In fulfillment of the

Master’s degree

(M.Sc.) Vision Science and Business (Optometry)

at the faculty of Aalen University, Germany

in cooperation with

New England College of Optometry, Boston, MA, USA,

and

Pacific University College of Optometry, Forest Grove, OR, USA

Comparing axial eye length to other physiological properties of the eye, body height and the head

by

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MASTER’S THESIS

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May, 2022

Abstract

Purpose: To find, if there is any relationship between axial eye length and other physiological properties of the eye (horizontal corneal diameter, average corneal radius, central corneal thickness, objective spherical equivalent, pupillary distance), body height, and head size. Can any of these correlations eventually complement models in myopia progression or be the model for further research.

Methods: To measure axial eye length and horizontal corneal diameter Topcon MYAH was used. Topcon MYAH measure axial length by means of repeated interferometry scans. Topcon TRK-2P was used for measuring average corneal radius, central corneal thickness, pupillary distance and objective refraction. Objective spherical equivalent was calculated from objective refraction. Body height was measured using wall mounted tape. Participants were standing straight up and barefooted. Head size was measured with a sewing measuring tape. Head size was measured over the most prominent part on the back of the head and just above the eyebrows.

Results: Linear regression was used to examine the relationship between axial eye length and other physiological properties of the eye, body height, and the head. Pearson correlation coefficients and scatter plots were used to demonstrate correlations between axial eye length and other physiological properties of the eye, body height, and the head of 82 participants and their 164 eyes. Results of axial eye length with: Body height (R=0,14; p=0,07), show no correlation; Head size (R=0,128; p=0,103), show no correlation; Objective spherical equivalent (R=-0,676; p<0,001), show strong and statistically significant correlation; Average corneal radius (R=0,555; p<0,001), show moderate and statistically significant correlation; Horizontal corneal diameter (R=0,433; p<0,001), show moderate and statistically significant correlation; Central corneal thickness (R=0,248; 0,004), show weak and statistically significant correlation; Pupillary distance (R=0,161; p=0,04), show very weak and statistically significant correlation. Multilinear regression model between axial eye length, objective spherical equivalent and average corneal radius (R=0,857; p<0,001), show a very strong and statistically significant correlation.

Conclusions: Based on analysis of data in this master thesis we can conclude a strong and statistically significant correlation between axial eye length and objective spherical equivalent, a moderate and statistically significant correlation with average corneal radius and horizontal corneal diameter, weak and statistically significant correlation with central corneal thickness and very weak and statistically significant correlation with pupillary distance. Correlation between axial eye length and body height and head size was not statistically significant. Based on multilinear regression model, we can conclude that eyes with longer axial eye length will on average have flatter cornea and spherical equivalent will be, as expected, more myopic. Some possible implications in practice of these findings: Contact lens manufacturers should be aware of the possible necessity of altering standard back surface radii with increasing myopic power due to flatter corneas in higher myopia found in our study. The eye models for calculating individual spectacle lenses could consider the newly established relationships between axial eye length and corneal radii. The positive (though weak) correlation between central corneal thickness and axial eye length could be considered important in myopia research, in corneal refractive surgery models and glaucoma models.

Keywords: Axial eye length; Body height; head size; Horizontal corneal diameter; Average corneal radius; Spherical equivalent; pupillary distance, central corneal thickness

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List of Abbreviations

EU	Europäische Union
CN II	Cranial nerve II or Optic nerve
CCT	Central corneal thickness
CCD	Charge-Coupled Device Camera
PD	Pupillary distance
IPD	Interpupillary distance
AL	Axial (eye) length
RPE	Retinal pigment epithelium

1 Introduction

1.1 Motivation for the Thesis

I was curious if axial eye length is proportional to other body parameters and eye parameters. The human body is usually proportional. If you are taller than average you probably have a bigger foot size, longer arms, longer legs than an average tall person. Is it the same with axial eye length and other physiological properties of the eye? Do proportions of the eyes also complement each other? Can any of these relationships eventually complement models in myopia progression or be the model for further research.

The idea and goal of this master thesis are to find, if there is any relationship between axial eye length and horizontal corneal diameter, average corneal radius, central corneal thickness, body height, objective spherical equivalent, pupillary distance, and head size.

