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OCULAR SURFACE TEMPERATURE IN HEALTHY SUBJECTS: A THERMOGRAPHIC STUDY

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SUMMARY

The aims of this study were 1) to measure by thermography the ocular surface temperature (OST) of a healthy population (178 subjects, 86M/92F), and 2) to investigate the influence of subject factors (*i.e.* age, gender, height, weight, body temperature, visual defects, physical activity and smoke) on the OST. Specifically, the OST of five anatomical points were measured on both eyes. Statistical analyses showed the repeatability of the measurements and the significant difference among all five points. Moreover, there was no significant difference between left and right eyes (P -value >0.05). Age, body temperature and physical activity did influence significantly the OST of both eyes (P -value <0.001), while gender, smoke and ocular defects did not influence significantly the OST (P -value >0.05). The strong correlations OST-age and OST-body temperature indicates the importance of these two subject factors when investigating different populations.

INTRODUCTION

Interest in the temperature of the eye spans almost 130 years [1,2], but accurate quantitative measurements of the profile of the ocular surface temperature (OST) has been possible only in the last few decades, thanks to the infrared thermography (IR) - a non-invasive, cheap and easy-to-use technique which allows measuring the OST with more accuracy, resolution, and speed than previously possible [2-4]. It is widely known that the ability to measure accurately the OST will increase the understanding of ocular physiology and should be a decisional support to the therapy integrated with classical diagnostic procedure. The use of ocular thermography offers great opportunities for monitoring the temperature of the anterior eye and analyzing the effects of some pathology in the OST [5-9]. However, it is firstly necessary to establish a normal range of the OST in order to correlate OST alterations to parameters which might describe pathologies. Unfortunately, the literature cannot be used as a reference as previous studies focused mainly on the OST of the central cornea [4,10,11], or examined only Chinese young adults [13]. The aims of this study were to measure the OST of a healthy population and to investigate the influence of subject factors (*i.e.* age, gender, height, weight, body temperature and visual defects, physical activity and smoke) on the OST.

METHODS

178 subjects (86M/92F of age 14-83) were enrolled in this study. Exclusion criteria were: ophthalmic pathologies, diabetes and a body temperature above 37.5°C. All participants were volunteers, who signed the informed consent before starting the measurements. Furthermore, each subject was asked to fill a questionnaire regarding personal data as well as general and ocular anamnesis. Table 1 shows the characteristics of the subjects investigated.

Table 1: Subjects' characteristics expressed as mean \pm SD.

	Females	Males
Subjects	92	86
Age (years)	43 \pm 16	45 \pm 19
Weight (kg)	64.5 \pm 13.0	75.7 \pm 10.9
Height (cm)	164.3 \pm 6.5	174.4 \pm 7.1

The thermocamera used was the FLIR 320A with an image resolution of 320x240 pixels, and image frequency of 30 Hz. The detectors time constant is 12 ms with accuracy $\pm 2^\circ\text{C}/\pm 2\%$ and sensibility of 0.05 °C at +30 °C.

OST measurements were carried out by only one examiner in order to avoid inter-examiner variation, in a room without windows, illuminated with neon lights. Both temperature and humidity were constantly monitored and maintained to an average of 22.1 \pm 0.5°C and 43 \pm 4% by using an air conditioning system.

The same procedure was applied for each thermographic acquisition. Subjects remained in the test-room for 20 minutes [10], so that the own body temperature could adapt to the climatic condition of test-room. Then, subjects' chin was positioned on an ophthalmic chinrest in front of the thermocamera, whose lens was positioned at 500 mm. The subject was asked to keep both eyes closed for 10 s before starting the measurement. Subjects were asked to keep both eyes widely open during the thermographic acquisition (7 s at 30 Hz), so that both eyes could be measured in just one recording. Three recordings were taken for each subject.

For each thermographic acquisition only the first frame corresponding to the eye opening was selected for further analysis, in order to avoid the influence of the tear-film evaporation [10]. A LabVIEW program (2012, National Instruments, USA) was used to calculate, from the selected

frames, the temperatures of five anatomical points (Figure 1) corresponding to the principal anatomical areas of the anterior eye: corneal centre (P_3), temporal and nasal *limbi* (P_5 and P_1), and scleroconjunctival region (P_2 and P_4). P_1 , P_3 and P_5 were manually identified, whereas P_2 and P_4 were automatically chosen on the arc of a parabola passing through the other points.

