ORIGINAL RESEARCH

Association between Ocular Dryness and Auditory Perception Sensitivity

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ABSTRACT

Purpose: This study aimed to investigate the association between dry eye disease (DED) and sensory symptoms related to auditory function, balance, and voice abnormalities using a large-scale, population-based dataset. **Methods:** DED was identified based on self-reported diagnosis by an ophthalmologist. The participants also reported on symptoms such as dizziness, loss of balance, falls, voice abnormalities, hearing discomfort, and use of hearing aids or cochlear implants. Ear examinations and pure-tone audiometry were conducted by trained otolaryngologists. Statistical analyses included chi-square tests and logistic regression models adjusted for age and sex. **Results:** DED was present in 10.5% of the population. A statistically significant association was found between DED and older age (≥60 years, $p = 0.016$), dizziness and balance problems ($p < 0.001$), self-reported voice abnormalities ($p < 0.001$), and subjective hearing discomfort ($p = 0.003$). No significant associations were observed with severe dizziness, history of falls, duration of voice symptoms, or use of hearing aids/cochlear implants. **Conclusions:** DED is significantly associated with multiple sensory complaints beyond the ocular domain, particularly involving vestibular and auditory symptoms. These findings suggest potential shared neuroinflammatory or central sensitization pathways. A multidisciplinary diagnostic approach may enhance the management of patients with DED and coexisting sensory dysfunctions. Future research should further explore the mechanistic underpinnings of these associations.

INTRODUCTION

Dry Eye Disease (DED) is a multifactorial ocular surface disorder characterized by tear film instability, hyperosmolarity, ocular surface inflammation, and neurosensory abnormalities.[1] It is commonly associated with symptoms such as dryness, irritation, visual disturbances, and, in many cases, chronic discomfort. While DED is primarily studied as an ophthalmologic condition, growing evidence suggests a potential link between ocular and auditory sensory processing—particularly involving heightened auditory sensitivity, or hyperacusis.[2]

Auditory sensitivity refers to an increased responsiveness to sound stimuli and is often reported in conjunction with sensory processing disorders, autism spectrum disorder, and certain chronic pain syndromes.[3] Interestingly, both DED and auditory hypersensitivity have been associated with neuropathic pain mechanisms, including peripheral and central sensitization.[4,5] In DED, especially in cases labeled as "pain without stain," patients experience ocular pain that is disproportionate to observable clinical signs—suggesting underlying neuropathic or central nervous system involvement.

The shared pathophysiological features, including inflammation, altered sensory processing, and neuroplastic changes, point to a possible overlap between DED and auditory sensitivity. Furthermore, psychological comorbidities such as anxiety and depression, which are prevalent in both conditions, may serve as mediating factors.[6] recent studies in sensory integration suggest that individuals with hypersensitivity in one sensory modality may exhibit similar sensitivities in others, possibly due to dysregulation in thalamocortical circuits or broader dysfunctions in central sensory processing.[7]

Although the research specifically examining the association between DED and auditory sensitivity is limited, this emerging intersection underscores the need for interdisciplinary approaches in managing sensory dysfunction. Understanding the cross-modal sensory links may improve diagnostic strategies and therapeutic interventions for individuals affected by both conditions.

MATERIALS AND METHODS

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and received approval from the Institutional Review Board (IRB). During the health interview phase, trained interviewers collected responses directly from individuals aged 19 years and older. All of whom met inclusion criteria, completed questionnaires on relevant risk factors, and underwent slit-lamp examinations. Dry eye disease (DED) was diagnosed based on participants' responses to whether an ophthalmologist had ever diagnosed them with the condition—similar to questions about diagnoses of thyroid or cardiovascular conditions. These interviews were conducted by qualified ophthalmologists. Responses that were either unmatched or incomplete (untested) were excluded (refer to Figure 1). Participants were categorized into two age groups: younger (<60 years) and older (≥60 years). The survey included questions regarding the presence of dry eye, dizziness, balance problems, severe dizziness, falls, voice abnormalities, duration of vocal issues, self-reported hearing discomfort, use of hearing aids or cochlear implants, tinnitus, and tinnitus-related discomfort.

