



Determination of Intraocular Pressure Reference Values in Gazelles in Şanlıurfa*

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This study aimed to determine species-specific reference values for intraocular pressure (IOP) in healthy gazelles (*Gazella subgutturosa*) living in the Şanlıurfa region by performing IOP measurements using rebound tonometry without sedation and in a natural standing posture. A total of 20 healthy individuals aged between 0 and 6 months (10 females and 10 males) were included in the study, and both eyes of each subject were evaluated separately, resulting in a total of 40 eyes. IOP measurements were performed using the Icare® TONOVET Plus device in "d" mode, without the application of topical anesthetics or sedatives, with the animals in a standing position. For each eye, the mean of six consecutive measurements was used. Data were analyzed using parametric methods, and the level of significance was set at $p < 0.05$. The mean IOP values for the right and left eyes were 20.5 ± 8.1 mmHg and 22.1 ± 9.7 mmHg, respectively, with no statistically significant difference between them ($p = 0.471$). The overall mean IOP was calculated as 21.3 ± 9.0 mmHg. IOP was found to be significantly higher in female individuals compared to males (24.3 ± 9.1 vs. 17.6 ± 6.8 mmHg; $p = 0.026$). No statistically significant difference in IOP was observed among the age groups. This study defines the first IOP reference values obtained without sedation using rebound tonometry in *Gazella subgutturosa* and provides clinically valuable reference data for the diagnosis and monitoring of traumatic, inflammatory, and glaucoma-like ophthalmic conditions.

Key Words: Gazelle, intraocular pressure, rebound tonometry, reference values, ophthalmology

Şanlıurfa'daki Ceylanlarda Göz İçi Basıncı Referans Aralıklarının Belirlenmesi

Bu çalışmada, Şanlıurfa bölgesinde yaşayan sağlıklı ceylanlarda (*Gazella subgutturosa*) sedasyon uygulanmaksızın ve doğal ayakta duruş pozisyonunda rebound tonometri kullanılarak göz içi basıncı (GİB) ölçümleri gerçekleştirilmiş ve türe özgü referans aralıklarının belirlenmesi amaçlanmıştır. Çalışmaya, 0–6 ay yaş aralığında 10'u dişi ve 10'u erkek olmak üzere toplam 20 sağlıklı birey dâhil edilmiş; her bireyin her iki gözü ayrı ayrı değerlendirilerek toplam 40 göz incelenmiştir. GİB ölçümleri, topikal anestezi veya sedatif madde kullanılmadan, hayvanlar ayakta pozisyondayken, Icare® TONOVET Plus cihazının "d" modu kullanılarak gerçekleştirilmiştir. Her göz için ardışık altı ölçümün ortalaması analizlerde esas alınmıştır. Verilerin istatistiksel değerlendirilmesinde parametrik testler kullanılmış ve anlamlılık düzeyi $p < 0.05$ olarak kabul edilmiştir. Sağ ve sol gözler için ortalama GİB değerleri sırasıyla 20.5 ± 8.1 mmHg ve 22.1 ± 9.7 mmHg olarak belirlenmiş olup, gözler arasında istatistiksel olarak anlamlı bir fark saptanmamıştır ($p = 0.471$). Genel ortalama GİB değeri 21.3 ± 9.0 mmHg olarak hesaplanmıştır. Dişi bireylerde GİB değerlerinin erkeklere kıyasla anlamlı derecede daha yüksek olduğu belirlenmiştir (24.3 ± 9.1 mmHg'ye karşı 17.6 ± 6.8 mmHg; $p = 0.026$). Yaş grupları arasında GİB açısından istatistiksel olarak anlamlı bir fark bulunmamıştır. Bu çalışma, *Gazella subgutturosa* türünde sedasyon uygulanmadan rebound tonometri kullanılarak elde edilen ilk GİB referans aralıklarını tanımlamakta olup; travmatik, inflamatuvar ve glokoma benzeri oftalmik hastalıkların tanı ve izlenmesinde klinik açıdan değerli referans veriler sunmaktadır.

