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Study on the influence of body position, eyelid manipulation, and jugular vein compression on intraocular pressure in healthy horses

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Abstract
This research aims to investigate the impact of body position, eyelid manipulation, and jugular vein compression on intraocular pressure in healthy horses. Seven healthy horses, including both male and female, aged between 5 to 8 years, and weighing between 250 to 350 kilograms, were selected. After thorough examination and confirmation of the horses' health, intraocular pressure was measured using rebound tonometry. Initially, baseline intraocular pressure was measured with the head positioned horizontally relative to the ground and without any pressure on the neck or eyelid. Subsequently, five manipulation conditions were applied to each eye, including unilateral jugular vein compression, bilateral jugular vein compression, eyelid dorsal-ventral traction, eyelid lateral traction, and external eye compression. After completing the manipulations, intraocular pressure was measured in the head-up position. The obtained data results were statistically analyzed using the T-Student method. The mean intraocular pressure in baseline, unilateral compression, bilateral compression, eyelid dorsal-ventral traction, eyelid lateral traction, head position, and external eye compression conditions were 76.4 ± 23.86 mmHg, 29.5 ± 26.93 mmHg, 80.5 ± 30.49 mmHg, 83.5 ± 32.78 mmHg, 96.4 ± 27.43 mmHg, 99.4 ± 27.28 mmHg, and 20.5 ± 27.21 mmHg, respectively. The results indicated a significant difference ($p<0.05$) only in the left eye intraocular pressure values between BJC and DE treatments compared to the Baseline treatment. Conversely, a significant difference ($p<0.05$) was observed in the right eye intraocular pressure values between all treatment conditions and the Baseline treatment. Unilateral jugular vein compression, bilateral jugular vein compression, eyelid dorsal-ventral traction, head position, eyelid lateral traction, and external eye compression exerted an effect on intraocular pressure in horses, leading to its increase.

Keywords: Body position, intraocular pressure, rebound tonometry, horse

Introduction

The eye, one of the most intricate and fascinating structures in the body, consists of interrelated components working together to create the sense of vision. Generally, the eye is composed of three layers: fibrous, vascular, and neural [1]. The eye, or visual organ, is the most advanced sensory organ in the body. All normal mammals possess a pair of eyes situated within a bony orbit in the skull. The posterior part of the eye is filled with a gel-like substance called the vitreous, while the anterior part is filled with a fluid known as aqueous humor. This transparent and gelatinous fluid is referred to as aqueous humor. Aqueous humor is in a constant state of flux, being produced within the eye and exiting after fulfilling its metabolic role in eye physiology. The presence of aqueous humor creates pressure from within to the external surface in the anterior part of the eye, maintaining the shape and structural integrity of the eye's surface while playing a crucial role in its nutrition and metabolism [2].

The firmness and pressure felt on the external surface of the eye from the front are known as intraocular pressure, resulting from the force exerted by the aqueous humor per unit area of the outer eye layer. If, for various reasons, the production or drainage of aqueous humor within the eye faces challenges, leading to either excess production or insufficient drainage, the intraocular pressure will exceed the normal range.

Tonometry is a method utilized to determine the intraocular pressure within the eye. This examination stands as one of the foremost approaches for diagnosing glaucoma, also known as "black water." Most tonometers are calibrated to measure intraocular pressure in millimeters of mercury. Glaucoma is a common disorder affecting the aqueous humor flow, resulting in elevated intraocular pressure. Factors contributing to its development include impediments in fluid drainage, constricted passageways, anterior chamber angle closure, neoplasms, and lens dislocation. Increased intraocular pressure, stemming from decreased aqueous humor circulation, leads to reduced blood supply to the vessels, retina, and optic nerve, ultimately causing visual impairment and potential blindness [3].

