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Is a Dry Eye Disorder in Firefighters an Occupational Disease?

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Abstract

Background: *To examine firefighters (FFs) exposed to high levels of fire smoke and, as a result, to uncover risk factors for a dry eye disorder (DED) compared to age-and gender-matched healthy individuals.* **Methods:** *In this cross-sectional study, 51 FFs from the Afyonkarahisar Municipality Fire Department were chosen randomly (Group 1). A control group (Group 2) included 51 healthy relatives of patients who had routine ocular examinations. The Ocular Surface Disease Index (OSDI) questionnaire was administered after all participants thoroughly explained the study's objectives and procedures. Then, an ocular exam was performed on-site using a portable hand biomicroscope. DED was defined as a non-anesthetic Schirmer test result of <10 mm and a tear film break-up time (TBUT) of <5 seconds.* **Results:** *Groups 1 and 2 had mean ages of 44.82±7.29 and 44.73±7.41 years, respectively (p=0.946). The median work duration in Group 1 was 14 years (min-max: 1-27 years). The TBUT test revealed a significantly increased DED prevalence in Group 1 than in Group 2 (p=0.046). Despite the non-significant difference (p=0.276), the Schirmer test revealed that Group 1 had a higher DED prevalence than Group 2. The OSDI score showed that Group 1 had more mild, moderate, and severe DED than Group 2 (p=0.359). In addition, longer work duration was associated with a higher DED prevalence (p=0.179).* **Conclusions:** *Given the high prevalence of fire smoke-induced DED in FFs, preventive measures such as regular ocular exams, recommending personal protective equipment usage, and health education programs can assist in avoiding complications and reducing the burden of ocular diseases.*

1. Introduction

Occupational hazards have been regarded as potential reasons for ocular morbidity in various professions [1]. Fire, smoke, dust, flying particles, and other factors can contribute to occupational-related ocular disorders [2]. Repeated exposure to these toxic agents predisposes the eyes to a spectrum of ocular surface pathologies, including dry eye disorder (DED) [3]. This disorder is an ocular surface inflammatory condition characterized by increased osmolarity in the tear film, resulting in discomfort, burning, and stinging [4]. DED is often caused by reduced tear production (aqueous-deficient) and increased tear film evaporation (hyper-evaporative). While aqueous-deficient DED is caused by lacrimal gland pathology, hyper-evaporative DED is caused by a decrease in the blink reflex caused by prolonged screen exposure or being in air-conditioned environments, resulting

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in dry eye symptoms [5]. The prevalence of DED ranges from 3.9 to 33.7%, and advanced age and prolonged computer use have been linked to an increased DED frequency. Conditions, including prior refractive surgery, contact lens (CL) wear, diabetes, hypertension, thyroid disease, and poor sleep quality, may also aggravate DED [6]. Aside from decreased employees' work performance and productivity [7], DED has long been recognized for its effects on visual function, interference with daily activities such as computer use, reading books and newspapers [8], as well as its association with poor quality of life [9].

As far as fire is concerned, this is an essential component of our daily lives [10]. Accordingly, the possibility of fire incidents continues to be challenging, and efficient fire suppression by firefighters (FFs) is essential in reducing human and economic damage [11]. The terms "firefighting" and "firefighters (FFs)" are broad in scope, encompassing a wide range of fire scenarios such as municipal, wild-land, industrial, military, aviation, and oil wells. Generally, FFs respond to a wide range of incidents, including structure, wild-land, vehicle fires, vehicle accidents, medical emergencies, hazardous material releases, and building collapses [12]. In essence, municipal, structural firefighting is divided into two stages: (i) knockdown (when firefighters control and extinguish the fire) and (ii) overhaul (when any remaining small fires are extinguished). Almost 90% of municipal structural fires are killed or abandoned and fought from the outside in up to 10 minutes, resulting in a 10-min average duration of heavy physical activity at fires [13]. Larger fires, on the other hand, can take much longer to extinguish. Although the atmosphere during overhaul is not as hot or smoky as it is during knockdown, it still contains combustion products from small fires or smoldering material. For this reason, exposure levels can differ significantly between the two stages of firefighting [14]. Occupational exposure as an FF is complex, encompassing many hazards caused by fires and non-fire incidents. Frankly, FFs work in one of the most dangerous occupations, involving daily firefighting activities that are both physically and psychologically demanding to ensure the public's safety and well-being [15]. They are repeatedly exposed at work to a wide range of pollutants emitted during fire incidents, including particulate matter, carbon monoxide, nitrogen dioxide, volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers, and so on [16]. They are also exposed to temperatures ranging from 1200 °C to 1400 °C while fighting fires due to thermal sources such as smoke blankets, hot surfaces, and hot fumes. This could hurt their overall health as well as their ocular health.

