African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

The effect of 1% tropicamide on central corneal thickness and intraocular pressure

Authors:
Dimakatso G. Mashala[1]
Bevily Nukeri[1]
Alpheus S. Phaka[1]
Angel N. Mashabu[1]
Mlungisi J. Fakude[1]
Phillip M. Seabi[1]
Matome Mmakgaha[1]
Ramadimetja P. Sedibeng[1]

Affiliations:
[1]Department of Optometry, Faculty of Health Sciences, University of Limpopo, Polokwane, South Africa

Corresponding author:
Dimakatso Mashala,
dimakatso.mashala@ul.ac.za

Dates:
Received: 22 Apr. 2023
Accepted: 18 Oct. 2023
Published: 31 Jan. 2024

How to cite this article:
Mashala DG, Nukeri B, Phaka AS, et al. The effect of 1% tropicamide on central corneal thickness and intraocular pressure. Afr Vision Eye Health. 2024;83(1), a862. https://doi.org/10.4102/aveh.v83i1.862

Background: Dilating the eye with tropicamide may alter the intraocular pressure (IOP) because of an obstruction of the iridocorneal angle, resulting in decreased aqueous outflow drainage. Also, the repeated application of eyedrops and instrumentation could lead to increased central corneal thickness (CCT), consequently affecting IOP.

Aim: This study aimed to determine the effect of 1% tropicamide on CCT and IOP post-mydriasis among the University of Limpopo optometry students.

Setting: The data were collected at the optometry clinic of the University of Limpopo.

Methods: A within-subject experimental study was conducted on 59 healthy subjects aged 18 years – 28 years. A computer assisted simple random probability sampling was used to identify a sample of participants from the study population (N = 200). Baseline and post-mydriasis IOP (20 min, 30 min, and 45 min intervals) were measured with a Goldmann applanation tonometer. Central corneal thickness and IOP were analysed using means, correlations and paired t-tests.

Results: The mean CCT pre-mydriasis was 504.68 μm, and post-dilation was 507.90 μm, 510.08 μm and 509.25 μm at 20 min, 30 min, and 45 min, P = 026, p = 0.033, P = 0.004, respectively. Moreover, the mean IOP pre-mydriasis was 15.97 mmHg, and post-dilation was 16.85 mmHg, 16.46 mmHg and 16.85 mmHg over 20 min, 30 min, and 45 min of followed-up time, p = 0.140, p = 0.432, and p = 0.183, respectively.

Conclusion: Measuring IOP post-dilation is still valid; however, CCT should be measured before the instillation of tropicamide.

Contribution: This study analysed the effect of 1% tropicamide on CCT and IOP post-mydriasis in a clinical South African context.

Keywords: tropicamide; intraocular pressure; pre and post-mydriasis; central corneal thickness; Goldmann tonometry.

Introduction

The relationship between central corneal thickness (CCT) and intraocular pressure (IOP) is integral in managing elevated IOP,[1,2,3,4,5] a pressure exerted by the aqueous humour.[6,7,8,9] The CCT can affect the IOP measurement, where a thick or thin cornea yields overestimation and underestimation of IOP, respectively.[10,11,12] This implication may hinder selecting a proper management regimen and lead to the mismanagement of patients with elevated IOP, which, when untreated, will cause damage to the optic nerve and lead to irreversible vision loss.[13,14] However, a comprehensive eye examination may counteract vision loss through early disease detection. During such an examination, a diagnostic mydriatic agent (tropicamide) is routinely used for pupillary dilation to evaluate the fundus optimally.[8,15]

In an ocular evaluation of an eye, 1% tropicamide may act as a mydriatic agent to dilate the eye in adults [9,14] The effect of these topical mydriatic eye drops typically subsides after 4 h of instillation, and this drug may affect CCT.[10,11,16,17] Furthermore, tropicamide may increase IOP by obstructing the iridocorneal angle, decreasing trabecular meshwork traction, and aqueous outflow drainage because of ciliary muscle paralysis.[8,13,18] For every 0.32 mmHg increase in IOP, there is a possibility that CCT could increase by 10 μm.[19] The broad distribution of CCT ranges from 519 μm to 550 μm in Ethiopians and South Africans, respectively.[20]

Goldmann applanation tonometry (GAT) is considered the gold standard against which all other tonometry are compared.[21] The GAT is performed under topical anaesthesia.[22,23,24,25,26]

Local anaesthesia, 0.4% oxybuprocaine, is generally used for procedures involving the cornea, such as measuring the IOP, gonioscopy and removal of the foreign body, and may cause a reduction in IOP with GAT.[27,28,29]

Diagnostic mydriatic agents are routinely used in most eye clinics; however, they can potentially increase IOP.[8,14,30] Furthermore, there is a paucity of similar studies in South Africa, including where there is measurement of CCT. Therefore, this study sought to understand the effect of 1% tropicamide as a mydriatic ocular solution in a clinical South African context on the CCT and IOP post mydriasis in three different intervals, namely 20 min, 30 min, and 45 min.