1.2 Structure

The introduction section shows the idea, motivation, and a goal of the study. It briefly describes human eye anatomy. The Second chapter methods describe how measurements were taken and what devices were used to get all the measurements. The third chapter describes the results of the statistical analysis. Linear regression was used to examine relationship between axial eye length and other physiological properties of the eye, body height and the head. Pearson correlation coefficients and scatter plots were used to demonstrate correlations between axial eye length and other physiological properties of the eye, body height, and the head. The fourth chapter discusses and compares results with other studies and the last chapter provides a conclusion of the master thesis.

1.3 Eye anatomy

The eyes are organs of the visual system. In the emmetropic eye the light from the environment focuses on the retina. The retina is neural tissue of the eye. It is responsible to convert the light into a neural signal, that travels from the retina through the optic nerve (CN II[1]) to the brain into visual cortex. The eye can be divided into 3 layers:

- Fibrous layer or the outer layer of connective tissue (the cornea and sclera)
- Vascular layer or the middle layer (the iris, ciliary body, and choroid)
- Neural layer or the inner layer (the retina)(1)

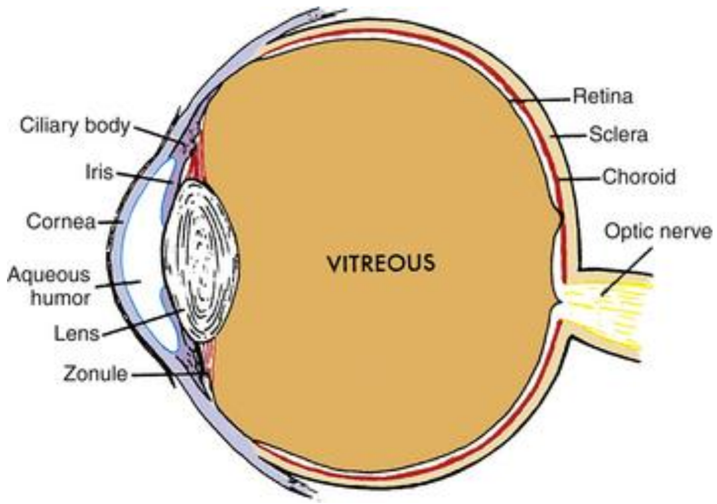

Figure 1 Eye structure(1)

[1] CN II – Cranial nerve II or optic nerve

The eye sits in a protective bony socket called the orbit. The orbit is a pear-shaped cavity. It consists of:

- The roof (consists of two bones: The orbital plate of frontal bone and the lesser wing of the sphenoid bone)
- The lateral wall (consists of two bones: the zygomatic bone and the greater wing of sphenoid bone)
- The floor (consists of the three bones: palatine, zygomatic and maxillary bone)
- The medial wall (consists of four bones: ethmoid, sphenoid maxillary, and lacrimal)
- The superior orbital fissure
- The inferior orbital fissure(1,2)