Furthermore, occupational exposure as an FF has been labeled "carcinogenic to humans" due to "sufficient" evidence of humans developing cancer, such as mesothelioma and bladder cancer, among other things. According to "strong" mechanistic evidence, this exposure may also result in key carcinogen characteristics in humans, including being genotoxic, causing epigenetic changes, oxidative stress, chronic inflammation, and modulating receptor-mediated effects [12]. FFs are also almost always in perilous situations when fighting fires; thus, inadequate safety standards and personal protective equipment (PPE) may result in ocular surface pathologies, particularly DED, and, ultimately, general ill health [17].

Specifically, most studies have investigated DED prevalence concerning direct or passive cigarette smoking [18, 19]. However, there have been few studies on FFs regarding fire smoke-related ocular surface pathologies, particularly DED, which is a significant component of the global ocular health burden. Aside from developing cardiovascular [20] and mental disorders [21], as well as an increased risk of cancer development [12], FFs are at a high risk of developing ocular pathologies, whether acute or chronic, particularly DED, due to their physical and chemical environments.

Fire smoke exposure has the potential to be a debatable issue that FFs must deal with daily. Therefore, the current study intended to examine FFs who are likely to be exposed to high levels of fire smoke and, as a result, to uncover any associated risk for DED compared to age-and gender-matched healthy individuals.

2. Methods

2.1. Ethics Consideration and Study Consent

The study protocol followed the ethical principles of the Helsinki Declaration and was fully approved by the Afyonkarahisar Health Sciences University Ethics Committee with approval number 2022/316. All participants provided written informed consent before participation.

2.2. Study Design and Participant Selection

This non-interventional, cross-sectional study was conducted from June 3 to June 30, 2022. Initially, the study included all 59 FFs from the nearby Afyonkarahisar Municipality Fire Department. They had no hypertension or thyroid problems. After excluding two FFs with diabetes, two with glaucoma, one on antihistamines, one with a history of cataract surgery, one with prior refractive surgery, and one CL user (defined as wearing CLs≥1 day/week), 51 FFs (Group 1) with direct firefighting experience were eventually determined to be eligible for the study.

A control group (Group 2) included 51 age- and gender-matched healthy individuals who were relatives of patients who had routine ocular examinations at the ophthalmology clinic. These individuals had no systemic or ocular diseases, as determined by comprehensive systemic and ophthalmological exams, and they met all of the FF inclusion criteria. Given that smoking may be a predisposing factor for DED, the number of controls who smoked regularly (every day) was determined to be 27 (52.9%), the same as in FFs. In this context, regular smokers were defined as those who smoked >1 cigarette per day [22].

2.3. The Ocular Surface Disease Index

The Ocular Surface Disease Index (OSDI; Allergan, Inc, Irvine, California), a patient-reported outcome questionnaire, was created to provide a quick assessment of the range of ocular surface symptoms associated with chronic DED, their severity, and impact on the patient's functional capacity [23]. It is low-burdening to the patient, takes about 5 minutes to finish, and has been applied efficiently by physicians and researchers. This questionnaire has three sections: (i) ocular symptoms, (ii) vision-related function, and (iii) environmental triggers. Essentially, the objectives are to make ocular surface disease diagnosis faster and more reliable and to explain the discrepancy in ocular disability caused by DED. It also enables physicians to collect extensive subjective data in addition to clinical history, and it has the potential to evaluate the efficacy of a specific DED therapy [23, 24].

