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Transient effects of smoking on the eye

Nisar Latif, Shehzad A. Naroo *

College of Health and Life Sciences, Aston University, Birmingham B4 7ET, UK

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ABSTRACT

Purpose: To investigate the immediate short-term effects of smoking in habitual smokers, on the tear film, pupil size and accommodative ability of the human eye.

Methods: Habitual smokers were tested within 5 min of smoking a cigarette. The tear film analysis was undertaken using tear break–up time (TBUT), tear lipid layer thickness and tears meniscus height (TMH) measurements. Three different ways of tear break–up time (TBUT) were used; using fluorescein; a non-invasive TBUT using tearscope; and a video captured method with a corneal topographer. Pupil size was measured objectively using the video capture on the corneal topographer. Accommodative ability was checked by performing a 'push up test' to measure amplitudes of accommodation (AoA) and by measuring defocus curves.

Results: Forty-five participants were enrolled (mean age 22.0 ± 4.4 years). TBUT was reduced after smoking a cigarette with all three assessment methods and this reduction was statistically significant ($p < 0.001$). A reduction in lipid layer thickness was seen after smoking a cigarette with both methods used and was statistically significant ($p < 0.01$). A significant reduction in pupil size ($p < 0.01$) and in AoA ($p < 0.001$) was observed after smoking a cigarette. The difference in TMH and defocus curves, before and after smoking, were not statistically significant ($p > 0.05$).

Conclusion: The study shows that there is an immediate adverse effect of smoking on TBUT and AoA which seems to be very transient.

1. Introduction

Tobacco smoking is the leading cause of preventable morbidity and mortality in the world [1]. Smoking is related to many ocular conditions, including cataract formation [2] age-related macular degeneration [3], increased intraocular pressure [4], thyroid eye disease [5], colour vision defects [6] and dry eye disease [7]. The ocular surface is the most exposed mucosal surface of the human body and encounters challenges from the environment such as wind, extreme temperatures, UV radiation, pollen particles and debris such as tobacco smoke. The effects of cigarette smoke on the ocular tear film have been reported in the literature [8]. There are several articles published on the effects of smoking on the tear film and ocular surface [7,9–14]. All the studies have reported that chronic smoking is associated with tear instability and adverse effects on the ocular surface. Decreased corneal and conjunctival sensitivities, increased conjunctival squamous metaplasia, altered tear proteins and reduced goblet cell density amongst smokers have been reported [10,14,15].

Nicotine is one of the principal active chemical agents in a cigarette and is responsible for acute pharmacological effects of smoking [16]. The adverse effects of smoking have many short-term effects on the body, such as increased heart rate, increased blood pressure, breathlessness and a reduction of blood flow to hands and feet [17,18]. Many studies have reported an adverse effect of smoking on the tear film [7,11,14,19]. Only one study investigated the immediate effects of smoking on the tear film and found the tear film to be adversely affected after 5 min of exposure, and for up to 24 h, compared to baseline values. [15].

There are studies that have shown smoking to cause an increase in pupil diameter [20–23].The human iris receives both parasympathetic and sympathetic nervous innervations, the sphincter iris muscle under the control of sympathetic nerves and dilator iris muscles under the control of parasympathetic nerves [24]. Nicotine acts a sympathomimetic drug to increase heart rate and blood pressure (BP) as a result of releasing epinephrine [18]. The iris sphincter muscle is more activated by the parasympathetic system than the sympathetic system [22] and it has been seen that smoking is related to an initial immediate constriction of pupil followed by an increase in pupil size [22]. The initial

* Corresponding author.
E-mail address: s.a.naroo@aston.ac.uk (S.A. Naroo).

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transient pupil miosis also causes a rapid but transient increase in objective accommodation, probably due to an increased depth of focus through the smaller pupil diameter. [25]. The effects that a smoking a cigarette has on the eye is largely unknown. This study aims to investigate the immediate and transient effects of smoking a single cigarette and allows the participants a short abstinence period.