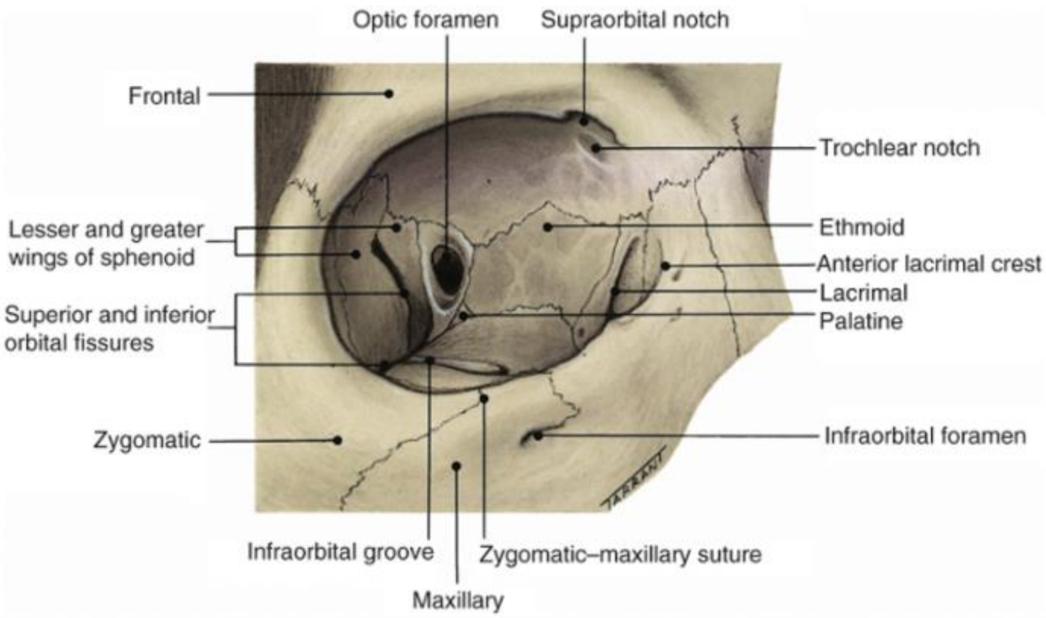

Figure 2 Anatomy of the orbit(2)

The eye has 7 extraocular muscles. 6 of them are responsible to move the eye: Superior rectus muscle, Inferior rectus muscle, Medial rectus muscle, Lateral rectus muscle, Superior oblique muscle, and Inferior oblique muscle. The Levator palpebrae superioris muscle is responsible for moving the upper eyelid. (2)

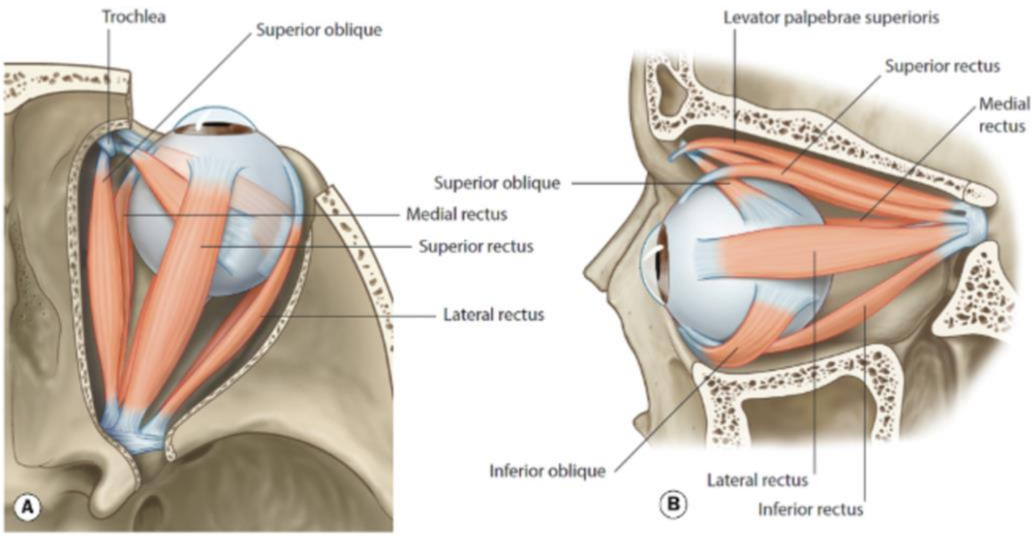

Figure 3 Extraocular muscles(2)

The eyelids cover and protect the anterior surface of the eye. The eyelids contain meibomian glands that produce lubricating tear film. Tear film covers the anterior surface of the globe. It has many functions. It lubricates the eye and keeps the surface moist. It provides a smooth refractive surface. It traps debris and helps remove sloughed epithelial cells and debris. It is a source of the oxygen for the cornea, and it helps to maintain corneal hydration. It contains antibacterial substances (lysozyme, beta-lysin, lactoferrin, IgA) to help protect against infection. The tear film is composed of 3 layers:

- The mucous layer – is produced by goblet cells
- Aqueous layer – produced by the lacrimal gland
- Lipid layer – produced by meibomian glands and Zeis glands. (1)

