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Tear Production in Three Captive Wild Herbivores in Israel

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ABSTRACT: The Schirmer tear test (STT) I was performed to evaluate tear production in 12 captive Nubian ibex (*Capra ibex nubiana*), 10 captive Burchell's zebras (*Equus burchelli*) and five Arabian oryx (*Oryx leucoryx*) at the Tel-Aviv Ramat-Gan Zoological Center (Israel). Mean (±standard deviation) STT values were 13.2 ± 5.1 mm/min in the ibex, 23.4 ± 3.4 mm/min in the zebra and 12.7 ± 4.8 mm/min in the oryx. There were no significant effects of gender, age, weight, or side of the eye. There were no significant differences in STT values between ibex and oryx, but tear production in both species was significantly lower than in zebras. Knowledge of normal tear production values is important for the differential diagnosis of conjunctivitis and keratitis in these species.

Key words: Arabian oryx, Burchell's zebra, *Capra ibex nubiana*, *Equus burchelli*, Nubian ibex, *Oryx leucoryx*, Schirmer tear test, tear production.

Tears play an important role in maintaining the health and normal function of the conjunctiva and cornea. Tears help remove foreign matter, provide essential nutrients to the avascular cornea, and contain immunoglobulins, lysozymes, and other proteins important for the defenses of the eye (Gum, 1991). The tear film also is one of the most important refractive surfaces of the eye in terrestrial species, because it is the first ocular surface through which incoming light passes. Deficiency in tear production results in inflammation of the conjunctiva and cornea known as keratoconjunctivitis sicca (KCS). In the dog, such inflammation may result in corneal ulceration, and, if untreated, even corneal perforation (Gelatt, 1991). Loss of vision due to progressive corneal pigmentation is also a possible sequela of the disease (Gelatt, 1991).

Traditionally, diagnosis of KCS is based on the Schirmer tear test (STT) I, which measures production of the aqueous portion of the tear film (Gelatt et al., 1975). However, there are large interspecies variations in normal STT values. For example, normal tear production in the rhesus monkey (*Macaca mulatta*) is 15.1 mm/min (Jaax et al., 1984) but it is 24.9 mm/min in the African lion (*Panthera leo*) (Ofri et al., 1997). Thus, what is considered normal tear production in the former would be deficient in the latter. Therefore, it would be most difficult to rule out KCS as a differential diagnosis for keratoconjunctivitis if the normal STT value for that species is not known. Due to the importance of establishing baseline values, and because keratoconjunctivitis has been diagnosed in large herbivores including ibex (Mayer et al., 1997), we decided to evaluate tear production in three wild ungulates.

All experiments were conducted on animals held at the Tel-Aviv Ramat-Gan Zoological Center (Tel Aviv, Israel; 32°3′N, 34°46′E). Tear production was measured in 12 Nubian ibex (*Capra ibex nubiana*) anesthetized 17 February to 25 March 1997 for hoof trimming. Tear production also was measured in 10 Burchell's zebras (*Equus burchelli*) anesthetized 12 March to 14 April 1997 for transportation. Later that year (24 June to 15 July 1997), tear production was measured in five Arabian oryx (*Oryx leucoryx*) which were anesthetized for castration. All animals were anesthetized with intramuscular injection by dart of etorphine hydrochloride and acepromazine maleate (Large Animal Immobilon, C-Vet Ltd., Leyland, UK) (Table 1). All animals were healthy as determined by thorough physical examination, including complete blood count and serum biochemistry panel.

Tear production was measured using the standard Schirmer tear test I as previously described by Gelatt et al. (1975). The test

TABLE 1. Tear production in captive herbivores using the Schirmer tear test in Israel

Species	Number[a] M	Number[a] F	Mean age (year ± SD)[b]	Mean weight (kg ± SD)	Anesthetic volume (ml)[c]	Tear production (mm/min ± SD)
Nubian ibex	6	6	8.3 ± 2.0	39.1 ± 8.3	0.85, 0.55[d]	13.2 ± 5.1
Burchell's zebra	2	8	1.08 ± 0.32	138 ± 24	0.95	23.4 ± 3.4
Arabian oryx	5	0	10.2 ± 2.1	132 ± 16.4	3.0	12.7 ± 4.8

[a] Number of animals; M = males, F = females.
[b] SD = standard deviation.
[c] Each ml contained 2.45 mg of etorphine hydrochloride and 10 mg of acepromazine maleate (see text).
[d] Males, females.

was conducted using commercial tear flow test strips (Schering Plough Animal Health Corp., Kenilworth, New Jersey, USA) of a single lot number. These test strips contain a small amount of dye that is carried by the tears which the paper absorbs. A sterile strip was inserted for 1 min in the lower conjunctival fornix of the eye. The distance in mm which the dye covered in 1 min was determined from the scale imprinted on the test strips. Values were recorded from both eyes of each animal; the first eye to be tested was determined randomly. Measurements were conducted 15 min after the animal was darted, and prior to any manipulation or examination of the eyes. Following STT measurement, a complete ophthalmological examination, including tonometry, slit lamp biomicroscopy and indirect ophthalmoscopy, was performed. No abnormalities were detected.