In horses, the normal range of intraocular pressure falls between 15 to 30 millimeters of mercury. Monitoring pressure beyond 30 to 35 millimeters of mercury proves valuable in diagnosing glaucoma. The jugular veins, situated on both sides of the neck, play a crucial role in collecting blood from various regions of the brain, head, and face. The primary function of eyelids is to safeguard and maintain the integrity of the eye [4]. The third eyelid, located on the inner corner of the eye, may enlarge as a sign of viral or bacterial infections. In recent years, tonometry has become a routine and periodic component of ocular examinations. Given the absence of prior research on the impact of body position, eyelid manipulation, and jugular vein compression on intraocular pressure in healthy horses, this study aims to investigate these effects.

In a study conducted by Andrade *et al*. in 2016 on 45 healthy horses, it was demonstrated that the use of a lip twitch leads to an increase in intraocular pressure. However, no significant correlation was found between the intraocular pressure of the left and right eyes following the use of a lip twitch (78).

In a study by Knollinger *et al*. in 2005, involving 25 healthy horse subjects, intraocular pressure was measured using rebound tonometry and Goldman applanation tonometry, registering 9.5 ± 1.22 and 9.5 ± 0.21 millimeters of mercury, respectively. The study indicated that the use of rebound tonometry provides a more accurate estimate of intraocular pressure in horses. Age, gender, and neck length did not have a significant effect on intraocular pressure [5].

In a study conducted by Komaromy *et al*. in 2006, it was demonstrated that head position influences the level of intraocular pressure in horses [6].

A study by Klein *et al*. in 2011, involving 30 dogs, revealed that if pressure is applied to the eyelid and jugular vein during intraocular pressure measurement, the intraocular pressure increases [7].

In a study conducted by Jeong Man Bok *et al*. in 2007, comparing Tonopen and Maklakov tonometers for measuring intraocular pressure in dogs, it was observed that there is no significant difference between these two tonometers in measuring intraocular pressure [8].

In a study by Salek Ghafari *et al*. in 2018, involving 16 dogs placed in prone, right lateral recumbency, and dorsal recumbency positions, the mean intraocular pressure in the dorsal recumbency position was significantly higher [9].

A study by Broadwater *et al*. in 2008, involving 24 dogs, placed all dogs in prone, seated, and right lateral recumbency positions, and then measured intraocular pressure in each of the three positions using a tonometer. It was observed that body positioning influences intraocular pressure, with dogs in prone and seated positions experiencing a decrease in eye pressure, while dogs in lateral recumbency showed minimal changes in intraocular pressure [10].

In a study by Kurt *et al*. in 2018, conducted on 24 calves, it was demonstrated that body position has no significant effect on intraocular pressure in calves [11].

Literature Review

Horse

The horse, scientifically known as Equus caballus, is a mammal belonging to the single-toed ungulate order Perissodactyla and the family Equidae, alongside zebras, donkeys, and asses. The horse, or Equus ferus caballus, represents one of the two subspecies of wild horses (Equus ferus). This mammal is a placental and herbivorous creature, classified under the Equidae family. The evolutionary history of horses spans from approximately 45 to 55 million years ago, evolving from large, single-toed ancestors to the smaller, odd-toed ungulates seen today.

In Middle Persian and Avestan, the horse was referred to as "asp." Many prominent figures in ancient Iran had names suffixed with "-asp," underscoring the significance of this animal among Iranians. In Sanskrit, the term "azva" denoted a horse, and the contemporary Persian words for "rider" and "mounted" share the same root. The etymology traces back to the Indo-European root "eḱwa" or "eḱwo." The domestication of horses commenced in the Middle East, later spreading to the plains of Iran. During ancient Persian periods, particularly the Achaemenid era, horses played a pivotal role, and trained horses were referred to as "Pars." The Arab culture incorporated the Persian term, rendering it as "sawar," signifying a skilled and mounted rider. Horses exhibit adaptability to cold and mountainous conditions, contrasting with camels, which thrive in hot, sandy Arab landscapes.

Jugular Veins: Anatomical Insights

The Jugular veins, specifically the external jugular vein (EJV) and the internal jugular vein (IJV), are two pivotal vascular structures situated bilaterally along the neck. These veins play a crucial role in draining blood from various regions of the brain, head, and face. The collected blood is directed towards the left subclavian vein on the left side and empties into the unnamed vein on the right side.