Anahtar Kelimeler: Ceylan, göz içi basıncı, rebound tonometri, referans değerler, oftalmoloji

Introduction

Gazelles (*Gazella subgutturosa*) are among the endangered wildlife species that naturally inhabit the Southeastern Anatolia Region of Türkiye, particularly around Şanlıurfa, and are characterized by high mobility (1). The innate sudden escape reflex, directional agility, and herd behavior of this species predispose it to trauma-related ophthalmic pathologies (2). In addition, environmental stressors and infectious agents encountered in natural habitats are major risk factors that may adversely affect ocular health.

Intraocular pressure (IOP) is a fundamental physiological parameter widely used in both human and veterinary medicine for the diagnosis, monitoring, and treatment of ophthalmological diseases such as glaucoma, uveitis, and conjunctivitis (3, 4). IOP reflects the dynamic balance between aqueous humor production and drainage. Disruption of this balance may result in optic nerve damage, permanent vision loss, and serious clinical conditions such as glaucoma (5, 6). Therefore, accurate and reliable measurement of IOP is of great importance, particularly in post-traumatic evaluations and cases of systemic diseases (7).

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Although reference values for IOP have been defined in veterinary literature for cats, dogs, horses, rats, and some exotic species, there are no available reference values for gazelles (8-10). This gap creates uncertainty, particularly during diagnostic and therapeutic processes, and the use of reference values extrapolated from different species, reduces the measurement accuracy and reliability of clinical decisions. Moreover, considering physiological variables, such as the effects of anesthetic agents on IOP and the influence of body position on measurements, the lack of species-specific reference values for *Gazella subgutturosa* represents a significant clinical limitation (11-13).

This study aimed to perform systematic IOP measurements in healthy male and female *Gazella subgutturosa* individuals using the rebound tonometry method without sedation and in a natural posture and to define scientifically based reference values for this species. The original dataset intended to be obtained is expected to provide clinical reference values applicable to the diagnosis, monitoring, and treatment of glaucoma, conjunctivitis, uveitis, and traumatic ocular diseases. In addition, these data are anticipated to contribute to clinical decision-making processes on an objective basis and to provide a scientific foundation for the long-term health management of this endangered species.

Materials and Methods

Research and Publication Ethics: The study protocol was approved by the Local Ethics Committee on Animal Experiments, Harran University (session and permit number: 2025/004/09).

Animal Material and Study Design: The study was conducted on 20 gazelles (*Gazella subgutturosa*) aged between 0 and 6 months, who were brought to the Harran University Faculty of Veterinary Medicine Animal Hospital for routine health examinations and were considered clinically healthy. Ten gazelles were female, and ten were male. Both eyes of each individual were evaluated separately, for a total of 40 eyes.

Prior to IOP measurement, all animals underwent a detailed ophthalmological examination. This evaluation included assessment of blink reflex, pupillary light reflex, and direct ophthalmoscopy (Gowllands® Ophthalmoscope, United Kingdom). Individuals with no signs of ophthalmic or systemic disease were included in the study.

Tonometry Procedure: IOP measurements were performed using the Icare® TONOVET Plus device (Finland), which operates based on the rebound tonometry principle (Figure 1). Because no species-specific calibration mode is available for gazelles, the “d” mode was selected based on its widespread use in medium-sized mammals with comparable corneal biomechanics. Manufacturer-specific recommendations for *Gazella subgutturosa* are currently unavailable. Measurements were conducted in the device’s “d” mode, in accordance with the manufacturer’s instructions,

without the use of topical or systemic anesthetics, and without sedation (3). All measurements were carried out by the same investigator within the same time interval to minimize circadian variability. All measurements were performed between 09:00 and 12:00 to minimize the effects of diurnal variation in intraocular pressure. During the procedure, gazelles were manually restrained in their natural standing posture. Measurements were first obtained from the right eye and subsequently from the left eye. The tonometer probe was positioned perpendicular to the center of the cornea at an approximate distance of 4–8 mm, and the mean of six consecutive measurements was used for evaluation. A new probe tip was used for each animal (14). Care was taken to avoid pressure on the neck region and eyelid manipulation was minimized. All the procedures were performed in a quiet environment to prevent stress. The values obtained from each eye were recorded separately and the arithmetic mean of the right and left eye measurements was calculated as the individual IOP value.