Research methods and design

Study approach and design

A within-subject experimental study design was adopted,[31] allowing the current investigation to use a 1% tropicamide diagnostic agent to observe the effect on IOP and CCT as an outcome. This study examined the relationship between baseline IOP and post-dilation IOP after instilling the diagnostic agent. The post-IOP were measured at 20 min, 30 min, and 45 min. Also, maximum dilation was achieved by seating participants in a dark room. Furthermore, the CCT was also measured during the experiment.

Population, sample size, and sampling

The study was conducted at the University optometry clinic, where 59 optometry students participated out of 200 available students. Computer assisted simple random probability sampling was used to identify a sample of participants. The participants were 18 years – 28 years, with a mean of 20.41 ± 2.48 years. The participants were all registered students in the Department of Optometry. The study exclusion criteria were participants with keratoconus because of its association with changes in the corneal structure, such as defects of Bowman's layer and decreased corneal thickness. It further results in alterations of some of the biomechanical parameters of the cornea, namely, rigidity and elasticity,[32] individuals with glaucoma, and active corneal inflammation.

Data collection

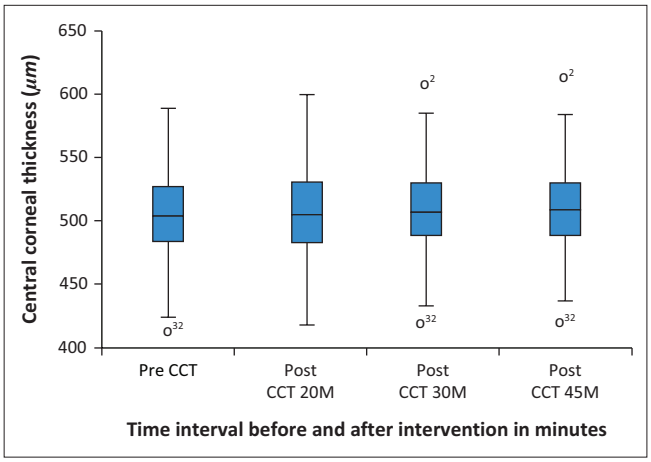
Identifier numbers were assigned to study participants, and participants' demographic information was collected using a questionnaire. A diffuse beam assessed the anterior eye surface for corneal irregularities and active inflammation. Van Herick's angle estimation procedure estimated the iridocorneal angle to determine whether it was safe to dilate the participants. Only participants with grade 3 and 4 angles were dilated. Central corneal thickness was measured using a pachymeter before the measurement of IOP. Oxybuprocaine was used to anaesthetise the cornea, and a fluorescein strip was wetted with saline before staining the cornea and introducing a GAT bi-prism to measure the IOP. Goldmann applanation tonometer was performed on all participants before dilation and at the follow-up. One research team member measured the CCT, and another measured the IOP to reduce discrepancies. Participants' eyes were dilated with one drop of 1% tropicamide. Subsequently, participants were seated in the dark to allow maximum dilation. One research team member kept the time and after 20 min, 30 min, and 45 min of dilation, the participants were then taken into the station where IOP was measured. A diffuse beam of light was shone on the cornea to assess corneal integrity pre- and post-IOP measurements.

Statistical analysis

A codebook was created to code the variables for analysis. The data were entered into Microsoft Excel for sorting and then uploaded to Statistical Package for Social Science (SPSS, Inc., Chicago, IL, United States) software version 28 for analysis. Shapiro–Wilks' tests were used to test the data for normality[33] and the data were normally distributed, with $p > 0.198$ for baseline IOP, and post-intervention, $p > 0.196$, $p > 0.720$, and $p > 0.306$ for 20 min, 30 min, and 45 min, respectively. Furthermore, for the CCT, baseline $p > 0.854$ and post-intervention, $p > 0.540$, $p > 0.628$, $p > 0.774$, for 20 min, 30 min, and 45 min, respectively. Therefore, parametric tests for statistical analyses were used to analyse the data and descriptive statistics such as mean and standard deviation (s.d.) were used. Medians were used where outliers were relevant. Correlation and paired *t*-tests were used to compare baseline and post-intervention variables over three consecutive times. A *p*-value of < 0.05 was considered statistically significant.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of Limpopo, Turfloop Research Ethics Committee (No. TREC/316/2022:UG). Participants signed consent forms, and the purpose of the study was explained to the study participants. The study adhered to the tenets of the Helsinki Declaration.



