.19 ± 0.76	1.21 ± 0.78	0.51 (NS)	−0.11, 0.06
Telangiectasia at lid margin	1051 (68.0%)	285 (69.3%)	0.60 (NS)	−0.06, 0.04
Schirmer's test (mm)	12.0 ± 7.2	11.4 ± 7.0	0.12 (NS)	−0.05, 0.04
Schirmer's test positive	21.0 ± 1.0%	20.4 ± 2.0%	0.84 (NS)	OR: 0.97 (0.74, 1.27)

Measurements are given as mean ± SD, frequencies are presented as mean ± SE. *P*-value: statistical significance of differences between both groups (univariate analysis). 95% CI: 95% confidence intervals of the differences. Undercorrection was defined as an improvement in visual acuity by wearing best correcting glasses compared with daily worn glasses by at least two Snellen lines; OR: odds ratio; NS: statistically not significant.

Table 3 Multivariate analysis of the association between dry eye symptom as dependent variable and ocular and general parameters as independent variables in the Beijing Eye Study

	P-value	Steepness of regression line or odds ratio	95% Confidence intervals
Age	<0.001	1.03	1.02, 1.05
Female gender	<0.001	1.56	1.23, 1.98
Urban region	<0.001	1.89	1.46, 2.45
Undercorrection of refractive error	0.005	1.42	1.11, 1.82
Nuclear cataract	0.02	0.81	0.69, 0.97

P-Value: statistical significance of the association.

Of the study population, 1546 (79.0%) subjects were asymptomatic defined as no symptoms of a dry eye at all or symptoms of dry eye felt only rarely or sometimes. Subjective symptoms of a dry eye felt often or at all times were present in 411 subjects (21.0%). In a univariate analysis, the symptomatic subjects compared with the asymptomatic subjects came significantly more often from the urban region, and more often were female than male subjects. Additionally, dry eye symptoms were associated with corneal astigmatism, low best-corrected visual acuity, undercorrection of refractive errors, degree of nuclear cataract, presence of diabetes mellitus, present or former smoker, and family income (Table 2). It was not associated with refractive error calculated as the mean spherical equivalent, degree of cortical cataract and subcapsular cataract, intraocular pressure, drinking of alcohol, the presence of glaucoma, age-related maculopathy, and arterial hypertension.

Performing a multivariate analysis, with subjectively dry eye as dependent variable, and age, gender, rural vs urban region, corneal astigmatism, best-corrected visual acuity, undercorrection, degree of nuclear cataract, presence of diabetes mellitus, present or former smoker, and family income as independent parameters showed that a dry eye was still significantly associated with age, female gender, urban region, low degree of nuclear cataract, and undercorrection of refractive error (Table 3).

The results of all performed tests, that is, the measurement of the tear-film break-up time, the assessment of the fluorescein staining of the cornea, the slit-lamp-based examination of a meibomian gland dysfunction, and Schirmer's test did not vary significantly between the subjectively dry eye group and the normal group (Table 2).

The prevalence of a subjectively diagnosed dry eye based on the symptoms as described the subjects was not significantly associated with the objective diagnosis of a dry eye based on the tests of ocular surface stability, tear production, and lid margin appearance; and using

definitions 1, 2, 3, 4, 5, and 6 the prevalence of dry eye was $98.5 \pm 0.3\%$ (mean $\pm$ standard error), $6.1 \pm 0.5\%$, $97.6 \pm 3.3\%$, $1.5 \pm 0.3\%$, $36.9 \pm 1.1\%$, and $4.1 \pm 0.4\%$, respectively. The subjective diagnosis of dry eye by the study participants was not significantly associated with the objective diagnosis of dry eye using definition 1 ($P = 0.66$), using definition 2 ($P = 0.26$), using definition 3 ($P = 0.48$), using definition 4 ($P = 0.83$), using definition 5 ($P = 0.29$), and using definition 6 ($P = 0.28$).

Discussion

Dry eye represents a multifactorial, heterogeneous disorder of the preocular tear film, which can result in multiple ocular surface disease. The tear film and ocular surface form a complex and stable system that can lose its equilibrium through numerous disturbing factors.[17] Reduction in quality of life is inevitable when symptoms of dry eye occur. These symptoms range from mild transient irritation to persistent dryness, burning, itchiness, redness, pain, ocular fatigue, and visual disturbance. In the United States alone, approximately 7–10 million Americans require artificial tear preparations, with consumers spending over $100 million per year.[18] Reported prevalence of dry eye is diverse, with questionnaire-based surveys documenting rates ranging from 14.4 to 33% of the population sampled.[1–14,19–21] Studies that also involve tests of tear function including Schirmer's test, tear break-up time, fluorescein staining, or rose Bengal staining for determination of dry eye have found generally lower prevalence rates.[3,21] Limitations in comparisons of studies in different populations include different age distribution of the population, definitions of dry eye, or methodology. Most studies of dry eye have been confined to developed nations and older populations, with resultant lack of ethnic diversity. Therefore, we aimed to report the prevalence of dry eye symptoms in mainland China and to identify the possible associated risk factors.