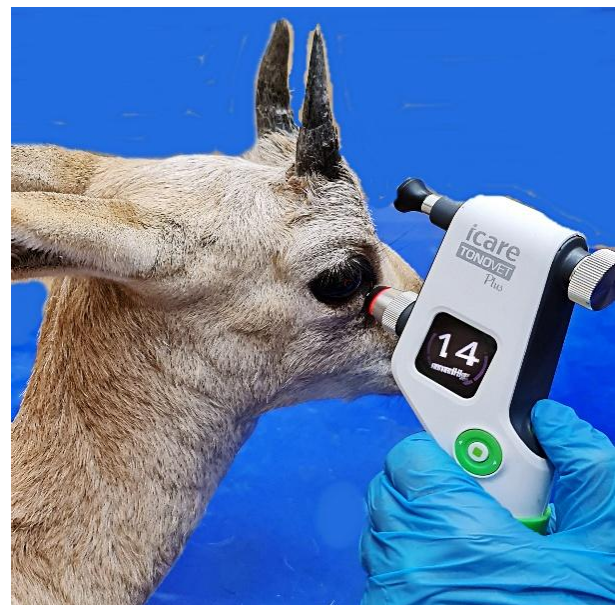


Figure 1. Measurement of intraocular pressure in a gazelle using the Icare® TONOVET Plus rebound tonometer without sedation

Statistical Analysis: Statistical analyses were performed using the IBM SPSS Statistics 22.1 software (IBM Corp., Armonk, NY, USA). The distribution characteristics of the quantitative data were assessed using the Shapiro–Wilk test. Results are reported as the mean $\pm$ standard deviation (SD) and median (min–max). To determine the differences between IOP values obtained from the right and left eyes, a paired-samples t-test was used when the data were normally distributed, whereas the Wilcoxon signed-rank test was applied when normality was not met. To avoid pseudoreplication, the mean of the right and left eye measurements was calculated for each individual and used as the unit of analysis in all subsequent comparisons. Comparisons of IOP between sex groups were performed using an

independent-samples t-test under parametric conditions and the Mann–Whitney U test. Homogeneity of variances was assessed using Levene's test prior to one-way ANOVA. One-way analysis of variance (ANOVA) was used to assess differences in mean IOP values among age groups, and the Kruskal–Wallis test was preferred when parametric assumptions were not satisfied. In all statistical analyses, the level of significance was set at $p < 0.05$.

Results

Evaluation of intraocular pressure (IOP) measurements in gazelles revealed a mean value of 20.5 ± 8.1 mmHg in the right eye and 22.1 ± 9.7 mmHg in the left eye. According to the paired-samples t-test, no statistically significant difference was detected between the right- and left-eye values ($p = 0.471$). Therefore, the mean of the right- and left-eye values for each individual was calculated and used as the representative IOP value in subsequent analyses (Table 1).

In comparisons based on sex, IOP values in female gazelles (24.3 ± 9.1 mmHg) were significantly higher than those in males (17.6 ± 6.8 mmHg). The independent-sample t-test demonstrated that this difference was statistically significant ($p = 0.026$). This finding suggests that sex may have a potential influence on IOP.

Evaluation according to age groups showed no statistically significant difference in IOP values based on the results of one-way analysis of variance (ANOVA) ($p = 0.222$). Among the age groups, the most commonly represented group, 30-day-old individuals, exhibited a mean IOP value of 21.3 ± 9.3 mmHg, which was comparable to those of the other age groups (Table 2).

Table 1. Descriptive statistics of intraocular pressure (IOP) values obtained by rebound tonometry in healthy *Gazella subgutturosa* individuals

Variable	Number of eyes	Mean $\pm$ SD (mmHg)	Median
Right eye	20	20.5 ± 8.1	19
Left eye	20	22.1 ± 9.7	21
Both eyes (mean)	40	21.3 ± 9.0	20
Male	20	17.6 ± 6.8	17
Female	20	$24.3 \pm 9.1^*$	23

Measurements were performed while the animals were in a standing position, without applying pressure to the head or neck region. * $p < 0.05$ indicates a statistically significant difference

Table 2. Descriptive statistics of intraocular pressure (IOP) values measured in *Gazella subgutturosa* individuals according to age groups

Age group	Number of eyes	Mean $\pm$ SD (mmHg)	Median
0–15 days	4	20.0 ± 5.2	20
30 days	28	21.3 ± 9.3	20
30–60 days	4	20.8 ± 11.4	20
60–360 days	4	23.0 ± 9.3	23
Total	40	21.3 ± 9.0	20

IOP values were calculated by averaging the right and left eye measurements for each individual. No statistically significant difference was detected among age groups (ANOVA, $p > 0.05$).