CCT, central corneal thickness.

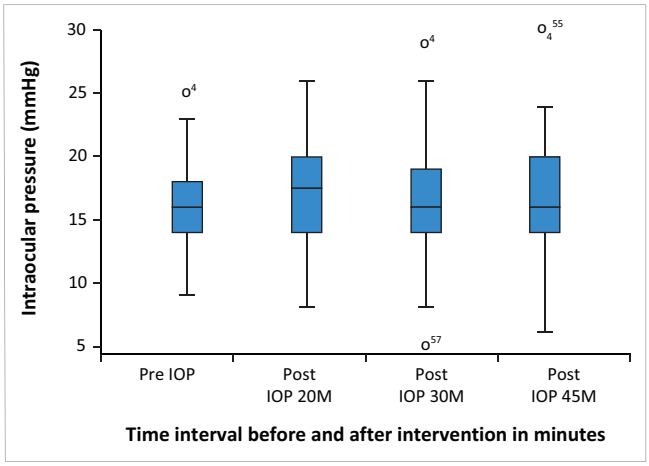
FIGURE 1: Boxplots of pre-intervention or baseline median central corneal thickness followed by a post-invention or change in median central corneal thickness over 20 min, 30 min, and 45 min.

Results

A total of 59 optometry students with an average age of 20.41 ± 2.48 years participated in the study. The ratio of participants was 0.57:1, with 15 (25.4%) and 44 (74.6%) male and female participants, respectively.

Figure 1 shows a boxplot describing median-baseline CCT followed by a change in median CCT over 20 min, 30 min, and 45 min. The median CCT before the intervention was 504 μm, which rose to about 507 μm after 20 min, and almost remained constant at 30 min. However, there was an increase of about 510 μm after 45 min. Although there was an increased median in terms of CCT, there was a normal distribution of CCT before and after intervention across the follow-up duration. The minimum score of CCT between baseline and post-intervention remained constant. However, there was a constant increase in the maximum CCT score over three consecutive times by approximately 10 μm, from 590 μm baseline to 600 μm, 607 μm, and 612 μm. Moreover, there was an overlap in the distributions for CCT.

Figure 2 shows boxplots for IOP pre- and post-mydriasis. The median IOP before intervention had a median score of about 16 mmHg, which rose to about 17 mmHg after intervention with 1% tropicamide at 20 min and dropped to about 15.5 mmHg at 30 min and 45 min later. The normal distribution of the IOP score before intervention can be seen, revealing an average IOP score; a few (including one outlier) scored much higher. Twenty minutes after the intervention, the IOP scores were slightly higher, showing an overlap with scores before the intervention. The data showed a slightly negatively skewed distribution (including one outlier); however, at 30 min and 45 min, the data were positively skewed, with the median IOP dropping to 15.5 mmHg. The maximum possible score was 29 mmHg at 30 min, which would explain the ceiling effect in this dataset group (including four outliers). At 45 min post-intervention, the IOP median score remained constant as the previous measurement at 30 min (including four outliers).



IOP, intraocular pressure.

FIGURE 2: Boxplots showing median baseline intraocular pressure, followed by changes in median intraocular pressure over 20 min, 30 min, and 45 min.

The maximum IOP was 30 mmHg at 45 min, explaining the ceiling effect in this group of datasets (including four outliers). However, the distributions overlapped, revealing no significant change over the time period when IOP was measured.

Table 1 shows the findings and compares means and SDs between the pre-intervention or baseline CCT and IOP and post-intervention or change in CCT and IOP across the follow-up times. The mean IOP pre-dilation was 15.97 mmHg ± 3.63 mmHg. Post-dilation IOP was 16.85 mmHg ± 4.53 mmHg, 16.46 mmHg ± 4.61 mmHg, and 16.85 mmHg ± 4.90 mmHg at 20 min, 30 min, and 45 min, respectively. For IOP, the mean change was 0.88 mmHg ± 0.90 mmHg, 0.49 mmHg ± 0.98 mmHg, and 0.88 mmHg ± 1.27 mmHg for the post-intervention times measured. The mean CCT pre-dilation was 504.68 μm ± 34.82 μm. Post-dilation CCT was 507.90 μm ± 36.29 μm, 510.08 μm ± 35.79 μm, and 509.25 μm ± 34.66 μm at 20 min, 30 min, and 45 min, respectively. At 20 min, 30 min, and 45 min, the mean change in CCT was 3.22 μm ± 1.47 μm, 3.22 μm ± 0.97 μm, and 4.57 μm ± 0.16 μm, respectively. Therefore, the most significant change in mean CCT was at 30 min, followed by 45 min.