In the upright position, the jugular venous pressure (JVP) in the neck is relatively low. The external jugular vein serves as a conspicuous indicator of central venous pressure. The intricate network of jugular veins and their role in draining blood from critical anatomical regions underscores their physiological significance.

Intraocular Pressure and Tonometry

The pressure of the fluid inside the eye, referred to as "intraocular pressure (IOP)," is a critical factor in eye health. Clinical examinations often employ tonometry tests to measure this pressure. These tests are conducted directly on the eye using various devices known as tonometers. Tonometry serves as a common method for diagnosing glaucoma, a condition resulting from elevated intraocular pressure.

Glaucoma is an ocular disease that gradually leads to permanent vision loss due to damage to the optic nerves behind the eyes. It is also known as the "silent thief of sight" because it typically presents no early warning signs.

Tonometry devices can be broadly categorized into indentation and applanation types. Indentation tonometers calculate intraocular pressure by measuring the depth of indentation produced by a small piston carrying a known weight.

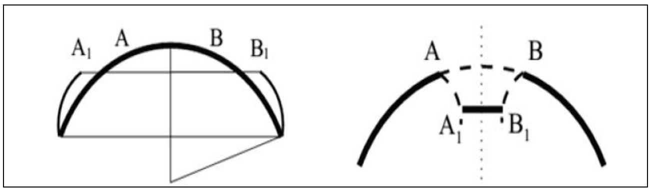

Fig 1: Types of Tonometry Methods

The depth of the effect created by the piston (change from the initial corneal surface (AB) to the deformed surface ($1A1B$) in Figure A) is depicted. By measuring and performing calculations on this depth, intraocular pressure is determined. In this type of tonometer, for eyes with elevated pressure, weights are added to the piston. The configurations of these tonometers, as illustrated in Figure A, exhibit displacement beyond the corneal back surface limit, leading to highly variable and imprecise calculated pressures. Due to the inadequacy of this type of tonometer, they are completely set aside.

Eye Structure in Horses

The eye is composed of various parts, as illustrated in Figure 2. These components include:

1. Cornea
2. Sclera
3. Aqueous humor
4. Iris
5. Lens
6. Vitreous humor
7. Retina
8. Choroid
9. Optic disc
10. Ciliary body
11. Optic nerve