1.3.1 Conjunctiva

The conjunctiva is a transparent mucous membrane. The conjunctiva is the inner surface of the eyelids and the anterior surface of the globe. It is densely vascular. It is blood supplied by the anterior ciliary and palpebral arteries. There is a dense lymphatic network, with drainage to the preauricular and submandibular nodes corresponding to that of the eyelids. It has a key protective role, mediating both passive and active immunity. Anatomically, it is divided into the three parts: the palpebral conjunctiva, the bulbar conjunctiva, and the fornix (2)

1.3.2 Cornea

The cornea is a complex structure that, as well as having a protective role, is responsible for about three-quarters of the optical power of the eye. The normal cornea is avascular and transparent. Nutrients are supplied and metabolic products are removed via the aqueous humour posteriorly and the tears anteriorly. The cornea is the most densely innervated tissue in the body. (2)

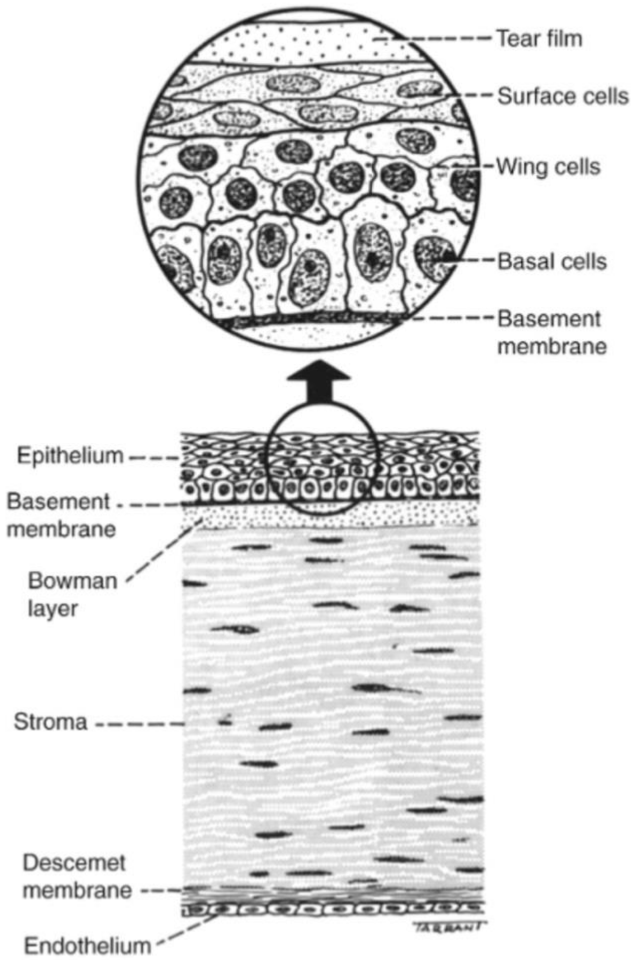

Figure 4 Anatomy of the cornea

Cornea consist of the following layers:

- The epithelium
- Bowman layer
- The stroma
- Descement membrane
- The endothelium(2)

1.3.2.1 Corneal radius, diameter, and central corneal thickness

The average corneal diameter is 11.5 mm vertically and 12 mm horizontally. The normal central corneal thickness is 540±30µm thick. Cornea is thicker towards the periphery. In profile, the cornea has an elliptic rather than a spheric shape. The curvature is steeper in the center and flatters near the periphery. The radius of the central cornea at the anterior surface is 7.8 mm and at the posterior surface is 6.5 mm. CCT[2] between males and females does not differ but varies between individuals and races. It is a key determinant of the intraocular pressure (IOP) measured with conventional techniques. (1,2)

1.3.3 Sclera

The sclera is the white tissue of the eye. It is tough, fibrous tissue. It covers 80% of the outer layer of the eye. The other 20% of the outer layer of the eye is cornea. The sclera maintains the shape of the globe, offering resistance to internal and external forces. It provides an attachment for the extraocular muscle insertions. Its thickness is about 1,0 – 0,3mm. The sclera is an opaque sphere, which has a radius of approximately 12 mm. The globe is not symmetric. its approximate diameters are 24 mm anteroposterior, 23 mm vertical, and 23.5 mm horizontal. (1)