Repeated measures and/or one-way analysis of variance was initially used to evaluate the main effects of age, weight, sex and eye side (left versus right eye), and their interactions on the dependent variable (the STT result). As none of these were found to have a significant effect on the STT result (see below), the average STT result for each animal was calculated and used to obtain the mean and standard deviation for each of the species. Post-hoc multiple comparison tests, using Scheffe's method, were conducted to study interspecies differences. All analyses were performed using a computer statistics program (PC 90, BMDP Statistical Software, Los Angeles, California, USA). Values of $P < 0.05$ were considered statistically significant.

The mean ± standard deviation STT value in 12 ibex was 13.2 ± 5.1 mm/min (Table 1). The mean STT value in 10 zebras was 23.4 ± 3.4 mm/min. The mean STT value in five oryx was 12.7 ± 4.8 mm/min. There were no significant differences between males and females ($P = 0.27$) (except in oryx, where only males were studied), nor between left and right eyes ($P = 0.68$). The effects of animal weight ($P = 0.92$) and age ($P = 0.67$) also were not significant.

When STT values of the different species were compared, no significant differences were found between ibex and oryx ($P = 0.98$). However, STT values in zebras were significantly higher than in ibex ($P = 0.002$) and in oryx ($P = 0.009$).

Previously reported STT values in various species include 15.1 mm/min in the rhesus monkey (Jaax et al., 1984), 16.9 mm/min in the domestic cat (Arnett et al., 1984), 21.0 mm/min in the dog (Gelatt et al., 1975), 23.9 mm/min in the horse (Brightman et al., 1983) and 24.9 mm/min in the lion (Ofri et al., 1997). Tear production in zebras is comparable to that of most species. It is interesting to note the similarity between STT values in the zebra and the closely-related horse. However, one should be careful not to extrapolate STT values of one species from those of other closely-related species. This becomes evident when comparing STT values of the domestic cat (Arnett et al., 1984) to those of the lion (Ofri et al., 1997).

To the best of our knowledge, STT values in both ibex (13.2 mm/min) and oryx (12.7 mm/min) are lower than those reported for any other species studied. These relatively low values may predispose the eye to secondary infection, and may explain the reported susceptibility of the ibex eye to *Mycoplasma* spp. infection (Mayer et al., 1997). Indeed, Mayer et al. (1997) state that neither *Mycoplasma conjunctivae* nor *Chlamydia psittaci* appear capable in themselves of producing the most severe form of infectious keratoconjunctivitis. We propose that the low STT values recorded in ibex may increase the susceptibility of this species to infectious corneal and conjunctival pathogens.

One possible explanation for the low values recorded in ibex and oryx is that tear production was measured in anesthetized animals. However, anesthesia does not always result in lower tear production. Schirmer tear test values obtained in horses anesthetized with xylazine (Brightman et al., 1983), in cats anesthetized with ketamine and acepromazine (Arnett et al., 1984) and in rhesus monkeys anesthetized with ketamine (Jaax et al., 1984) were not affected by anesthesia. Furthermore, we recorded significantly higher STT values in zebras using the same anesthetic protocol, thus showing that high tear production may be recorded in animals anesthetized with Large Animal Immobilon. Another possible explanation for lower STT vales is evolutionary adaptation. Both the ibex and the oryx are desert-dwelling species. Therefore, it is tempting to think that low tear production may be a fluid conservation mechanism of animals living in arid areas. However, the daily tear volume, for example 1.7 ml per eye per day in humans (Lemp and Wolfley, 1992), would probably make such a contribution to fluid conservation insignificant. Therefore, it is unlikely that there would be a significant evolutionary drive to lower tear production in these species. While one can only speculate about the reasons for the low STT values recorded in the ibex and oryx, it should be emphasized that tear production in the animals tested appears to be adequate. No signs of conjunctival or corneal inflammation were detected in any of the eyes examined.

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