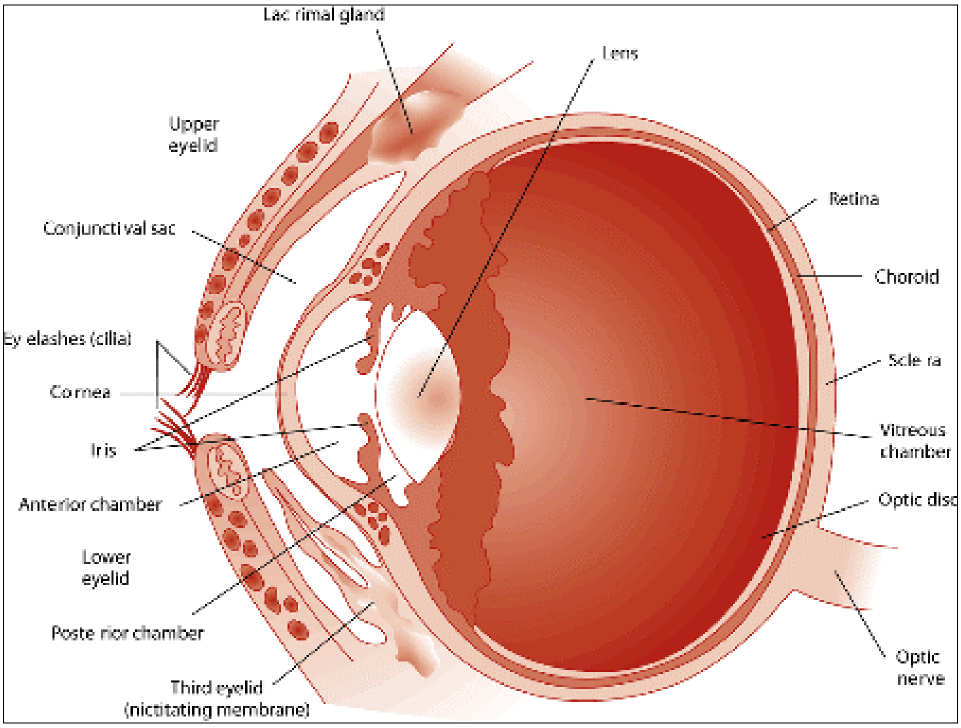

Fig 2: Eye Structure in Equids

Glaucoma in Horses

Glaucoma is an ocular condition in horses characterized by increased intraocular pressure. Clinical manifestations include cloudy or opaque cornea, dilated pupil, enlargement of the eyeball, and inflammation of the iris. If left untreated or not promptly addressed, it can lead to damage to the retina and optic nerve, ultimately resulting in blindness.

The horse's eye is nourished by fluids carrying nutrients dissolved in bodily fluids through various pathways within the eyeball. Obstruction of these entry and exit pathways disrupts the outflow of fluids within the eye, leading to primary glaucoma. Trauma or the accumulation of other materials in the eye can also block these pathways, resulting in fluid buildup inside the eye and increased intraocular pressure, known as glaucoma.

Symptoms of this condition include iris inflammation, tumors, cataracts, corneal swelling, and excessive fluid accumulation. In advanced stages, the eyeball may enlarge, and the lens may shift. Veterinarians typically associate any corneal edema, opacity, or severe ocular inflammation that remains untreated or lacks a clear explanation with glaucoma.

Accurate diagnosis is achieved through examination with a handheld tonometer, enabling the veterinarian to assess the eye and implement appropriate glaucoma management measures [12].

Causes and Classification of Glaucoma in Horses

The most prevalent and general reasons for glaucoma in horses involve episodic iris inflammation and ciliary body edema. Glaucoma in horses is commonly categorized into three groups: congenital, primary, and secondary. Primary glaucoma in horses is uncommon, typically affecting both eyes simultaneously, necessitating preventive measures for the unaffected eye. Secondary glaucoma in horses often develops following recurrent episodes of ocular disease, intraocular neoplasms, corneal perforation, and lens luxation. Although ocular disease is considered the most common predisposing factor for glaucoma, the exact mechanism leading to secondary glaucoma remains unclear. Secondary glaucoma does not necessarily involve both eyes but may affect both if the cause is iris inflammation.