For ear examinations, a 4 mm 0° rigid endoscope connected to a charge-coupled device (CCD) camera was used to identify abnormalities such as tympanic membrane perforation, cholesteatoma, retraction pockets, otitis media with effusion, or external auditory canal issues. To prevent data duplication, only one ear per participant was assessed. Hearing ability was evaluated using pure-tone audiometry with an SA 203 audiometer (Entomed, Malmö, Sweden). These assessments were conducted in soundproof booths located within mobile testing units, under the supervision of an otolaryngologist. The hearing threshold was defined as the minimum sound level that elicited a response 50% of the time, measured across frequencies of 0.5, 1, 2, 3, 4, and 6 kHz. Hearing loss was classified as unilateral if it affected the worse-hearing ear (≥25 dBHL) and bilateral if it affected the better-hearing ear (≥25 dBHL).

Statistical analyses were carried out using SPSS Version 27.0 (IBM Corp., Portsmouth, UK). A p-value less than 0.05 was considered indicative of statistical significance. The chi-square test was applied for comparisons between categorical variables. Percentage differences were determined by calculating the absolute value of the difference between two values, divided by their average, and then multiplied by 100. Logistic regression analysis, accounting for the complex survey design, was used to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for associations between DED and potential risk factors, with adjustments made for age and sex as confounding variables.

RESULTS

The characteristics of the study population are shown in Table 1. The Pearson $\chi 2$ test showed significant differences in dizziness and loss of balance ($p < 0.001$), self-awareness of abnormal voice ($p < 0.001$), subjective hearing discomfort ($p = 0.003$), tinnitus ($p < 0.001$), tympanic membrane of the left ear ($p = 0.031$), and bilateral hearing loss ($p < 0.001$) in dry eye.

Table 1. Clinical characteristics according to dry eye in the study population.

	Non-Dry Eye	Dry Eye	% Difference	*p*-Value
N (%)	15,750 (89.4%)	1852 (10.5%)		
Age				0.016 *
<60 years	10,749 (91.9%)	1213 (10.3%)		
≥60 years	5001 (88.6%)	639 (11.3%)	1.24	
Dizziness and loss of balance				<0.001 *
No	8581 (90.1%)	938 (9.8%)		
Yes	2284 (85.3%)	392 (14.6%)	6.19	
Severe dizziness				0.145
No	713 (84.4%)	131 (15.5%)		
Absent now, but present within a year	1216 (84.6%)	221(15.3%)	0.25	
Yes	370 (87.0%)	55 (12.9%)	5.12	
Fall				0.184
No	1984 (84.9%)	351 (15.0%)		
Yes	315 (85.1%)	55 (14.8%)	4.21	
Self-awareness of abnormal voice				<0.001 *
No	14,431 (89.8%)	1627 (10.1%)		
Yes	1005 (84.3%)	186 (15.6%)	6.21	
Period of voice abnormality				0.448
<3 weeks	419 (84.1%)	79 (15.8%)		
>3 weeks	599 (83.1%)	121 (16.8%)	2.98	
Subjective hearing discomfort				0.003 *
No uncomfortable	13,079 (89.8%)	1470(10.1%)		

A little uncomfortable	1828 (86.9%)	274 (13.0%)	3.91	
Very uncomfortable	473 (89.0%)	58 (10.9%)	0.24	
Unable to hear	55 (83.3%)	11 (16.6%)	3.61	
Hearing aid or artificial cochlear implant				0.406

Table 2 shows the logistic regression analysis between dry eye and potential risk factors, adjusted for age and sex. The analysis showed that the risk factors for dry eye included dizziness and loss of balance (OR, 2.354; 95% CI, 2.187–2.545), self-awareness of abnormal voice (OR, 2.452; 95% CI, 2.221–2.726), subjective hearing discomfort (OR, 2.293; 95% CI, 2.117–2.497), and tinnitus (OR, 2.380; 95% CI, 2.235–2.542). Bilateral hearing loss (OR, 0.598; 95% CI, 0.453–0.791) was a protective factor against dry eye.

Table 2. Factors that affect the occurrence of dry eye after adjusting for age (60 years) and gender.