Initially, all participants in this study were thoroughly explained the study's objectives and procedures by a senior ophthalmologist (HHG), who was also in charge of all questionnaire procedures. Then, the Ocular OSDI questionnaire was distributed to Group 1 at the fire department and Group 2 at an ophthalmology clinic during an ophthalmological assessment. The OSDI questionnaire consists of 12 items graded on a scale of 0 to 4, with 0 indicating no time, 1 sometimes, 2 half of the time, 3 most of the time, and 4 all the time. The total OSDI score was calculated as follows: OSDI=([sum of scores for all questions answered]×25)/([total number of questions answered]). The OSDI was scored on a scale of 0-100, with higher scores indicating more severe DED. The OSDI score was grouped as per the following: normal ocular surface (0-12 points), as well as mild (13-22 points), moderate (23-32 points), and severe (≥33 points) ocular surface disease. The OSDI was scored based on the reported guidelines. This questionnaire has adequate internal consistency, test-retest reliability, validity, sensitivity, and specificity for ocular surface disease patients [24].

Aside from socio-demographic characteristics such as age and gender, questionnaire participants were also asked if they had ever had any ocular surgical procedures or smoked.

2.4. Ophthalmological Assessment

Since the FFs were on duty, they were all ophthalmologically assessed by a single experienced ophthalmologist (IEA) using a portable hand biomicroscope (Portable Slit Lamp, Reichert Inc, NY, USA) in a large fire department-designated room with standard lighting. The same ideal conditions were applied to Group 2, whose assessment was performed in the

designated space at the ophthalmology clinic. The evaluation was carried out between 13:00-15:00 to avoid the potential influence of diurnal variations in the tear film layer. First, a non-anesthetic Schirmer test was performed by placing a Schirmer strip (Biotech, Ahmedabad, India) on the outer third of the lower eyelid and waiting five minutes. A saline drop was then placed on the fluorescein strip (Biotech, Ahmedabad, India), followed by a tear film break-up time (TBUT) test using the biomicroscope's blue cobalt filter with 10 times magnification [25]. DED was defined as a non-anesthetic Schirmer test result of less <10 mm or a TBUT of <5 seconds [26].

2.5. Statistical Analysis

The PAWS Statistics 18 program was used for statistical analysis. The Kolmogorov-Smirnov test was used to assess the distribution of data. Categorical variables were presented as percentages and frequencies, normally distributed continuous variables as mean±standard deviation, and non-normally distributed continuous variables as medians and quartiles (IQR). Chi-Square and Fisher-Freeman-Halton Tests were used to compare categorical variables. Further, the Independent t-Test was used to evaluate normally distributed data, whereas the Mann Whitney U test was used to assess non-normally distributed data. A logistic regression analysis was performed between subgroup variables. The statistical significance level for two-tailed data was set at $p<0.05$.

3. Results

Groups 1 and 2 were all males, with mean ages of 44.82±7.29 and 44.73±7.41 years, respectively (p=0.946). The median work duration for Group 1 was 14 years (min-max: 1-27 years) (IQR=7.0-22.0).

3.1. The Tear Film Test Results

The TBUT test revealed a statistically significant four-fold increase in DED prevalence in Group 1 compared to Group 2 (p=0.046). Even though the difference was not statistically significant (p=0.276), the Schirmer test also revealed that Group 1 had a higher DED prevalence than Group 2. Moreover, participants with DED who had an OSDI score of >12 were twice as numerous in Group 1 as they were in Group 2 (p=0.062) (Table 1).

Given a statistically significant difference in TBUT values between Groups 1 and 2, a logistic regression analysis, including age, smoking, and other group variables, was performed based on the TBUT results. Again, no statistically significant difference was found (p=0.170).

The OSDI score was used to categorize participants as having mild, moderate, or severe DED, as represented by OSDI Groups 1, 2, and 3. Statistically, non-significant differences existed between the FFs and the healthy individuals (p=0.359) (Table 2).