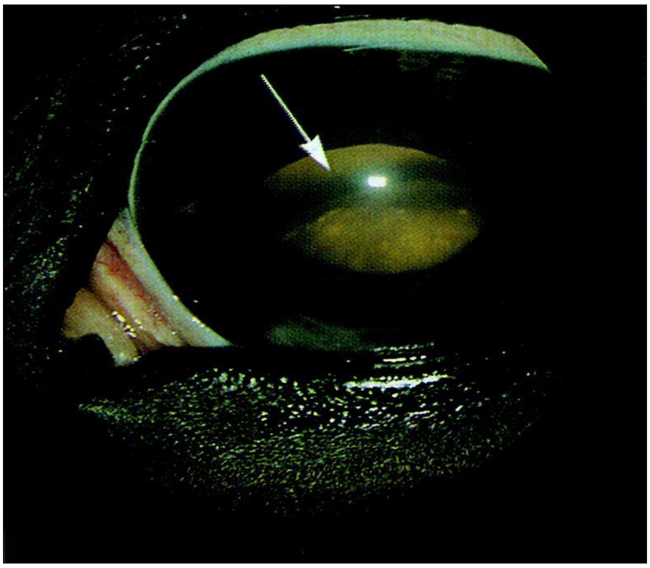

Fig 3: Glaucoma in Horses

Methodology

This study was conducted on 14 horses present in equestrian clubs and the educational hospital of the Islamic Azad University, Science and Research Branch, Tehran. The normal condition of the eyes was examined using an indirect ophthalmoscope. All horses underwent initial comprehensive clinical examinations. Subsequently, the animal's visual status, eye movement, conjunctival color, eyelid and third eyelid conditions, corneal status, eye globe health, frontal chamber condition in terms of bleeding, eyelash positioning, eyelid examinations, comparison of both eyes regarding light responsiveness, and lens observation were examined. In cases where specific diseases were suspected during clinical examinations, confirmatory health tests, including complete blood count and sonography, were conducted. After completing the clinical examinations and verifying the animal's health, the animal was kept in the examination room with its owner for a period of time until the animal reached complete calmness. In this study, dilating drugs were not used as they may affect the test results. Then, the intraocular pressure of healthy horses was measured using a tonometer. Initially, the horse was placed in a normal position (horizontal to the ground) without pressure on the neck and eyelid, and the intraocular pressure was measured. To assess the effect of eyelid manipulation on intraocular pressure, lateral eyelid expansion, dorsal-ventral eyelid stretching, and external Eyelid compression can be performed. In the subsequent study, the left and right vena vorticosae were individually compressed with the hand, and intraocular pressure was measured. In the next stage, both left and right vena vorticosae were compressed with the hand, and intraocular pressure was measured and recorded.

Statistical Population: Horses from private equestrian clubs and horses from the educational and research hospital affiliated with the Islamic Azad University, Science and Research Branch.

Sample Size: 14 horses

After measuring the intraocular pressure of the examined horses, each piece of information, including age, breed, and gender, which was predetermined, was statistically analyzed using the Student's t-test method. The analysis focused on the relationship between body position, eyelid manipulation, manual compression of the vena vorticosae, and intraocular pressure in healthy horses.

The Icare Tonovet eye tonometer device (manufactured in Finland) was used for intraocular pressure measurements. This device determines intraocular pressure by measuring corneal resistance to pressure. The system operates based on the principle of rebound, measuring intraocular pressure. As the contact area and time with the cornea are minimal, there is no need for local anesthesia.

Corneal Contact Time > 0.1 seconds

Corneal Contact Area > 8.0 square millimeters

Table 1: Study Variables

Measurement Unit	Scientific Definition	Variable Scale				Variable Role				Variable Name
		Qualitative		Quantitative						
		Ordinal	Nominal	Discrete	Continuous	Contextual	Confounding	Dependent	Independent	
			*				Contextual			Eye
Millimeters of mercury (mmHg)	Measurement of intraocular pressure						Dependent			Tonometer
							Dependent			Body position
Different breeds such as Turkmene, Caspian, etc.			*				Dependent			Breed
							Dependent			Eyelid manipulation
							Dependent			Manual compression of the vena cava

In this research, descriptive and inferential statistical methods were employed to describe some of the characteristics of the samples under study and investigate research hypotheses. Descriptive statistics at the statistical level were presented using the SPSS software and the Student's t-test.

Data Analysis

Data analysis in the descriptive statistics section involved examining measures of central tendency and measures of dispersion.

Table 2: Descriptive statistics related to the data of intraocular pressure in the treatments in the left eye (mm/Hg)

Maximum	Minimum	Standard Deviation	Mean	
34	19	5/06	24/43	**Baseline**
37	17	8/01	24/86	Ipsilateral jugular compression
39	26	5/25	33/29	Bilateral jugular compression
45	22	8/51	33/86	Dorsoventral extension
34	20	4/65	26/43	Lateral extension
35	20	5/15	27/14	Head up position
31	16	5/50	25/57	External ocular compression

Considering the obtained results in Table 2, it is observed that the mean intraocular pressure in the left eye in the baseline condition is 24.43. However, in the IJC (unilateral compression of the Vena Dacica), BJC (bilateral compression of the Vena Dacica), DE (posterior-anterior eyelid traction), LAE (lateral skin traction), HP (head position), and EOC (external eye compression) conditions, it exceeds this value. The minimum intraocular pressure corresponds to the IJC and EOC conditions, while the maximum is observed in the IJC, BJC, and DE conditions.