2. Methods

The study design was a prospective uncontrolled study. Ethical approval was obtained from the university ethics committee. The study followed the Tenets of the Declaration of Helsinki and written informed consent was obtained from all participants. Regular tobacco smokers, who smoked at least one cigarette per day and aged between 18 and 50 years were recruited to the study. Smokers of electronic cigarettes or other types of smoking were not included. Study participants had no ocular or systematic abnormality or any history of ocular surgery and trauma. Participants who were contact lens users or had LogMAR visual acuity of<0.0 (after best refractive correction) were also excluded. Only the right eye of each participant were examined with subjects wearing their best corrected refractive correction in spectacle lenses.

The non-invasive tear break-up time (TBUT) was measured with the Keratograph 5 M corneal topographer (Oculus Optigerate GmbH, Wetzlar, Germany) and EasyTearView + Tearscope (EasyTear SRL, Trentino, Italy) and invasively with the addition of fluorescein break-up of the tear film observed through a slit lamp. Three readings were recorded from each technique. Additionally, a single measurement of tear meniscus height (TMH) and tear film lipid layer from Keratograph 5 M (K5) and the EasyTearView + Tearscope were taken. For the tearscope the lipid payer thicknesses were estimated based upon the original Guillon-Keeler guide and the values used from this instrument are median values from the band estimates of that original device [26]. Pupil diameter was recorded from the image capture on the corneal topography unit. Amplitude of accommodation (AoA) were recorded using a push-up technique on a RAF near point ruler. Visual acuity and defocus curves were measured with a LogMAR visual acuity chart. The defocus curves were measured using the Landlot-C chart and a range of lenses from + 1.50 DS to –1.50 DS, following a previously reported method [27,28]. All measurements were repeated 3 times. Baseline measurements were recorded following at least one hour of abstinence from smoking. Subjects then smoked one cigarette and measurements were repeated.

3. Results

Forty-five participants (30 men and 15 women) with the mean age of 22.0 ± 4.4 years (range 18 to 42 years) were included. The mean age for male participants was 21.5 ± 3.4 years and for female participants it was 23.1 ± 5.9 years. The mean pre and post smoking TBUT by the three different methods are shown in Fig. 1. The post-smoking TBUT was statistically significantly lower by all three methods compared to baseline values (Wilcoxon Signed Rank test, $p < 0.001$ in each case). The visual acuity pre-smoking (LogMAR −0.05 ± 0.08) and post smoking (LogMAR −0.05 ± 0.09) was unaltered (Wilcoxon Signed Rank test $p > 0.05$).

The mean lipid layer thickness, pre and post smoking, measured by the two different methods are shown in Fig. 2. Again, the post-smoking lipid layer thickness was statistically significantly lower by both methods compared to baseline values (Wilcoxon Signed Rank test, $p < 0.001$ in each case).

The pre-smoking tear meniscus height (TMH) was 0.4 ± 0.1 mm and post-smoking this changed to 0.3 ± 0.1 mm, which was not statistically significantly different ($p > 0.05$, Wilcoxon Signed Rank test). Pre-smoking amplitudes of accommodation (AoA) were 10.5 ± 1.8 dioptres (DS) and post-smoking this dropped to 9.9 ± 1.7 DS and this was statistically significant different ($p = 0.001$, paired samples *t*-test). Fig. 3

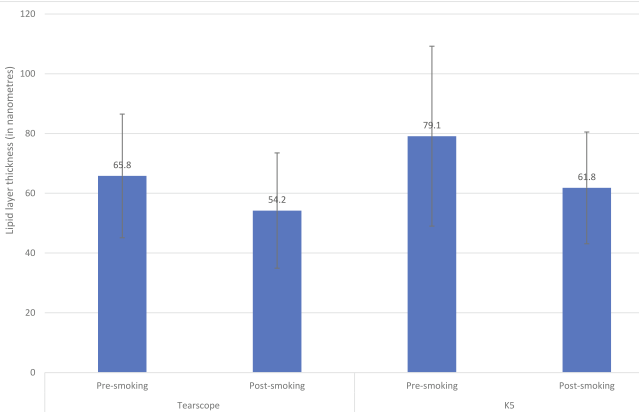


Fig. 2. Mean lipid layer thickness before and after five minutes of cigarette smoking measured in nanometres. The values of lipid layer thickness for the tearscope are median values taken from the band estimates of the original tearscope.