Table 1. A comparative analysis of DED test results between the two study groups.

Tests	Group 1, n (%)	Group 2, n (%)	P value
Schirmer	10 (19.6)	6 (11.8)	0.276
TBUT 8	8 (15.7)	2 (3.9)	0.046
OSDI*	16 (31.4)	8 (15.7)	0.062

*DED=Dry eye disorder, Group 1=Firefighters, Group 2=Healthy individuals, TBUT=Tear break-up time, OSDI=Ocular surface disease index, n=Number of participants, %=Percentage, *Individuals with DED were compared with a score of >12 according to the OSDI score.*

Table 2. A comparative analysis of DED severity based on OSDI score between firefighters and healthy individuals.

	OSDI Score					
	0	1 (mild DED)	2 (moderate DED)	3 (severe DED)	Total	P
Group 1, n (%)	35 (68.6)	8 (15.7)	6 (11.8)	2 (3.9)	51 (100)	
Group 2, n (%)	43 (84.3)	4 (7.8)	3 (5.9)	1 (2.0)	51 (100)	
Total	78 (76.5)	12 (11.8)	9 (8.8)	3 (2.9)	102 (100)	0.359

DED=Dry eye disorder, Group 1=Firefighters, Group 2=Healthy individuals, OSDI=Ocular surface disease index, n=Number of participants, %=Percentage.

3.2. Work Duration-Based Tear-Film Intra-Group Analysis

Group 1 was further evaluated independently of Group 2 based on work duration in years. In fact, when the Kolmogorov-Smirnov test was used to assess FF work duration, it was discovered that it did not fit the normal distribution. Thus, Group 1 was divided into two sub-groups based on the median value corresponding to 14 years of work duration: ≥14 years and <14 years FFs. These sub-groups could not be divided equally because the 10 FFs with the median value had worked for 14 years. Consequently, 28 (54.9%) had served as FFs for ≥14 years, while 23 (45.1%) had served for <14 years. Schirmer test revealed DED in 8 (28.6%) and 2 (8.7%) FFs with ≥14 and <14 years of work duration, respectively (p=0.075). The TBUT test revealed DED in 6 (21.4%) and 2 (8.7%) FFs with ≥14 and <14 years of work duration, respectively (p=0.213). According to the OSDI test, DED was found in 11 (39.3%) of the FFs with ≥14 years of work duration, with 4 (14.2%) having mild DED and 7 (25.0%) having moderate and severe DED. However, among FFs with <14 years of work duration, 5 (23.8%) were found to have DED based on the OSDI test, with 4 (19.0%) having mild DED and 1 (4.8%) having moderate and severe DED. Overall, the longer the work duration, the higher the DED proportion; however, no statistically significant difference between the two sub-groups was found in intra-group comparative analysis (p=0.179).

4. Discussion

Generally, FFs operate in one of the most hazardous occupations, with higher-than-average workplace fatalities and injuries. They conduct physically demanding tasks such as firefighting, search and rescue, exterior ventilation, and overhaul on the fire ground. They are also exposed to extremely high levels of a variety of toxic and carcinogenic chemicals, which may be associated with systemic pathological conditions and ocular surface pathologies [27]. Most studies have shown that FFs are at high risk of developing occupational diseases [28, 29]. The current study examined FFs who were likely to be exposed to high levels of fire smoke to see if there was any risk of DED, providing an important overview of their ocular surface health. Extremely high temperatures and smoke containing gaseous pollutants and particulate toxins may be associated with an increased DED prevalence among FFs, as well as an increased risk of other disorders such as cardiovascular [18, 30], mental [21], and neoplasia [12].

DED is one of the most common ophthalmological health issues [31, 32], and its prevalence is increasing, resulting in a lower quality of life [32]. It is thought to affect nearly one-third of the world's population [31]. As noted previously, most studies have investigated the prevalence of DED concerning cigarette smoking, whether direct or passive [18, 19]. However, to our knowledge, this is the first study to investigate DED, whether it is an occupational disease or not, and its potential risk factors in FFs, a group of workers frequently exposed to fire smoke from various sources.