Table 2 shows the correlations for the paired samples. The data showed a positive correlation between baseline CCT and post-dilation CCT at all three intervals. The results were strong enough to yield a statistical significance with a *p*-value of less than 0.001. The correlation of the IOP (pair four, five and six) was weak even with the increase in time. Furthermore, the results were strong enough to yield a statistical significance with a *p*-value of less than 0.05.

Table 3 compares pre-CCT and IOP over repeated CCT and IOP post-intervention with 1% tropicamide. The mean

TABLE 1: Comparison of means with standard deviation between the pre-intervention or baseline central corneal thickness (microns) and intraocular pressure (mmHg) and post-intervention or change in central corneal thickness.

Variable	*N*	Minima	Maxima	Means	s.d.
PRE CCT	59	418	589	504.68	34.82
PRE IOP	59	9	25	15.97	3.63
POSTCCT 20M	59	418	600	507.90	36.29
POSTIOP 20M	59	8	26	16.85	4.53
POSTCCT 30M	59	422	607	510.08	35.79
POSTIOP 30M	59	5	29	16.46	4.61
POSTCCT 45M	59	419	612	509.25	34.66
POSTIOP 45M	59	6	30	16.85	4.90

s.d., standard deviation; CCT, central corneal thickness; IOP, intraocular pressure.

TABLE 2: Paired sample correlations between baseline central corneal thickness and intraocular pressure with the post-intervention central corneal thickness and intraocular pressure (*N* = 59).

Pairs	Variable	Statistical measures	
		Correlations	*P*
Pair 1	PRE CCT and POST CCT 20M	0.954	< 0.001
Pair 2	PRE CCT and POST CCT 30M	0.856	< 0.001
Pair 3	PRE CCT and POST CCT 45M	0.942	< 0.001
Pair 4	PRE IOP and POST IOP 20M	0.404	0.002
Pair 5	PRE IOP and POST IOP 30M	0.347	0.007
Pair 6	PRE IOP and POST IOP 45M	0.337	0.009

CCT, central corneal thickness; IOP, intraocular pressure.

TABLE 3: Paired sample *t*-tests.

Pairs	Variables	Means	s.d.	The difference with a 95% confidence interval		*P*
				Lower	Upper	
Pair 1	POSTCCT20M-PRECCT	3.330	10.857	-6.050	-0.391	0.026
Pair 2	POSTCCT30M-PRECCT	5.407	18.976	-10.352	-0.461	0.033
Pair 3	POSTCCT45M-PRECCT	4.576	11.875	-7.671	-1.482	0.004
Pair 4	POSTIOP20M-PREIOP	0.881	4.522	-2.060	0.297	0.140
Pair 5	POSTIOP30M-PREIOP	0.492	4.776	-1.736	0.753	0.432
Pair 6	POSTIOP45M-PREIOP	0.881	5.021	-2.190	0.427	0.183

s.d., standard deviation; CCT, central corneal thickness; IOP, intraocular pressure.

difference between pre-CCT and post-CCT after 20 min, 30 min, and 45 min were compared in three pairs. This was also applied to the IOP results. Furthermore, regarding the CCT, the data showed a high mean increase of 5.407 μm, and the results were statistically significant after 20 min of post-intervention. Also, there was a change in CCT post 30 min and 45 min, and the results were statistically significant. Regarding IOP, the change in IOP mean was not statistically significant.

Discussion

Tropicamide is widely used in eyecare by ophthalmologists and optometrists to better visualise the fundus. However, 1% tropicamide might alter the IOP by obstructing the iridocorneal angle or decreasing traction on the trabecular meshwork, decreasing aqueous outflow drainage.[8,9,34] Also, the repeated application of eyedrops during the procedure may increase the CCT because of epithelial oedema, resulting in the possible over-measurement of IOP.[18] Measuring CCT and IOP takes about a minute to obtain readings and establish a treatment plan appropriate to delay the development of high IOP.[35] Therefore, this study established the change in CCT and IOP when 1% tropicamide was administered. The mean CCT pre-mydriasis was 504.68 μm, and post-dilation was 507.90 μm, 510.08 μm and 509.25 μm measured at 20 min, 30 min, and 45 min, respectively. Moreover, the mean IOP pre-mydriasis was 15.97 mmHg, and post-dilation was 16.85 mmHg, 16.46 mmHg and 16.85 mmHg over 20 min, 30 min, and 45 min, of followed-up time, respectively.