1.3.4 Anterior chamber

The anterior chamber is a space in the eye located between corneal endothelium and the crystalline lens epithelium, and peripherally by the trabecular meshwork and the iris root. The center of the anterior chamber is deeper than the periphery. It is filled with aqueous humor. According to the study: Anterior chamber depth in relation to refractive status measured with the Orbscan II Topography System, the anterior chamber depth is deeper in myopes vs hyperopes. Anterior chamber depth is a part of axial eye length. (1,3)

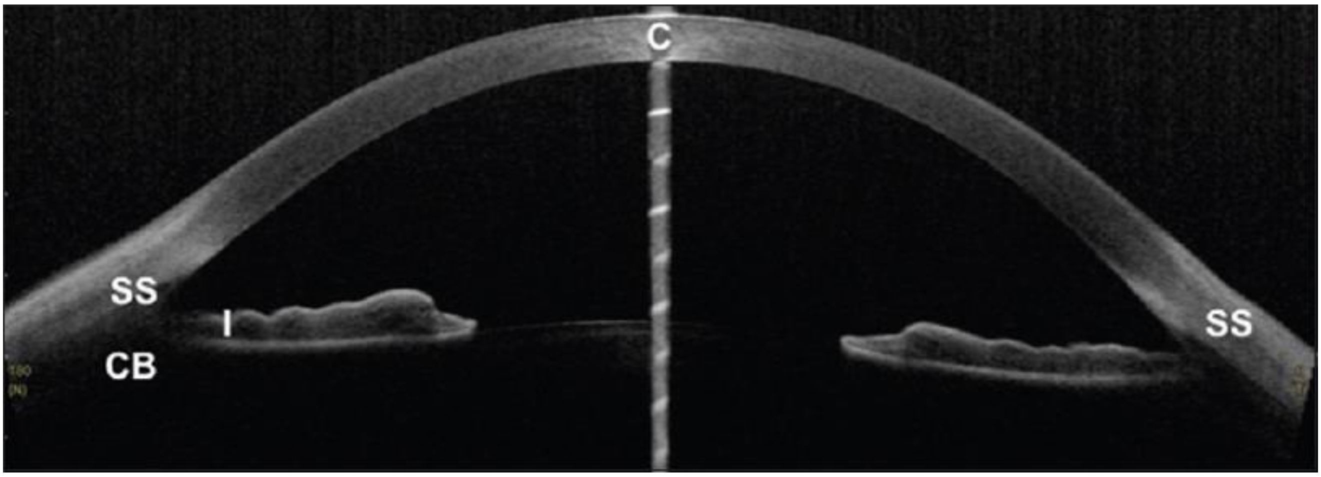

Figure 5 Anterior chamber OCT scan(4)

1.3.5 The crystalline lens

The crystalline lens is a biconvex transparent structure that is responsible to focus light on the retina. It is avascular and located in a posterior chamber between the iris and vitreous. It is lens is connected to the ciliary body with zonular fibers. The crystalline lens has the ability to change the shape and with that increase dioptric

[2] CCT - Central corneal thickness

power. This process is called accommodation. Accommodation allows near objects to be in focus. Accommodative amplitude of the crystalline lens is about 14 diopters at about 8 years. Accommodative amplitude decreases with age and is approaching zero after the age of 50. The anterior radius of curvature of the crystalline lens measures 8 to 14 µm, and the posterior surface radius of curvature measures 5 to 8 µm. The thickness of the unaccommodated crystalline lens is 3.5 to 5 mm. The thickness of the crystalline lens increases by 0.02 mm each year throughout life. The refractive power of the unaccommodated crystalline lens is approximately 20 diopters and depends on the:

- Surface curvatures
- Refractive index
- Change in index between the lens and surrounding environment
- Crystalline lens thickness(1)

The thickness of the crystalline lens is a part of the measurement of the axial eye length.