Usually, fire smoke is composed of unburned microscopic particles, gases, and water vapor. Standing near fire smoke allows tiny particles to enter the eyes unknowingly, causing ocular irritation, which is why FFs are recommended to wear PPE [33]. In addition, fire smoke particles, which are undetectable, linger in the air for a long time after the smoke has cleared [34]; thus, FFs can go about their business without being aware of the presence of the particles. Consequently, if smoke enters the eyes, the particles are likely to become trapped there as well, resulting in stinging, burning, hyperemia, excessive watering, and temporary vision changes caused by ocular rubbing-induced corneal damage in the short-term [3].

In the current study, FFs were found to be significantly associated with increased DED prevalence, four times higher than in healthy individuals, and prominent corneal staining in the TBUT test. Moreover, the Schirmer test revealed FFs to be associated with nearly twice the DED prevalence than healthy individuals, as did the OSDI questionnaire assessment, despite non-significant differences in both test results. The current study also investigated whether there was any relationship between FF work duration and DED prevalence. In this context, work duration had no significant impact on DED prevalence, as evidenced by the TBUT and

Schirmer tests and the OSDI score. Nonetheless, those who had worked for a more extended period, in this case ≥14 years, were more likely to be detected with DED. These findings clearly show that FFs may be at higher risk of developing DED when compared to healthy individuals, significantly as their work duration increases [35, 36]. In addition, longer working experience entails greater exposure to fire smoke hazards [34, 37], which can result in the development of some ocular surface pathologies like DED.

Exposure to fire smoke and gases is challenging to characterize. This is primarily due to a combination of factors, including longer work schedules throughout the year, wide variations in FFs' time spent at fires, intermittent exposures, exposure to a complex mixture of gases, vapors, and particulate matter, as well as the unrevealed effect of heat. Because of the variety of chemicals in smoke, some may produce metabolites that, alone or in combination with other substances or metabolites, may be extremely dangerous, causing DED in this context [38].

Fire smoke microscopic particles and gases are two physical phases of combustion products. Microscopic particles, however, should be viewed as a complex mixture consisting of a particle core onto which other substances, such as gases and volatile organic compounds, are adsorbed. Gaseous combustion products are primarily of acute and on-scene concern, though they may have long-term consequences. Following ocular contact, the solubility of gases in water governs almost entirely their penetration into deep ocular tissues. This can lead to acute and, in the case of long-term exposure, chronic inflammatory damage to tear production processes and the entire ocular surface [34].

The carbonaceous smoke particles produced by fire are almost entirely the result of the combustion of organic matter. Visible flame fires produce smaller particles than smoldering or charring fires without flames, owing to inefficient combustion. Particles produced by both flaming and nonflaming fires can aggregate to form larger particles over time [16, 39]. This could be related to increased ocular surface problems in FFs, particularly DED, as evidenced in the current study, where prolonged exposure to fire smoke was associated with an increased DED prevalence. It is essential to remember that fire smoke is not the same as cigarette smoke, which is far more complex and contains chemicals like nicotine that suppress acute inflammation. Fire smoke particles also differ significantly from fine particulate air pollution, primarily sulfate-derived instead of carbonaceous [39].

Fire smoke can alter the composition of tears in two ways: gases in smoke cause increased evaporation of the water component of tears, and toxins and particulates cause increased protein production. Several approaches are available to alleviate the symptoms of fire smoke-induced DED in FFs. This includes using artificial tears to reestablish the proper balance of tear components, as well as tear duct plugs inserted in the natural tear drainage openings in the eyelids to help maintain natural tears on the eyes for a longer period. Furthermore, despite the lack of clinical DED, FFs may benefit from commercially available hyaluronic acid-containing artificial tear drops as a preventative measure following a fire incident. This approach could alleviate fire smoke-induced ocular surface inflammation by facilitating ocular surface cleaning. This may be the first study in the literature to address this specific topic; therefore, additional research may be worthwhile.