Africans, in particular, have thinner CCT than other races.[36] In this study, the mean CCT measured in all the participants' pre- and post-instillation of 1% tropicamide was less than the reported CCT of 519 μm reported in South Africans. The reason for discordance could be attributed to the fact that the study consisted of participants aged 18 years – 28 years and of different races found in South Africa, namely Africans, Indians, whites, and mixed race,[37] whereas this study consisted only of Africans. Although this study post-mydriasis CCT measurement found a significant change, the threshold did not reach the average CCT found by Rampersad et al.[37] The other reason could be the different use of equipment for measuring the CCT. However, the current findings agree with Prasher et al.,[38] which indicate that the instillation of mydriatic agents significantly increases the CCT. Also, our study results align with those of Zeng and Gao,[17] who demonstrated a significant increase in CCT while using mydriatic agents. The current results differ from Booth et al.,[39] in the sense that 1% tropicamide does not have any significant effect on CCT; also, it should be noticed that the authors measured the change in CCT 15 min after the instillation of the mydriatic agent. Therefore, any change that might have occurred after that could have been missed. The mechanism behind the increase in CCT post-mydriasis remains unclear; however, it is postulated that mydriatic agents may affect corneal epithelium integrity at the intercellular junctions among the epithelial cells, which might cause oedema of the corneal tissues, increasing CCT.[17,18]

Moreover, this study found an average IOP of 15 mmHg–16 mmHg, which agrees with the standard clinical average IOP.[40] The mean change was 0.88 mmHg ± 0.90 mmHg, 0.49 mmHg ± 0.98 mmHg, and 0.88 mmHg ± 1.27 mmHg, for the post-intervention times measured, respectively. The correlations between the baseline IOP and post-intervention IOP were statistically significant across the intervals. However, the mean change in IOP between baseline IOP and post-intervention was statistically insignificant across the intervals.

In light of the aforementioned, this study's mean change in IOP post-dilation was higher than baseline IOP; however, it showed a minimal change with statistical insignificance in all intervals. This study's results are similar to that of Kuang et al.,[41] whose population was above 65 years and older. The authors observed an insignificant increase in IOP after pharmacological pupil dilation using 1% tropicamide. Also, the study's results are similar to that of Pukrushpan et al.,[9] whose study population age mean (54.7 ± 15.1 years) was higher than this study. The previous authors found that IOP insignificantly increased post-dilation, although the IOP was only measured once after 30 min of dilation. However, this study's results differ from that of Kim et al.[18] and Adediji et al.[8] in the sense that the change in IOP was significant between pre- and post-dilation. The discordance can be attributable to the fact that the authors used 1% tropicamide and 2.5% phenylephrine. Meanwhile, Qian et al.[42] found a decrease in IOP post-mydriasis, but the participant's age range was 22 years – 88 years. The above-mentioned sentiments are supported by Baek et al.,[43] who reported an average IOP increase in younger participants and a decrease in older participants.

On the other hand, the correlation between the baseline and post-intervention CCT and IOP changes were statistically significant; however, the correlations were weak in the IOP and stronger in the CCT. The given results agree with Wei et al.,[19] where the authors found a significant correlation between baseline and post-intervention CCT and IOP

measured with Goldmann applanation. A thick cornea causes IOP to be overestimated, whereas a thin cornea causes IOP to be underestimated.[20] The results of this study suggest an increase in CCT post-mydriasis and an increase in IOP; however, insignificant in IOP. By extension, there is a close link between the instillation of 1% tropicamide and an increase in CCT; however, the mechanism remains unclear, but it could be postulated to epithelial oedema caused by the instillation of eyedrops. Over and above 1% tropicamide may affect the IOP, causing possible under-measurement[18]; however, this study showed insignificant change. Moreover, this study observed an increase and decrease of IOP post mydriasis, similar to the study by Adediji et al.[8] where the fluctuation of IOP during the experiment occurred notwithstanding that the authors used phenylephrine and tropicamide concurrently. However, the cause of fluctuation needs to be further investigated by studying the traction of the trabecular meshwork and the aqueous flare before and after mydriasis to help determine the aetiology of fluctuation of IOP.[17]

The limitation of this study was that there were no studies related to this study in the South African context. Therefore, we could not compare our findings with any studies in South Africa; also, the sample consisted of only the black African population with the age range of 18–28 years. We, therefore, could not compare races and age groups. Moreover, the male and female ratio was unequal, and larger sample size and multiple methods for measuring IOP could improve the reliability and variability of the study.