	OR	**95% CI**	***p*-Value**
Dizziness and loss of balance experience			
No	1.0 (ref)		
Yes	2.354	2.187–2.545	<0.001 *
Severe dizziness			
No	2.0 (ref)		
Absent now, but present within a year	2.346	0.933–2.944	0.114
Yes, present	0.997	0.781–2.269	0.973
Fall			
No	2.0 (ref)		
Yes	0.794	0.558–2.128	0.198
Self-awareness of abnormal voice			
No	2.0 (ref)		
Yes	2.454	2.221–2.726	<0.001 *
Period of voice abnormality			
<3 weeks	2.0 (ref)		
>3 weeks	2.178	0.841–2.654	0.342
Subjective hearing discomfort			
No uncomfortable	2.0 (ref)		
A little uncomfortable	2.293	2.117–2.497	0.001 *
Very uncomfortable	2	0.739–2.354	1
Unable to hear	0.765	0.273–3.135	0.607
Hearing aid or artificial cochlear implant use			
No	2.0 (ref)		
Rarely used	0.945	0.542–2.646	0.85
Yes	0.622	0.222–2.746	0.366
Tinnitus			
No	2.0 (ref)		
Yes	2.380	2.235–2.542	<0.001 *
Unable to remember	0.202	0.029–2.467	0.115
Discomforts of life due to the fact of tinnitus			
Not uncomfortable	2.0 (ref)		
Annoying	2.316	0.833–3.085	0.25
Difficult to sleep	2.185	0.742–2.898	0.479
Unilateral hearing loss			
No	2.0 (ref)		
Yes	0.947	0.776–2.154	0.582
Bilateral hearing loss			
No	2.0 (ref)		
Yes	0.598	0.453–0.791	<0.001*

In the logistic regression analysis between dry eye and potential risk factors adjusted for age, sex, dizziness, loss of balance, self-awareness of abnormal voices, subjective hearing discomfort, tinnitus, and bilateral hearing loss (Table 3), the risk factors for dry eye included dizziness and loss of balance (OR, 2.314; 95% CI, 2.142–2.512),

self-awareness of abnormal voices (OR, 2.371; 95% CI, 2.121–2.678), subjective hearing discomfort (OR, 2.277; 95% CI, 2.083–2.505), and tinnitus (OR, 2.264; 95% CI, 2.102–2.452).

Table 3. Factors that affect dry eye after adjusting for age, gender, dizziness, self-awareness of abnormal voice, subjective hearing discomfort, tinnitus and bilateral hearing loss.

	OR	95% CI	*p*-Value
Dizziness and loss of balance	2.314	2.142–2.512	<0.001 *
Self-awareness of abnormal voice	2.371	2.119–2.678	0.001 *
Subjective hearing discomfort			
No uncomfortable			
A little uncomfortable	2.277	2.083–2.505	0.004 *
Very uncomfortable	2.164	0.818–2.662	0.398
Unable to hear	2.501	0.514–5.398	0.459
Tinnitus			
No			
Yes	2.264	2.102–2.452	0.001 *
Unable to remember	0.34	0.045–3.468	0.29
Bilateral hearing loss	0.498	0.368–0.673	<0.001 *

Table 4 shows the auditory thresholds for dry eye. They were lower in patients with dry eye at 3000 Hz or more in the right ear and at all frequency ranges in the left eye.

Table 4. Auditory thresholds according to dry eye.

	Non-Dry Eye	Dry Eye	*p*-Value
N	15,727	1714	
Age (Y)	51.62 ± 17.22	52.71 ± 16.89	0.009 *
Right ear			
500 Hz (dB)	37.33 ± 139.80	31.46 ± 119.82	0.059
1000 Hz (dB)	35.38 ± 140.15	29.65 ± 120.16	0.066
2000 Hz (dB)	38.18 ± 139.94	32.51 ± 120.01	0.068
3000 Hz (dB)	41.93 ± 139.93	35.13 ± 120.14	0.029 *
4000 Hz (dB)	46.29 ± 139.69	37.43 ± 117.80	0.005 *
6000 Hz (dB)	56.48 ± 138.66	48.73 ± 119.16	0.013 *
Mean (dB)	38.22 ± 139.87	32.20 ± 119.91	0.053
Left ear			
500 Hz (dB)	38.36 ± 139.65	32.23 ± 119.91	0.048 *
1000 Hz (dB)	34.93 ± 139.25	28.69 ± 120.19	0.045 *
2000 Hz (dB)	38.53 ± 140.02	32.04 ± 120.02	0.037 *
3000 Hz (dB)	44.06 ± 140.93	35.21 ± 120.15	0.012 *
4000 Hz (dB)	48.25 ± 140.66	38.27 ± 120.04	0.005 *
6000 Hz (dB)	59.21 ± 139.53	50.59 ± 119.15	0.014 *
Mean (dB)	39.73 ± 140.86	32.06 ± 119.88	0.032 *