1.3.6 Vitreous

The vitreous is a transparent extracellular gel consisting of collagen, soluble proteins, hyaluronic acid, and water. Approximately 4.0 ml is the total vitreous volume. The few cells normally present in the gel are located predominantly in the cortex and include hyalocytes, astrocytes, and glial cells. The vitreous provides structural support to the globe while allowing a clear and optically uniform path to the retina. (2)

1.3.7 The Retina

The retina is a sensory layer of the eye, located between the vitreous and choroid. It includes the macula, the area at the posterior pole. The macula is used for the sharpest acuity and color vision, because of a high density of cones in that area. The retina extends from the circular edge of the optic disc to the ora serrata. The retina is the site of the transformation of light energy into a neural signal, which travels through the optic nerve to the visual cortex. Retina consists of 10 layers:

1. Retinal pigment epithelial layer
2. Photoreceptor layer
3. External limiting membrane
4. Outer nuclear layer
5. Outer plexiform layer
6. Inner nuclear layer
7. Inner plexiform layer
8. Ganglion cell layer
9. Nerve fiber layer
10. Internal limiting membrane(1)

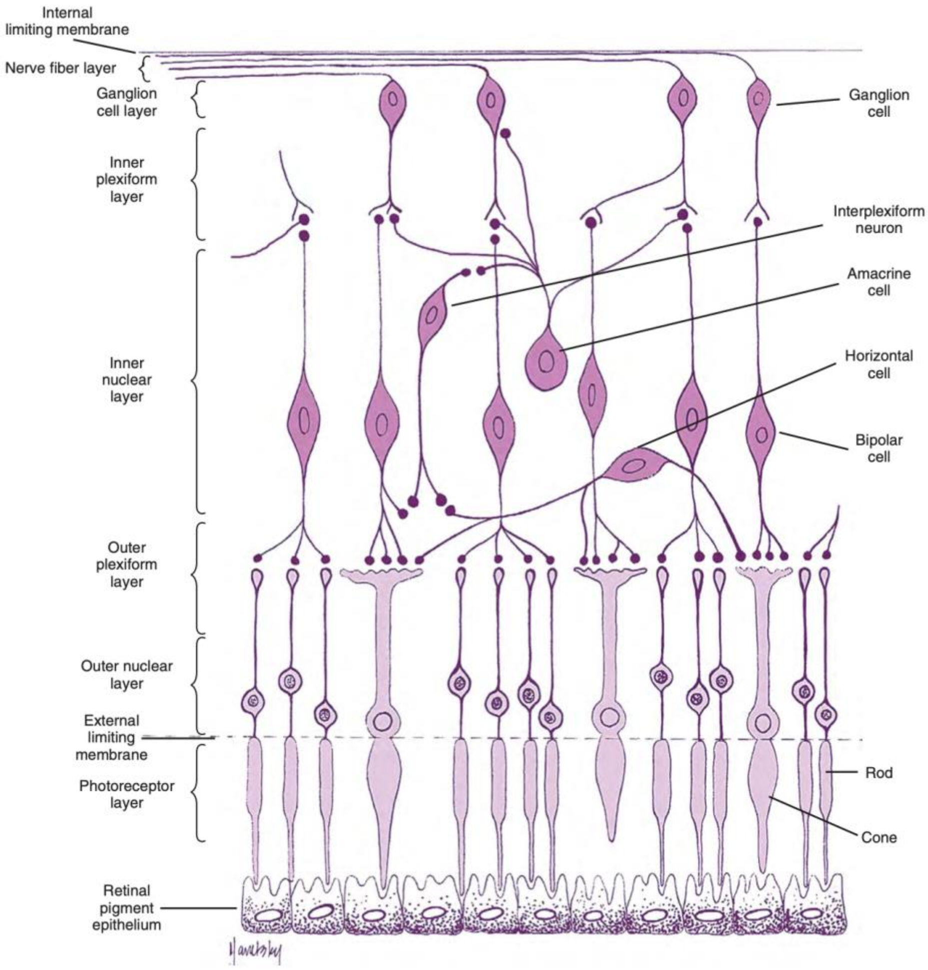

Figure 6 Retina layers(1)

1.3.7.1 The macula

The macula is a round area at the posterior pole. It measures between 5 and 6 mm in diameter and subserves the central 15–20° of the visual field. Macula is subdivided into the foveola, foveal avascular zone, fovea, parafovea, and perifovea. Macula has the highest density of cones. Cone density is the highest in the foveola and decreases to the periphery of the retina. The inner layers of the macula contain the yellow xanthophyll carotenoid pigments lutein and zeaxanthin in far higher concentration than the peripheral retina (hence the full name 'macula lutea' – yellow plaque). (1,2)