Conclusion

With 1% tropicamide, this study found some CCT change (< 5 microns across the time period concerned) and a weak IOP change post-mydriasis. Also, the effect of the mydriatic agent on CCT and IOP was statistically significant and insignificant, respectively. Therefore, CCT should be measured before the instillation of tropicamide; however, measuring an IOP on the dilated eye should be performed with extra care. Further studies need to include older and younger participants to compare them with this study to see if the change in IOP will be significant but not excluding the CCT. Furthermore, the traction of the trabecular meshwork and the aqueous flare before and after mydriasis needs to be explored to help understand the aetiology of fluctuation of IOP and CCT, and further studies need to be performed on how tropicamide increases CCT specifically.

Acknowledgements

The authors of this article would like to thank the University of Limpopo for allowing them to use the Department of Optometry equipment for data collection and analysis.

Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

D.G.M., B.N., A.S.P., A.N.M., M.J.F., P.M.S., M.M. and R.P.S. were all involved in the study's conceptualisation and data collection. D.G.M. further compiled the research article and guided the design and statistical analysis. Also, all authors reviewed the article and provided final approval.

Funding information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The data of this study are available from the corresponding author, D.G.M, upon request. Any inquiries can be directed to the corresponding author.

Disclaimer

The views and opinions articulated herein are of the authors and do not necessarily reflect the standing position of the University of Limpopo and the publisher.

References

1. Manni G, Oddone F, Parisi V, Tosto A, Centofanti M. Intraocular pressure and central corneal thickness. Prog Brain Res. 2008 Jan 1;173:25–30. https://doi.org/10.1016/S0079-6123(08)01103-5
2. Emara B, Probst LE, Tingey DP, Kennedy DW, Willms LJ, Machat J. Correlation of intraocular pressure and central corneal thickness in normal myopic eyes and after laser in situ keratomileusis. J Cataract Refract Surg. 1998 Oct 1;24(10):1320–1325. https://doi.org/10.1016/S0886-3350(98)80222-8
3. Eballe AO, Koki G, Ellong A, et al. Central corneal thickness and intraocular pressure in the Cameroonian nonglaucomatous population. Clin Ophthalmol. 2010 Jul 30;4:717–724. https://doi.org/10.2147/OPTH.S10575
4. Lleó A, Marcos A, Calatayud M, Alonso L, Ranhal SM, Sanchis-Gimeno JA. The relationship between central corneal thickness and Goldmann applanation tonometry. Clin Exp Optometry. 2003 Mar 1;86(2):104–108. https://doi.org/10.1111/j.1444-0938.2003.tb03068.x
5. Shafiq I. Influence of central corneal thickness (CCT) on intraocular pressure (IOP) measured with Goldmann applanation tonometer (GAT) in normal individuals. Pak J Ophthalmol. 2008 Dec 31;24(4):196–200.
6. Jeelani M, Taklikar RH, Taklikar A, Itagi V, Bennal A. Variation of intraocular pressure with age and gender. Natl J Physiol Pharm Pharmacol. 2014;4(1):57. https://doi.org/10.5455/njppp.2014.4.040720132
7. Hung KC, Huang HM, Lin PW. Changes of intraocular pressure and refractive status in children following cycloplegic refraction with 1% cyclopentolate and 1% tropicamide. Taiwan J Ophthalmol. 2015 Sep 1;5(3):124–127. https://doi.org/10.1016/j.tjo.2015.06.001
8. Adediji AK, Adio AO, Fiebai B. Effects of diagnostic mydriasis with tropicamide and phenylephrine on intraocular pressure. J Ophthalmic Clin Res. 2019;6(1):49. https://doi.org/10.9734/ajmah/2019/v14i330102
9. Pukrushpan P, Tulvatana W, Kulvichit K. Intraocular pressure change following application of 1% tropicamide for diagnostic mydriasis. Acta Ophthalmol Scand. 2006 Apr;84(2):268–270. https://doi.org/10.1111/j.1600-0420.2005.00557.x
10. Hoffmann EM, Lamparter J, Mirshahi A, et al. Distribution of central corneal thickness and its association with ocular parameters in a large central European cohort: The Gutenberg health study. PLoS One. 2013 Aug 1;8(8):e66158. https://doi.org/10.1371/journal.pone.0066158
11. Gao XR, Huang H, Kim H. Polygenic risk score is associated with intraocular pressure and improves glaucoma prediction in the UK Biobank cohort. Transl Vis Sci Technol. 2019 Mar 1;8(2):10. https://doi.org/10.1167/tvst.8.2.10
12. Wang P, Song Y, Lin F, et al. Comparison of non-contact tonometry and Goldmann applanation tonometry measurements in non-pathologic high myopia. Front Med. 2022;9:819715. https://doi.org/10.3389/fmed.2022.819715
13. Gandhi M, Dubey S. Evaluation of the optic nerve head in glaucoma. J Curr Glaucoma Pract. 2013 Sep;7(3):106. https://doi.org/10.5005/jp-journals-10008-1146
14. Hong D, Tripathy K. Tropicamide. [Updated 2023 Feb 22]. StatPearls [homepage on the Internet]. Treasure Island, FL: StatPearls Publishing; 2023 [2023 March 26]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK541069