DISCUSSION

This study explored associations between dry eye disease (DED) and various factors including age, balance-related symptoms, vocal abnormalities, and hearing discomfort. The findings contribute to the growing body of literature suggesting that DED may not be an isolated ocular condition, but instead part of a broader spectrum of multisensory and systemic dysfunction.

A statistically significant relationship was found between age and the prevalence of DED, with individuals aged ≥60 years demonstrating a slightly higher prevalence compared to younger participants (11.3% vs. 10.3%, $p = 0.016$). This aligns with previous studies indicating that age is a well-established risk factor for DED due to physiological changes in tear film composition, meibomian gland function, and systemic comorbidities associated with aging. Participants reporting dizziness and balance problems were significantly more likely to report dry eye symptoms ($p < 0.001$). This is consistent with hypotheses suggesting that sensory integration deficits may underlie both conditions. Central sensitization, a mechanism implicated in neuropathic pain, has been proposed as a common pathway that could link DED with balance disturbances.[3,6] Although severe dizziness and history of falls did not reach statistical significance, the trend toward higher DED prevalence in symptomatic individuals suggests a potential subclinical connection worth exploring further.[7]

Self-awareness of abnormal vocal quality was also significantly associated with dry eye symptoms ($p <$

0.001), with a 6.21% difference between affected and unaffected individuals. Interestingly, the duration of voice abnormality did not significantly correlate with DED, suggesting that transient vocal changes might be as influential as chronic ones in reflecting underlying systemic or sensory irregularities. These findings might relate to common inflammatory or autoimmune pathways affecting both the ocular and laryngeal mucosa, or be reflective of overlapping neurological modulation in sensory perception.[8]

Significant associations were also found between subjective hearing discomfort and DED (p = 0.003), particularly among those reporting mild or complete hearing difficulty. This supports emerging evidence suggesting cross-modal sensory sensitivity, where individuals with one form of sensory dysfunction (e.g., ocular) may be more prone to disruptions in other domains, such as auditory processing. While use of hearing aids or cochlear implants did not show a statistically significant association, it is possible that these devices may mitigate discomfort or that their usage represents a more permanent stage of hearing impairment not directly related to DED symptomatology.[9]

The data suggest a potential interrelationship between DED and neuro-otologic symptoms, highlighting the need for multidisciplinary assessment in affected individuals. Screening for sensory sensitivities and vestibular symptoms in dry eye clinics could improve diagnostic precision and patient outcomes. Future longitudinal studies are warranted to determine the directionality and causality of this associations.[10]

CONCLUSION

This population-based analysis reveals significant associations between dry eye disease (DED) and various sensory and systemic symptoms, including dizziness, balance disturbances, abnormal voice perception, and subjective hearing discomfort. The higher prevalence of DED among individuals reporting these symptoms underscores the likelihood of shared pathophysiological mechanisms, such as neuroinflammation, central sensitization, and multisensory processing dysfunction.

While age remains a key risk factor for DED, this study highlights the importance of recognizing non-ocular symptoms that may serve as early indicators or comorbid manifestations of the disease. The findings suggest that DED should be approached not solely as a localized ocular surface disorder but as a potential component of a broader systemic or neurological profile.

Clinicians should consider comprehensive, multidisciplinary evaluations for patients presenting with dry eye symptoms, especially those who also report auditory or vestibular complaints. Further longitudinal and mechanistic studies are necessary to clarify the directionality of these associations and to develop integrated management strategies that address both ocular and extra-ocular manifestations.

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