Discussion

This study makes a significant contribution to the literature as the first scientific investigation to report intraocular pressure values measured by rebound tonometry in gazelles (*Gazella subgutturosa*). Considering both the biological characteristics of the species and the challenges associated with ophthalmic examinations, the data obtained are of particular importance for establishing reference values and improving clinical approaches.

Despite the lack of interocular statistical differences, each eye should be evaluated individually, as certain ophthalmic disorders may develop unilaterally. However, for greater reliability and to reduce measurement error, evaluation of both eyes together is considered more appropriate (5, 8, 15, 16). The significantly higher IOP observed in females compared with males in the present study (24.3 ± 9.1 mmHg vs. 17.6 ± 6.8 mmHg; $p = 0.026$) suggests the presence of species-specific and potentially sex-related physiological differences. Although similar sex-related effects have been reported in some avian species in association with head position (e.g., higher IOP in male adult cranes) (17), sex-related differences are not consistent between members of the Cervidae and Bovidae families. Therefore, confirmatory studies on gazelles that concurrently investigate variables such as ocular biometry, hormonal status, and corneal thickness are warranted. However, given the relatively small overall sample size, this finding should be interpreted cautiously and warrants confirmation in larger population-based studies.

The mean IOP obtained in gazelles in the present study (both eyes: 21.3 ± 9.0 mmHg) was close to, but slightly lower than, the values reported in conscious red deer measured by rebound tonometry (26.8 ± 4.1 mmHg) (8). When compared with the mean values reported using applanation tonometry in eland and fallow deer (14.6 ± 4.0 and 11.9 ± 3.3 mmHg, respectively) (4), it is evident that differences in device type and measurement method can significantly influence absolute IOP values. Indeed, in white-tailed deer, measurements obtained with the TonoPen® were higher than those obtained with the TonoVet® in the same individuals (15.6 ± 2.9 vs. 12.9 ± 2.6 mmHg), demonstrating a systematic measurement bias between the two devices (9). Similar rebound–applanation comparisons in dogs and horses have also indicated small but clinically significant interdevice offsets (18). Previous studies in cervids and other ungulate species have reported variability in intraocular pressure measurements depending on the selected TonoVet calibration mode and device type. Therefore, further manometric validation studies are required to determine the most appropriate calibration mode for gazelles. In addition, deviations from manometric measurements may be significant among the species modes of TonoVet Plus®; for example, in the porcine eye, the “equine” mode yielded the highest accuracy, whereas the “canine” and “leporine” modes systematically overestimated IOP (19). In the present protocol, the “d” mode was used; however, because no

species-specific calibration is available for gazelles, further studies involving manometric validation or determination of the most appropriate mode are considered necessary.

In this study, all measurements were performed with the animals in a standing position, without applying pressure to the head or neck region, and with minimal manipulation of the eyelids to avoid position- and manipulation-related increases or decreases in IOP. This approach is consistent with strong evidence in horses showing that IOP increases markedly when the head is lowered below the heart level and decreases when it is elevated (20). A wide range of IOP changes associated with head position during hoisting or inversion have been reported (11). In dogs, measurable short-term changes in IOP related to body position have been described (21). In cranes, the position of the head relative to the heart level has been shown to significantly affect IOP (17). This body of literature reinforces the necessity of recording body position during both field and clinical IOP measurements as well as ensuring identical conditions during repeated measurements.

No significant differences were detected among age groups in the present study, which is consistent with findings in white-tailed deer showing no age-related differences in IOP (9). However, in some species, IOP has been reported to increase with age and body weight during development (e.g., in crane chicks) (17). Sensitivity to environmental conditions may vary among species. For instance, significant location-related variability in IOP has been reported in Pygoscelis penguins (7), highlighting the potential influence of environmental stressors and climate in field studies. In addition, a slight but significant age-related decrease in IOP has been reported in black-footed penguins (22), which may be associated with changes in corneal or ocular biomechanics or autonomic tone. Because central corneal thickness (CCT) was not measured in the present study, the potential effect of CCT cannot be excluded. Although reports in some species indicate that the influence of CCT on IOP measurements is limited or negligible (22), this relationship requires confirmation in gazelles.