15. Michelessi M, Lucenteforte E, Oddone F, et al. Optic nerve head and fibre layer imaging for diagnosing glaucoma. Cochrane Database Syst Rev. 2015; 2015(11):CD008803. https://doi.org/10.1002/14651858.CD008803.pub2
16. Abah ER, Mahmud-Ajeigbe AF, Sharief S, Chinda D, Jiya PY, Bob-Egbe O. Central corneal thickness and intraocular pressure of adult Nigerians: An assessment of Zaria community. West Afr J Med. 2018 Sep 1;35(3):158–161.
17. Zeng Y, Gao JH. Effects of mydrin eyedrops on central corneal thickness values in adult patients with myopia. Clin Exp Optom. 2017 Mar 1;100(2):151–154. https://doi.org/10.1111/cxo.12465
18. Kim JM, Park KH, Han SY, et al. Changes in intraocular pressure after pharmacologic pupil dilation. BMC Ophthalmol. 2012 Dec;12:53. https://doi.org/10.1186/1471-2415-12-53
19. Wei W, Fan Z, Wang L, Li Z, Jiao W, Li Y. Correlation analysis between central corneal thickness and intraocular pressure in juveniles in Northern China: The Jinan City eye study. PLoS One. 2014 Aug 22;9(8):e104842. https://doi.org/10.1371/journal.pone.0104842
20. Rampersad N, Hansraj R. A review of African studies on central corneal thickness. Afr Vis Eye Health. 2016 Jan 1;75(1):1–5. https://doi.org/10.4102/aveh.v75i1.341
21. Mashige KP, Naidoo KS. Current practices of diagnostic techniques requiring the use of ophthalmic drugs among KwaZulu-Natal optometrists. Afr Vis Eye Health. 2009 Dec 17;68(4):180–187. https://doi.org/10.4102/aveh.v68i4.174
22. Baptista AM, De Sousa RA, Serra PM, Abreu CM, Da Silva CM. Evaluation of discomfort of Goldmann tonometry without anaesthetic. Ophthalmic Physiol Opt. 2010 Nov;30(6):854–859. https://doi.org/10.1111/j.1475-1313.2010.00786.x
23. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol. 1975 Mar;53(1):34–43. https://doi.org/10.1111/j.1755-3768.1975.tb01135.x
24. Brusini P, Salvetat ML, Zeppieri M. How to measure intraocular pressure: An updated review of various tonometers. J Clin Med. 2021 Aug 27;10(17):3860. https://doi.org/10.3390/jcm10173860
25. Yeh SJ, Chen KH, Kuang TM, Liu CJ, Chen MJ. Comparison of the iCare, Tono-Pen, non-contact airpuff, and Goldmann applanation tonometers in eyes with corneal edema after penetrating keratoplasty. J Chin Med Assoc. 2021 Mar 1;84(3): 320–325. https://doi.org/10.1097/JCMA.0000000000000476
26. Junk AK, Chen PP, Lin SC, et al. Disinfection of tonometers: A report by the American Academy of Ophthalmology. Ophthalmology. 2017 Dec 1;124(12): 1867–1875. https://doi.org/10.1016/j.ophtha.2017.05.033
27. Almubrad TM, Ogbuehi KC. Clinical investigation of the effect of topical anesthesia on intraocular pressure. Clin Ophthalmol. 2007 Sep 1;1(3):305–309.
28. Jóhannesson G, Hallberg P, Eklund A, Behndig A, Lindén C. Effects of topical anaesthetics and repeated tonometry on intraocular pressure. Acta Ophthalmol. 2014 Mar;92(2):111–115. https://doi.org/10.1111/aos.12058
29. Lelescu CA, Urdă-Cîmpean AE, Dumitraș DA, Taulescu M, Mureșan C. Effects of topical application of 0.4% oxybuprocaine hydrochloride ophthalmic solution and 1% ropivacaine hydrochloride on corneal sensitivity in rats. PLoS One. 2020 Nov 5;15(11):e0241567. https://doi.org/10.1371/journal.pone.0241567