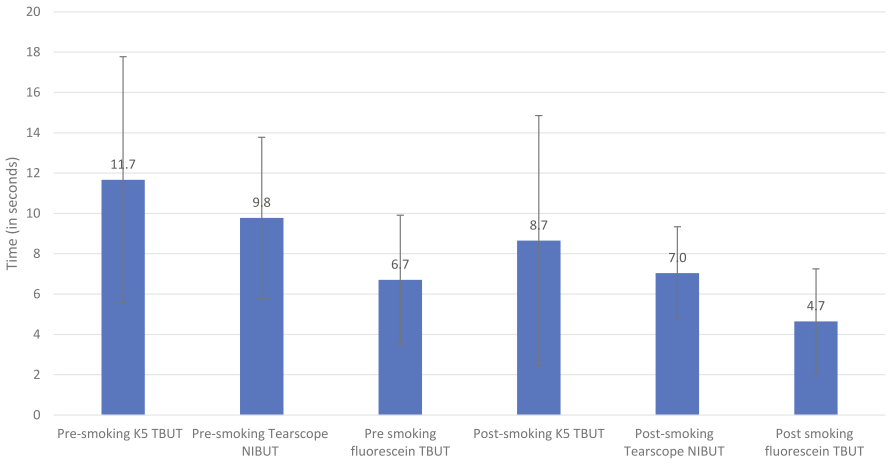
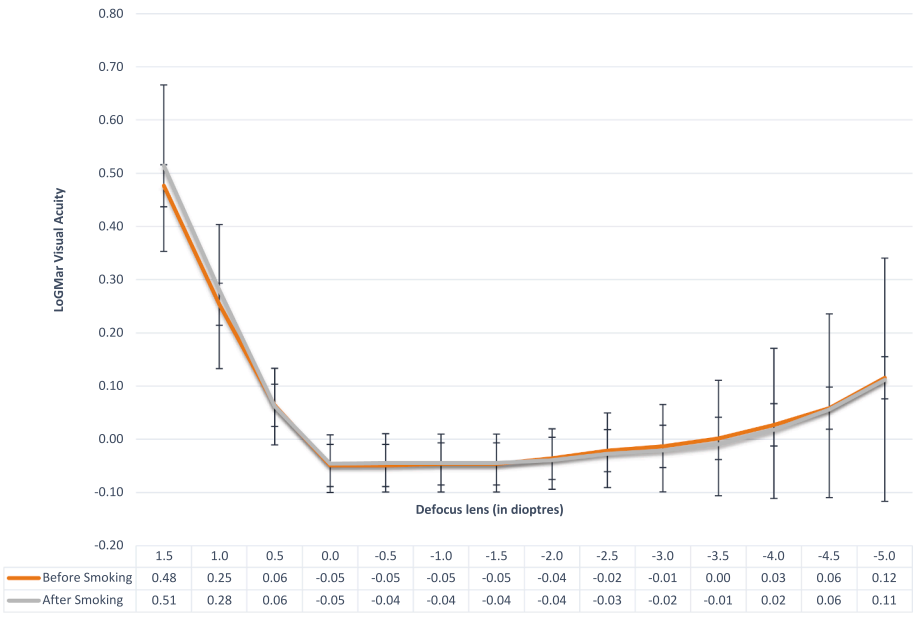


Fig. 1. Tear break–up time (TBUT) before and after five minutes of cigarette smoking from three different methods.