Veterinary studies have demonstrated that anesthetic and sedative agents can significantly reduce IOP and, more rarely, increase it; moreover, sensitivity may vary depending on the measurement device and mode used (13, 15). Pronounced device- and mode-related differences have been reported in coaties (23). TonoVet® has been shown to be more accurate and sensitive than TonoLab® in chinchillas (24), and TONOVET Plus has demonstrated high accuracy within

the clinical range in the rabbit eye (25). In the present study, the use of a sedation-free measurement protocol was considered particularly important for reference value generation because it eliminates pharmacological influences. In addition, the distance between the probe and cornea and the perpendicular contact of the probe with the corneal surface are critical for measurement accuracy (18). During application in gazelles, strict adherence to these standardization criteria was ensured.

The findings of this study provide the first reference IOP values that allow objective interpretation of IOP in gazelles in cases of trauma, suspected uveitis, or glaucoma, and postoperative follow-up. Despite the absence of interocular differences, bilateral assessment remains essential in clinical settings. The higher IOP values observed in females should be interpreted with caution until validated by larger studies. It should be emphasized that IOP values obtained without standardization of body position, head and neck pressure, and measurement techniques may lead to false-positive or false-negative results (11, 17, 20, 21). Device selection and calibration mode should also be considered when defining clinical thresholds (18, 19, 24).

This study had several limitations. First, the sample sizes within the age subgroups were small, limiting the statistical power of the subgroup comparisons. The absence of statistically significant age-related differences should be interpreted cautiously, as the statistical power of subgroup analyses was limited by small and highly unbalanced sample sizes across age categories. Second, the single-center design and performance of measurements within a single time period of the day did not allow the assessment of known diurnal fluctuations in IOP. Third, because CCT and ocular biometry were not measured in gazelles, the potential effects of these covariates on IOP cannot be excluded. Furthermore, multicenter studies encompassing different habitats and climatic regions would provide a more comprehensive understanding of the effects of environmental factors on IOP (7).

In conclusion, IOP data, obtained without sedation in a natural posture using a standardized technique, provide a clinical reference value for gazelles. This study offers the first indication of sex-related differences and highlights the critical importance of the triad of body position, device selection, and calibration mode in IOP measurements. These reference values are expected to support clinical decision-making in the diagnosis and monitoring of traumatic and inflammatory ocular diseases, and contribute to the preventive health management of this species.

References

- Demircioğlu I, Gezer Ince N. Three-dimensional modeling of limb bones of gazelles (*Gazella subgutturosa*) using computed tomography images. *Anat Histol Embryol* 2020; 49(6): 695-707.
- Bozkaya F, Gürlür Ş. Sequence diversity of MHC class-II DRB gene in gazelles (*Gazella subgutturosa*) raised in Şanlıurfa of Turkey. *J Genet* 2018; 97: 897-903.
- Ofri R, Horowitz IH, Kass PH. How low can we get? Tonometry in the Thomson gazelle (*Gazella thomsoni*). *J Glaucoma* 2000; 9(2): 187-189.
- Ofri R, Horowitz IH, Levison M, Kass PH. Intraocular pressure and tear production in captive eland and fallow deer. *J Wildl Dis* 2001; 37(2): 387-390.