Moreover, FFs must wear protective equipment such as helmets, boots, gloves, and so on, in addition to thermal protective clothing, to effectively and efficiently suppress fires [40]. These widely used devices, which are generally certified by the International Organization for Standardization (ISO), the European Committee for Standardization (EN), or the National Fire Protection Association of the United States (NFPA), reduce FF injuries and fatalities by providing adequate comfort as well as protection for various body parts, including the eyes [41]. While any level of fire smoke exposure is hazardous to anyone, it is especially dangerous to FFs with DED or ocular allergies. After all, FFs can achieve optimum ocular protection from fire smoke by wearing PPE [33]. Generally, PPE refers to the equipment worn by FFs, including eye and hearing protection, helmets, trousers, coats, boots, protective gloves and hoods, self-contained breathing

apparatus, and personal alert safety system devices. Although eye injuries are among the most common injuries sustained by FFs while fighting fires, they are not always reported because they are not always incapacitating. Unfortunately, severe eye injuries can also occur; however, they are relatively easy to avoid. Self-contained breathing apparatus face-pieces, helmet-mounted face-shields, goggles, and safety glasses are just a few examples of eye PPE. In addition, when engaging in firefighting activities that require protection from flying particles or chemical splashes, NFPA requires using goggles or other relevant primary eye protection [42].

Demographically, males consist of a more significant proportion of FFs. Most male FFs are frequently involved in mainstream firefighting, whereas female FFs are primarily engaged in administrative duties. This disparity could be explained by the fact that the FF profession is high-risk, making it more appealing to males, who are more likely to work in high-risk occupations [37,43]. In the current study, all FFs were males, preventing a comparison of DED prevalence by gender. Even so, because DED prevalence appears to be increasing in FFs compared to healthy individuals, this finding supports previous reports, even if no relevant conclusions can be drawn because the study only examined male FFs.

Fundamentally, DED is a multifactorial disorder that significantly impacts the quality of life and work productivity [44]. Not only do FFs' unhealthy culture, shift work, and irregular sleep patterns play a role in DED, but so do genetic and environmental factors, with environmental factors accounting for up to 70% of the variation in DED symptoms [45]. Several studies have linked specific ecological factors to DED, including air pollution [46], use of visual display terminals [47], low humidity, and air conditioning [48]. In line with these reports, the occupation, in this case, firefighting, could undoubtedly play a significant role in DED. Many other risk factors, such as smoking, have been shown to impact disease outcomes, including DED. With the exception of Beaumont et al. [49], almost no studies on FFs have adjusted for confounders such as smoking. The most serious source of consternation, however, maybe work duration. This is due to the fact that work duration, exposure duration, latency of a particular pathology and age are all closely related but not the same, and there is never enough evidence to separate the covariance. In epidemiologic studies of FFs, smoking is the most common potential confounding factor, as it is in many, if not the majority, of occupational and public health epidemiology studies. Even so, it may not have as strong an impact as generally believed, and it is likely to be less of a problem than in other occupations. It has never been proven that FFs smoke more than the general population. Besides, the scant historical data suggests that, at least in modern times, FFs smoked less than other occupations. Since cigarette smoke is a combustion product, it contains many of the same carcinogenic and toxic constituents as fire smoke. As a result, smoking poses a unique challenge in the study of various systemic and ocular pathologies, including DED.