Dry eye symptoms were rather common in the present population-based sample of Chinese with an age of 40 + years and living in Greater Beijing. Of 1957 participants, 411 (21%) reported having a dry eye symptom. In a multivariate analysis, the dry eye symptoms were significantly associated with age, female gender, urban region, and undercorrection of refractive error (Table 3). The prevalence figures of dry eye symptoms as found in the present study are mostly in agreement with findings from other investigations on other ethnic groups. These figures range from 14 to 34%.[1–14,19–21]

The published data regarding the relation between dry eye and gender are partially inconsistent.[22,23] The study performed in Australia by McCarty et al[3] indicated that

women were more likely to report symptoms of dry eye (odds ratio: 1.85). The study performed in North America by Moss et al[6] indicated that the age-adjusted prevalence in men was 11.4%, which was significantly lower than the 16.7% prevalence in women ($P < 0.001$). The studies by both Bjerrum et al[24] and Schein et al[2] indicated no gender difference in the prevalence of dry eye. In clinical experience, menopausal and postmenopausal women both tend to have dry eye complaints. Lamberts et al[25] demonstrated that the tear production decreased significantly in women aged 50–59 years. McCarty et al[3] reported that women were significantly more likely to be diagnosed with dry eye by rose Bengal assessment in the 50- to 59-year and 60- to 69-year age groups, but not in the 40- to 49-year age group.

However, a poor correlation between dry eye symptoms and dry eye tests has been demonstrated in population-based studies by Schein and co-workers[1] in the United States and McCarty et al[3] in Australia. The heterogeneity of dry eye and the reporting bias of the participants are potential explanations suggested by the authors.[1–7] Each dry eye test that is frequently performed in clinical practice seeks only to measure a specific disorder of dry eye. Consequently, a patient with normal Schirmer test results, which reflects normal aqueous tear secretion, may report dry eye symptoms resulting from meibomian gland disease. If the dry eye symptoms could also be categorized into subtypes (that is, symptoms of aqueous tear deficiency, symptoms of meibomian gland diseases, and symptoms of mucin anomalies), then more logical analyses of the correlations between symptoms and signs could be made.

Another explanation of the poor association between dry eye symptoms and signs is that the frequently used dry eye tests do not reliably reflect the tear-film conditions in the nonclinic-based general population and consequently have limited value as screening tests.

To clarify the correlation between dry eye symptoms and signs, analyses were performed on data gathered from the Shihpai Eye Study, a population-based survey of subjects ⩾65 years of age in Shihpai, Taipei, Taiwan.

Interestingly, the tests assessing the tear production and the condition of the corneal surface and meibomian glands in the lids were not significantly associated with the subjective assessment of a dry eye by the subjects themselves. It agrees with the results of previous studies. To cite an example, Schein et al[2] observed no association between the presence of more frequent symptoms and a lower Schirmer result, regardless of whether the analysis was based on mean scores with a cut-off value of 5 or a cut-off value of 7. One of the major reasons for the low sensitivity and specificity of Schirmer's test to detect a dry eye syndrome may be the heterogeneity of the dry eye syndrome itself.

An interesting finding in the present investigation was dry eye syndrome was more commonly reported in the urban region than in the rural region. Future studies may address whether it may be because of air pollution in the city of Beijing compared with its surroundings. In addition, undercorrection of an existing refractive error was another significant factor associated with dry eye symptoms, a finding that has not been usually found in the preceding studies. It may imply for daily practice that, for patients with dry symptoms, an undercorrected refractive error should be ruled out.

In conclusion, the dry eye symptoms as evaluated subjectively in a questionnaire occurred in about 21% of the adult population in the Greater Beijing area, with associations to age, female gender, urban region, and undercorrection of a refractive error. Measurement of the tear-film break-up time, assessment of the corneal fluorescein staining, slit-lamp based examination of a meibomian gland dysfunction, and Schirmer's test were not significantly associated with dry eye symptoms.

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