5. Çetin Ç, Pamuk K, Yaprakçı MV. Intraocular pressure in buffalo calves. *Kocatepe Veteriner Dergisi* 2014; 7(2): 1-8.
6. Gum GG, Gelatt KN, Miller DN, Mackay EO. Intraocular pressure in normal dairy cattle. *Vet Ophthalmol* 1998; 1(2-3): 159-161.
7. Bayram LC, Isler CT, Ekebas G. Determination of reference values for tear production and intraocular pressure in *Pygoscelis* penguins of the Antarctic Peninsula. *BMC Vet Res* 2023; 19: 235.
8. Kovalcuka L, Malniece A. Measurement of tear production and intraocular pressure in clinically conscious normal captive red deer (*Cervus elaphus*). *Animals* 2024; 14(6): 940.
9. Villar T, Pascoli AL, Klein A, et al. Tear production, intraocular pressure, and central corneal thickness in white-tailed deer (*Odocoileus virginianus*). *Vet Ophthalmol* 2020; 23(1): 123-128.
10. Yener K, Yavuz Ü, Hayat A, et al. Effect of xylazine, midazolam and dexmedetomidine preanaesthetics on changes in intraocular pressure in rats. *Acta Sci Vet* 2024; 52(1): 141948.
11. Alling CR, Cremer J, Liu CC, et al. Effect of multiple head positions on intraocular pressure in healthy anesthetized horses during hoisting. *Vet Ophthalmol* 2020; 24(1): 71-79.
12. Meekins JM, McMurphy RM, Roush JK. The effect of body position on intraocular pressure in anesthetized horses. *Vet Ophthalmol* 2020; 23(4): 668-673.
13. Yener K, Hurma MS. Intraosseous, intranasal and intramuscular administration of butorphanol and midazolam on intraocular pressure in pigeon. *Rev MVZ Córdoba* 2025; 30(3): e3749.
14. Rodrigues BD, Montiani-Ferreira F, Bortolini M, et al. Intraocular pressure measurements using the TONOVET rebound tonometer: influence of the probe-cornea distance. *Vet Ophthalmol* 2021; 24(Suppl 1): 175-185.
15. Varga EJ, Colon VA, McDermott CT, Lam HK, Magouras I. Intraocular pressure in Chinese edible frogs (*Hoplobatrachus rugulosus*) by rebound tonometry: Comparing sex and use of anesthesia. *J Herpetol Med Surg* 2024; 34(4): 251-255.
16. Wojick KB, Naples LM, Knapp CR. Ocular health assessment, tear production, and intraocular pressure in the Andros Island iguana (*Cyclura cychlura cychlura*). *J Zoo Wildl Med* 2013; 44(1): 116-123.
17. Garcés Torres RS, Carter RT, Gafen HB, et al. Longitudinal intraocular pressure measurements in whooping cranes (*Grus americana*) and Mississippi sandhill cranes (*Grus canadensis pulla*). *Vet Ophthalmol* 2024; 27(5): 414-423.
18. Knollinger AM, La Croix NC, Barrett PM, Miller PE. Evaluation of a rebound tonometer for measuring intraocular pressure in dogs and horses. *J Am Vet Med Assoc* 2005; 227(2): 244-248.
19. Chae J, Mills PO, Walker A, Curry B. Calibration of the TonoVet Plus tonometer to measure intraocular pressure in porcine eyes. *Invest Ophthalmol Vis Sci* 2023; 64: 1382.
20. Komáromy AM, Garg CD, Ying GS, Liu C. Effect of head position on intraocular pressure in horses. *Am J Vet Res* 2006; 67(7): 1232-1235.
21. Broadwater JJ, Schorling JJ, Herring IP, Elvinger F. Effect of body position on intraocular pressure in dogs without glaucoma. *Am J Vet Res* 2008; 69(4): 527-532.
22. Gonzalez-Alonso-Alegre EM, Martinez-Nevado E, Caro-Vadillo A, Rodriguez-Alvaro A. Central corneal thickness and intraocular pressure in captive black-footed penguins (*Spheniscus demersus*). *Vet Ophthalmol* 2015; 18(Suppl 1): 94-97.
23. Carvalho CM, Rodarte-Almeida ACV, Moore BA, et al. Ocular examination findings and measurements of tear production and tonometry of ring-tailed coatis (*Nasua nasua*). *Vet Ophthalmol* 2021; 24(3): 210-217.
24. Snyder KC, Lewin AC, Mans C, McLellan GJ. Tonometer validation and intraocular pressure reference values in the normal chinchilla (*Chinchilla lanigera*). *Vet Ophthalmol* 2018; 21(1): 4-9.
25. Gloe S, Rothering A, Kiland JA, McLellan GJ. Validation of the Icare TONOVET Plus rebound tonometer in normal rabbit eyes. *Exp Eye Res* 2019; 185: 107698.