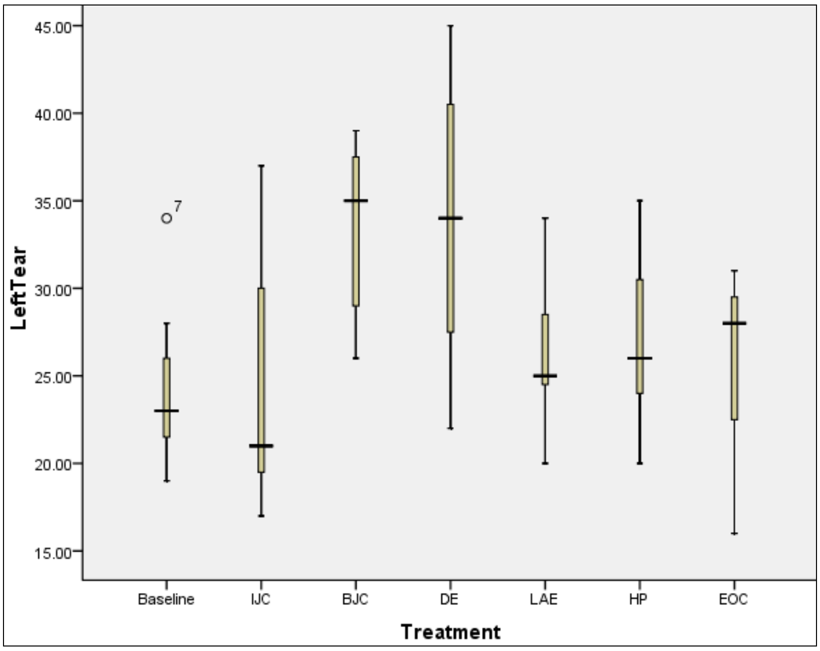

Fig 1: illustrates the mean intraocular pressure in the left eye across different treatment conditions

Table 3: presents the descriptive statistics related to the data on intraocular pressure in the right eye under different treatment conditions (mm/Hg).

Maximum	Minimum	Standard Deviation	Mean	
30	18	4/46	23/29	Baseline
38	24	4/58	29	Ipsilateral jugular compression
36	20	6/50	29/7	Bilateral jugular compression
41	20	7/16	31/71	Dorsoventral extension
37	21	5/26	28/43	Lateral extension
34	19	4/83	27/43	Head up position
39	20	6/91	28/86	External ocular compression

Considering the obtained results in Table 3, it is observed that the average intraocular pressure in the right eye under Baseline condition is 23.29 mm/Hg. This is while, under treatments such as Unilateral Jugular Compression (IJC), Bilateral Jugular Compression (BJC), Head Position (HP), Dorsal-Eye Compression (DE), External Eye Compression (EOC), and Lateral Eye Skin Stretch (LAE), it exceeds this value. The minimum intraocular pressure corresponds to the Baseline and HP treatments, while the maximum is associated with IJC, DE, and EOC treatments. Figure 2 illustrates the mean and dispersion of intraocular pressure in the right eye under various treatments.