	1.5	1.0	0.5	0.0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
Before Smoking	0.48	0.25	0.06	-0.05	-0.05	-0.05	-0.05	-0.04	-0.02	-0.01	0.00	0.03	0.06	0.12
After Smoking	0.51	0.28	0.06	-0.05	-0.04	-0.04	-0.04	-0.04	-0.03	-0.02	-0.01	0.02	0.06	0.11

Fig. 3. Defocus curves showing the subjective clear vision range before and after five minutes of smoking.

shows the defocus curves. The mean pupil diameter pre-smoking was 5.6 ± 1.1 mm and post-smoking this changed to 5.4 ± 1.0 mm, which was statistically significant different (p = 0.001, paired samples *t*-test). There was a significant difference found between pre and post smoking mesopic pupil size (p = 0.001, paired samples *t*-test) and photopic pupil size (p = 0.003, paired samples *t*-test) (see Fig. 4).

4. Discussion

The current study has investigated the short-term effects of smoking on ocular health. One of the transient effects of smoking is decreased TBUT post-smoking. Lipid peroxidation of the outer layer of the tear film is one of the possible mechanisms that might be responsible for pre-corneal tear film break down as argued by Thomas *et al.* (2012) and Altinors' *et al.* (2006). Cigarette mainstream smoke contains over 4000 active compounds in its tar and gas phases, which includes nicotine and tar. The substances in the gas phase can enter through the airway epithelial barrier, enter the systemic circulation via the pulmonary circulation, and increase systemic oxidative damage, leading to the development of cigarette smoking-related diseases [29].

Nicotine activates macrophage reactions at the cellular level. Human macrophages interacting with carbonyl or cigarette smoke have been observed to modify extracellular matrix proteins that reduce their ability to phagocytose apoptotic neutrophils [30]. It is hypothesised that this mechanism may also apply on the ocular surface as increased apoptosis of conjunctival epithelial cells is observed in patients with kerato-conjunctivitis sicca. Alternatively, smoking can cause ocular epithelial damage by its direct contact with the ocular surface, as suggested by Satici *et al.* (2003) [31]. Satici *et al.* (2003) observed a higher number of squamous cell metaplasia in the conjunctival epithelium of smoker, which could be caused by toxic and irritant materials present in cigarette smoke.

Few studies have shown the association of smoking with pupil size. Roberts and Adams (1969) observed that rapidly after puffing cigarette smoke, there is an average 0.75 mm increase in pupil size of their participants and pupil retained back their original size in less than three minutes of post-smoking exposure [20]. Sobaci *et al.* (2013) observed that photopic pupil sizes of chronic smokers were different from non-smokers and suggested that chronic smoking may dilate the pupil size [23]. A latest pre and post–smoking study by Bardak *et al.* (2017) found no significant mean pupil size difference before and after smoking of a single cigarette [25]. On the contrary, Lie and Domino (1999) noticed a decreased pupil size among smokers after smoking one cigarette in their pre and post–smoking study [21].

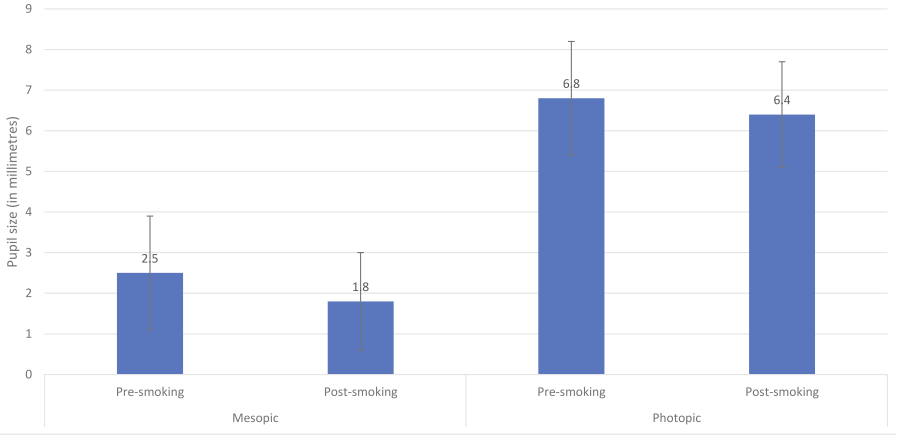


Fig. 4. The mean pupil size before and after 5 min of smoking.