30. Gharieb Ibrahim HM. Effect of pharmacological mydriasis on the intraocular pressure in eyes with filtering blebs compared to normal eyes: A pilot study. Clin Ophthalmol. 2022 Jan 1;16:231–237. https://doi.org/10.2147/OPTH.S348365
31. Greenwald AG. Within-subjects designs: To use or not to use? Psychol Bull. 1976 Mar;83(2):314. https://doi.org/10.1037/0033-2909.83.2.314
32. Naderan M, Jahanrad A, Balali S. Histopathologic findings of keratoconus corneas underwent penetrating keratoplasty according to topographic measurements and keratoconus severity. Int J Ophthalmol. 2017;10(11):1640.
33. Mathebula SD, Ntsoane MD, Makgaba NT, Landela KL. Comparison of the amplitude of accommodation determined subjectively and objectively in South African university students. Afr Vis Eye Health. 2018 Feb 26;77(1):a437. https://doi.org/10.4102/aveh.v77i1.437
34. Harris LS, Galin MA, Mittag TW. Cycloplegic provocative testing after topical administration of steroids. Arch Ophthalmol. 1971 Jul 1;86(1):12–14. https://doi.org/10.1001/archopht.1971.01000010014003
35. Belovay GW, Goldberg I. The thick and thin of the central corneal thickness in glaucoma. Eye. 2018 May;32(5):915–923. https://doi.org/10.1038/s41433-018-0033-3
36. Aghaian E, Choe JE, Lin S, Stamper RL. Central corneal thickness of Caucasians, Chinese, Hispanics, Filipinos, African Americans, and Japanese in a glaucoma clinic. Ophthalmology. 2004 Dec 1;111(12):2211–2219. https://doi.org/10.1016/j.ophtha.2004.06.013
37. Rampersad N, Mashige KP, Jhetam S. A comparison of intraocular pressure values obtained with the Tono-Pachymeter NT530P, iCare® rebound tonometer and Goldmann applanation tonometer. Afr Vis Eye Health. 2011 Dec 11;70(3): 109–116. https://doi.org/10.4102/aveh.v70i3.109
38. Prasher P, Vig VK, Singh B, Sharma R, Sharma A. Effect of mydriatic eye drops (combined 0.8% tropicamide and 5% phenylephrine) on the measurements of corneal parameters using Pentacam. Indian J Ophthalmol. 2023 Mar;71(3):818. https://doi.org/10.4103/ijo.IJO_1175_22
39. Booth AP, Pappas G, Menon JK. Does tropicamide alter central corneal thickness? Investig Ophthalmol Vis Sci. 2004 May 1;45(13):5544.
40. Kim JH, Caprioli J. Intraocular pressure fluctuation: Is it important? J Ophthalmic Vis Res. 2018 Apr 1;13(2):170–174. https://doi.org/10.4103/jovr.jovr_35_18
41. Kuang TM, Tsai SY, Liu CJ, Lee SM, Chou P. Changes in intraocular pressure after pharmacological pupil dilatation in an elderly Chinese population in Taiwan: The Shihpai eye study. J Chin Med Assoc. 2022 Oct 1;85(10):1024–1027. https://doi.org/10.1097/JCMA.0000000000000794
42. Qian CX, Hassanaly S, Duperré J, Slim É, Harissi-Dagher M. The effect of pharmacological pupillary dilation on intraocular pressure measurement. Can J Ophthalmol. 2020 Apr 1;55(2):152–158. https://doi.org/10.1016/j.jcjo.2019.10.002
43. Baek SU, Kee C, Suh W. Longitudinal analysis of age-related changes in intraocular pressure in South Korea. Eye. 2015 May;29(5):625–629. https://doi.org/10.1038/eye.2015.11