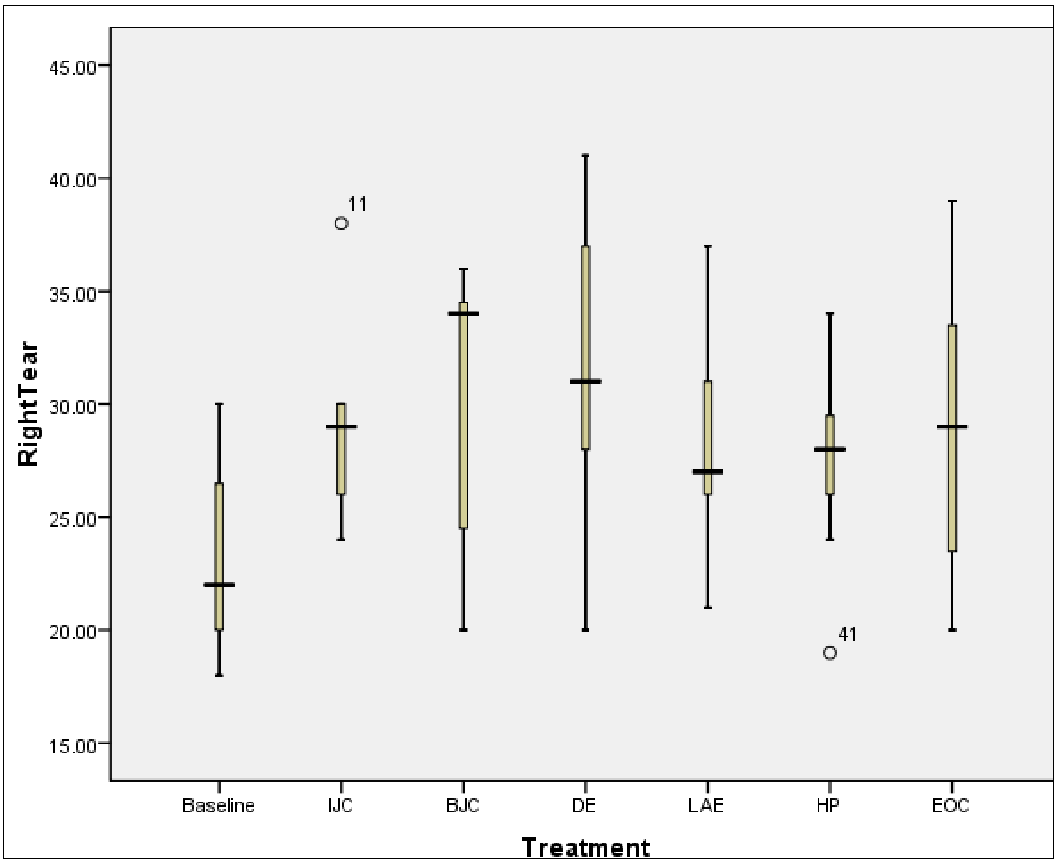

Fig 2: Average Intraocular Pressure in Treatments for the Right Eye

For the comparison between the treatments in different eyes, it is necessary to first determine the normality of the data distribution. The Kolmogorov-Smirnov one-sample test was employed to assess whether the raw data are normally distributed. The results are presented in Tables 4 and 5. As Indicated in Tables 4 and 5, the data distribution for both groups related to the left and right eyes is normal. Therefore, the use of parametric tests for comparing treatments is permissible.

Table 4: Kolmogorov-Smirnov one-sample test for data related to the left eye.

EOC	HP	LAE	DE	BJC	IJC	Baseline	
0/640	0/422	0/664	0/511	0/586	0/678	0/656	KS
0/807	0/994	0/770	0/956	0/883	0/747	0/782	Significant Level

Table 5: Kolmogorov-Smirnov Single-Sample Test for Right Eye Data

EOC	HP	LAE	DE	BJC	IJC	Baseline	
0/496	0/692	0/472	0/525	0/838	0/716	0/489	KS
0/967	0/725	0/979	0/946	0/484	0/684	0/971	Significant Level

For the comparison of the treatment groups with T0 (baseline), the t-test was employed. As seen in Table 6, a significant difference was observed only between the intraocular pressure values of the BJC and DE treatments compared to the Baseline treatment.

Table 6: Comparison of intraocular pressure values in the left eye among different treatments relative to Baseline.

EOC	HP	LAE	DE	BJC	IJC	
-0/679	-1/571	-1/911	-3/541	-8/212	-1/55	t
0/522	0/167	0/105	0/012	0/000	0/882	Significant Level

Based on the results presented in Table 7, significant differences in intraocular pressure values are observed between all studied treatments and the Baseline treatment in the right eye.

Table 7: Comparison of intraocular pressure values in the right eye among different treatments relative to Baseline.