Smoking is inversely related to socio-economic class and is more common in certain occupations, particularly those that are either boring, requiring stimulation as a relief from tedium, or involve social mixing, owing in part to the transactional nature of sharing smokes. Intriguingly, firefighting possesses both of these characteristics and is considered a working- class, or 'blue-collar,' occupation, implying higher cigarette smoking. This was, however, more applicable in the past than now. Modern FFs are far more knowledgeable, health- conscious, and concerned about the effects of smoke as a result of their occupation [34]. Despite this, FFs have a high rate of co-occurring mental illness and substance abuse. This is a primary challenge for FFs because substance abuse has the potential to impair cognitive and behavioral performance, posing workplace productivity issues as well as safety risks such as improper use of PPE during fire incidents. It has also been reported that 30% of FFs have alcohol problems, which is twice the rate of the general population [50]. Furthermore, the effect of shiftwork on sleep patterns and overall health in FFs has been reported to be significant. Many FFs noted sleeping problems, particularly during the day when working the night shift, while others claimed that their sleeping problems were entirely related to hypervigilance, as the readiness to respond to alarms while on duty transfers to off-duty life [27]. Therefore,

despite focusing primarily on DED prevalence among FFS in relation to fire smoke exposure in the current study, other factors could, of course, influence the rate of DED among FFs. Nonetheless, as noted earlier, no participants reported consuming alcohol or any other substance abuse, with the exception of participants in both FFs and healthy individuals who used to smoke regularly. Furthermore, in the current study, work duration had no significant effect on DED prevalence, and participants in both groups were age- and gender-matched.

There are some limitations to the current study. Because of the study's cross-sectional single-centered design, it may have been difficult to decipher relatively more clinically significant prospective findings regarding the relationship between DED and fire smoke exposure, as well as FFs' work duration. Another limitation could be the small number of study participants, as well as the fact that no FF was asked if he had recently been involved in any firefighting operations. Ocular examination immediately following firefighting may reveal an expectedly increased DED incidence due to intense smoke exposure. Nevertheless, given that FFs work 24-hour shifts, it should be noted that they may experience difficulty sleeping, which may have an impact on DED. The healthy worker effect (HWE) is one of the most pressing issues confronting occupational health researchers [27]. This phenomenon could also limit the current study in that it is a special type of selection bias, commonly seen in observational studies of occupational exposures with an incorrect choice of comparison group, usually the general population. Matter of fact, the general population is, by definition, a mixed bag of healthy and unhealthy individuals. The employed workforce is expected to have fewer sick individuals than the general population [27, 51]. Several professions, such as FFs, require strenuous physical and endurance tests prior to recruitment to assess their physical as well as ophthalmological health. Consequently, comparisons of DED prevalence between FF cohorts who are fitter and healthier and healthy relatives of patients having routine ocular examinations, in this case, may be skewed because not everyone in the latter group is at risk of being recruited, resulting in an underestimation of DED among FFs. Additionally, it is clear that FFs in the current study did not use computers regularly and were directly responsible for firefighting. However, given the prevalence of smartphone use, the fact that the FFs' time spent with their smartphones was not questioned may be viewed as another study limitation.

Despite the limitations, we believe that the current study, as the first of its kind, has yielded valuable results, particularly in relation to the global ocular health problem of DED. This may eventually raise questions about whether an occupational disease is the best definition for these frequently diverse smoke-exposed FFs.

5. Conclusions

Because of the high prevalence of DED caused by fire smoke in FFs, pragmatic measures are required. As detailed above, regular ocular exams, recommendations to wear PPE regularly, and health education programs that can improve the current situation, avoid potential complications, and reduce the burden of ophthalmological pathologies are examples of such measures. This could be especially beneficial for both occupational health and work productivity. As a result, this evidence-based association may help define fire smoke-induced occupational ocular disorder and highlight the importance of taking a thorough occupational and social history in patients with DED to better understand the symptom etiological factors. When implemented earlier and with more resources, a better understanding of occupational hazards and agreed-upon and coordinated actions among occupational physicians, primary care physicians, and specialists such as ophthalmologists will produce far more effective results. Nonetheless, further large-scale prospective research into DED prevalence among FFs and whether it is an occupational disease could yield clinically and occupationally valuable results.

Declaration of Interest: The authors declare no conflict of interest to disclose.

Institutional Review Board Statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards (IRB approval number: 2022/316.)

Informed Consent Statement: Informed consent was obtained from all participants.

Availability of Data And Materials: The manuscript contains all data. The datasets used and/or analyzed during the current study, however, are available upon reasonable request from the corresponding author.

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