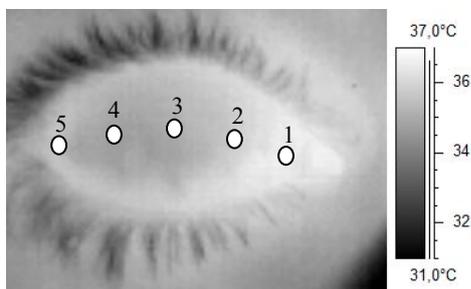


Figure 1: IR image of an eye. 1=nasal limbus, 3=corneal centre, 5=temporal limbus, 2-4=scleroconjunctival regions.

One-way ANOVA was applied in order to assess the measurements repeatability as well as the difference among the temperature of the five points selected. Paired *t*-test was carried out in order to compare right (RE) and left (LE) eyes, while a multivariate regression analysis was used to evaluate which predictors were significantly influencing the OST. A P -value <0.05 was chosen to indicate a significance.

RESULTS AND DISCUSSION

A typical OST profile was found for both eyes (Figure 2). ANOVA tests confirmed the repeatability of the measurements (P -value >0.05), so for each subject the OST was calculated as the average of the three temperatures, and a significant difference among the temperature of all five points for both RE and LE (P -value <0.0001). Paired *t*-test showed that there was no significant difference between RE and LE. In order to carry out the multivariate regression analysis, some stratifications were made: 1) visual defects were divided into: myopia ($N=53$), astigmatism ($N=37$), presbyopia ($N=59$) and hypermetropia ($N=6$); 2) the levels of physical activity were classified as: none, mild, moderate or intense; 3) the smoking history was simplified by dividing the subjects into three groups: smokers, non-smokers and ex-smokers. Specifically, the non-smokers included also those who had stopped smoking for more than fifteen years. Table 3 shows P -values obtained by the multivariate regression analysis. Gender, smoke and ocular defects did not influence significantly the OST of any points of both RE and LE, whereas age, body temperature and physical activity influenced significantly the OST of all points. Specifically, results showed a negative correlation between age and OST (Figure 3), and a positive correlation between body temperature and OST. The effect of weight and height on the OST needs more investigations as these two predictors seem to influence only two points.

CONCLUSIONS

Results confirmed the repeatability of the measurements as well as the significant difference among all five points. The latter finding confirms the necessity to evaluate the OST of each anatomical region of the eye. Furthermore, the strong correlations OST-age and OST-body temperature indicate

the necessity to take into account these two subject factors when investigating different groups. This database will be used for further analysis on pathologic eyes.

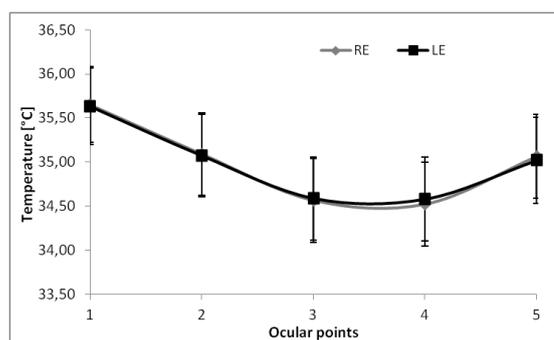


Figure 2: Average OST profile for both right and left eyes.

Table 3: P -values found by multivariate regression analysis

	T1	T2	T3	T4	T5
Age	0.000	0.000	0.000	0.000	0.000
Gender	0.410	0.728	0.883	0.924	0.690
Height	0.027	0.150	0.081	0.269	0.064
Weight	0.013	0.028	0.073	0.122	0.199
Body Temperature	0.000	0.000	0.000	0.000	0.000
Ocular defects	0.247	0.410	0.349	0.143	0.243
Physical activity	0.039	0.033	0.017	0.020	0.025
Smoke	0.661	0.620	0.615	0.708	0.914

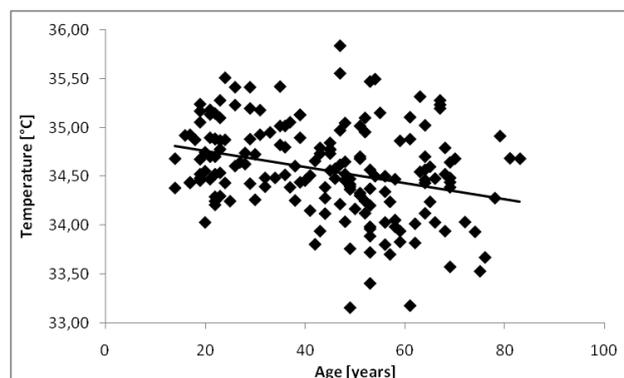


Figure 2: Typical OST behavior as a function of age.

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