Similarly, Erdem *et al.* (2015) supports the findings of Lie and Domino (1999) related to pupil size, in their pre and post–smoking results and found a significant decrease in mean photopic and mesopic pupil size after smoking [22]. The results from this study are also consistent with the results from Lie and Domino (1999) & Erdem *et al.* (2015), as this study found a significant constriction in mesopic pupil size and photopic pupil size. In this study, all participants were asked to abstain from smoking at least one hour before their baseline measurements while a previous study by Bardak *et al.* (2017) followed an abstinence period from smoking of at least 12 h. The variation in the abstinence period of smoking could be associated with pupillometry results. It has been noticed that previous studies (Erdem *et al.* 2015 & Bardak *et al.* 2017) included only those smoker participants who smoked at least 10 or more cigarettes for at least five years whereas, in this study, participants were considered as a smokers' if the smoked at least one cigarette per day. This variation in the smoking pattern can also be associated with different results as the smoking habit is a high dose responsive.

Bardak *et al.* (2017) in their pre and post–smoking study found that after acute smoking, objective amplitude of accommodation increased with every dioptre of stimulus and the increase of accommodation was statistically significant at 2D and 3D. The current study observed a decrease of AoA measured by subjective method (RAF rule) after smoking exposure. The study found an approximate of 0.50D (average) decrease in AoA after cigarette smoke. However, the study did not find any statistically significant decrease in subjective clear vision range by performing defocus curves before and after smoking exposure apart from + 1.50D lens and + 1.0D lens where the decrease was statistically significant.

The contradiction between the results of Bardak *et al.* 2017 and this study may be due to factors discussed above (such as the difference in the abstinence period from smoking and smoker participants meeting the study criteria). Another possible reason for variations in results could be due to the nature of the method used to measure accommodation; this study used the subjective way which may overestimate the objective accommodation due to a depth of focus phenomenon [32]. Last but not the least, it can be hypothesised that smoking might alter the elasticity of lens zonules or ciliary muscles which then affect the accommodative ability of the eye similar to corneal prospective where smoking is associated with increased corneal rigidity [33].

The current study is the first study to report the acute effect of smoking on subjective accommodation of the eye without controlling for pupil size and participants are compared to their own baseline results. The current study utilises both invasive and non-invasive methods of measuring TBUT. This study has some limitations; this study did not measure any objective method of measuring accommodation and defocus curves for near vision etc. Additionally, this study lacks a second impartial observer who can take measurements of the same participant independently to reduce the risk of observer related bias. Finally, this study did not restrict participants to use a single brand cigarette with a set level of nicotine and other ingredients as they were free to use their brand of cigarette. Furthermore, the number of cigarettes or the number of years that a participant was a smoker was not considered since the aim of this study was to investigate the immediate and transient effects of smoking a single cigarette. This abstinence period of one hour may be insufficient for residual systemic nicotine levels to undergo clearance. A future study using a placebo-controlled randomised design may be a useful investigation.

In conclusion this study revealed that tobacco smoking could immediately decrease TBUT, alter the tear lipid layer, cause miosis of the pupil and reduce the amplitude of accommodation. A possible reason for short-term effects of smoking may be related to the short life span of nicotine as nicotine rapidly changed into a less toxic and relatively inactive substance which may cause a reversal in any change caused by it. However, further studies are required to establish these facts considering all the factors mentioned in previous studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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