EOC	HP	LAE	DE	BJC	IJC	
-2/679	-3/442	-4/869	-4/168	-4/131	-4/264	**t**
0/037	0/014	0/003	0/006	0/006	0/005	Significant Level

Conclusion

The findings of the study revealed that the only significant difference in intraocular pressure values was observed in the left eye between the treatments of bilateral jugular vein compression and eyelid dorsal-ventral stretching compared to the Baseline treatment. However, in the right eye, all studied treatments showed a significant difference in intraocular pressure compared to the Baseline. In a study conducted by Andrade *et al*. in 2016 on 45 healthy horses, the use of lip twitch was shown to increase intraocular pressure, with no significant correlation between left and right eye pressures following lip twitch application. In another study by Knollinger *et al*. in 2005 on 25 healthy horses, the rebound tonometry method was compared with the Goldmann method, resulting in recorded pressures of 9.5 ± 1.22 and 9.5 ± 0.21 mmHg, respectively. The study demonstrated that the rebound tonometry method provides a more accurate estimate of horse intraocular pressure. Age, gender, and neck length had no significant effect on intraocular pressure. In a study by Komaromy *et al*. in 2006, the position of the head was found to be influential on intraocular pressure. Furthermore, a study by Heidi Kelein *et al*. in 2011 on 30 dogs revealed that applying pressure on the eyelid and jugular vein during intraocular pressure measurement leads to an increase in intraocular pressure. Lastly, in a study conducted by Jeong Man Bok *et al*. in 2007 comparing tonometers Tonopen and Makl Mark, no significant difference was found between the two tonometers in measuring intraocular pressure in dogs.

In a study conducted by Salek Ghafari *et al*. in 2018, 16 dogs were placed in different positions, including lying down, lying on the right side, and dorsal recumbency. The study revealed a significant increase in the average intraocular pressure in the dorsal recumbency position.

Broadwater *et al*. conducted a study in 2008 on 24 dogs, where all dogs were placed in lying, sitting, and lateral recumbency positions. The intraocular pressure was then measured using a tonometer in all three positions. The study observed that the body position significantly influences intraocular pressure.

Kurt *et al*. conducted a study in 2018 on 24 calves, demonstrating that the body position has no significant effect on intraocular pressure in calves.

In a study by Pigatto *et al*. in 2010, which investigated the relationship between age and intraocular pressure in Saanen goats, it was concluded that intraocular pressure increases up to 180 days of age and remains constant thereafter.

In a study conducted by Toris *et al*. in 1999 on humans, no significant correlation was found between intraocular pressure and age. However, with increasing age, the aqueous humor outflow and production decrease in its drainage angle.

Hiller *et al*. conducted a study in 1982 on humans and concluded that intraocular pressure increases with age.

In a study by Pauli *et al*. in 2006 on 26 dog packs, neck compression using a collar or necktie led to an increase in intraocular pressure (IOP).

Baek *et al*. found in their study that eyelid compression results in an increase in intraocular pressure.

Rajaei *et al*. conducted a study in 2018 on cats and concluded that eyelid compression and compression of the vena cava affect intraocular pressure.

In a study conducted by Salek Ghafari and colleagues in 2018 on cats, they concluded that body position has an effect on intraocular pressure.

Given that an increase in intraocular pressure can contribute to visual impairment, especially damage to the optic nerve, and this disorder can be a disabling factor, it is expected that timely control of this issue will lead to a reduction in this disorder. Intraocular pressure is the result of a balance in the function of alpha-2 adrenergic receptors as inhibitors and beta-2 adrenergic receptors as fluid secretion stimulators on one side, and the outflow of aqueous humor through the trabecular meshwork or the uveoscleral pathway on the other side. Therefore, investigating changes in intraocular pressure in horses with glaucoma is of particular importance. In the present study, it was identified that intraocular pressure in the examined horses is influenced by three factors: eyelid manipulation, manual compression of the vena cava, and body position.

In conclusion, this study demonstrated that body position, eyelid manipulation, and manual compression of the vena cava have an impact on intraocular pressure, leading to an increase in intraocular pressure in horses. The compression of the vena cava results in increased intraocular pressure, attributed to venous stasis and the resistance of the episcleral veins against the outflow of aqueous humor. Additionally, eyelid manipulation affects the eye's soft tissue, causing a compression effect that further contributes to the increase in intraocular pressure. Given the significance of intraocular pressure, this thesis can serve as a reference for the influence of body position, eyelid manipulation, and manual compression of the vena cava on intraocular pressure in horses. It is hoped that future research will delve deeper into this subject, providing more insights into intraocular pressure in horses.

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