1.4 Axial eye length

The axial eye length is the length from the cornea to the retinal pigment epithelium layer in the Retina. A newborn baby's axial eye length is about 16 mm. The average axial eye length in adults is 24 mm. Axial eye length in the adult remains practically unaltered, except in myopes. The axial eye length of hyperopic eyes is shorter than the axial eye length of myopic eyes. Axial eye length measurement is necessary for effective myopia progression management. Without this data, it's impossible to accurately judge the results of treatment. (5)

2 Methods

This chapter describes what devices and methods were used to get all the measurements. First device used for measurements is TOPCON TRK-2P, a fully automated device that measures objective refraction, keratometry, tonometry, and central corneal thickness. Second device used for measurements is TOPCON MYAH. It is a corneal analyzer with an integrated pupillometer and optical biometer. For measuring head size and body height no sophisticated device was used. For head size measuring, a sewing meter was used and for body height measurements, a wall taped meter was installed to measure the body height.

2.1 TOPCON TRK-2P

Topcon TRK-2P device is a fully automated device, that combines a refractometer, keratometer, non-contact tonometer and pachymeter all in one.

Figure 7: TOPCON TRK-2P

The following table is showing specifications and performance of refractive power measurement, keratometry measurement, ocular pressure measurement, and cornea thickness measurement.

Refractive power measurement	
Measurement Range	Spherical refractive power: -30D to +25D (Display unit: 0.12D/0.25D steps) Cylindrical refractive power:0D to ±12D (Display unit: 0.12D/0.25D steps) Direction of astigmatic axis:0° to 180° (Display unit: 1°/5° steps) (where, spherical refractive power + cylindrical refractive power +25D, or spherical refractive power + cylindrical refractive power -30D)
Measured minimum pupil diameter	∅2.0mm
PD measurement range	20 to 85mm (1mm steps)
Target fixation	Auto fog system
Keratometry measurement	

Measurement Range	Cornea curvature radius: 5.00mm to 13.00mm (Display unit: 0.01mm) Corneal refractive power: 67.50D to 25.96D (Display unit: 0.12D/0.25D steps) (where, corneal refractive power =1.3375) Corneal astigmatic power: 0D to ±12D (Display unit: 0.12D/0.25D steps) Direction of corneal astigmatic axis: 0° to 180° (Display unit: 1°/5° steps)
Ocular pressure measurement	
Measuring range	1mmHg to 60mmHg (Display unit: 1mmHg step display, Average value: 1mmHg/0.1mmHg step display)
Measuring range	1 to 30mmHg/1 to 60mmHg, 2 step display
Cornea thickness measurement	
Measuring range	0.400mm to 0.750mm (Display unit: 0.001mm step display)

Table 1 Topcon TRK-2P specification and performance (6)

2.1.1 Objective refraction and Spherical equivalent calculation

Objective refraction is the term used when the refractive error is measured without input by the patient. The objective refraction measurement can be taken using a device called an auto refractometer or manually using an instrument called a retinoscope. Objective refraction with TOPCON TRK-2P is measured with near infrared light projected to the retina and the reflected image is received by a CCD[3] camera. The spherical refractive power, cylindrical refractive power and the axis of astigmatism that are required for the correction lens for making a patient's eye astigmatism are determined through computation. (6)

TOPCON TRK-2P has measurement range of spherical refractive power: -30 to +25D (Display unit: 0.12D/0.25D steps), cylindrical refractive power:0D to ±12D (Display unit: 0.12D/0.25D steps) and direction of astigmatic axis: 0° to 180° (Display unit: 1°/5° steps). All measurements are performed three times on each eye with three times fogging the distance target inside of the device. (6)

Spherical equivalent is calculated with the formula:

Equation 1 The spherical equivalent formula

$$SE = \frac{sph + cyl}{2}$$

SE – Spherical equivalent
Sph – Spherical power
Cyl – Cylindrical power

2.1.2 Average corneal radius

Keratometry is the measurement of the anterior corneal curvature. TOPCON TRK-2P is a multifunctional device that measures refraction and keratometry simultaneously. The instrument performs corneal curvature radius measurements through computation by projecting a kerato-ring by KRT illumination LED to the cornea and receiving the reflected image by a REF observing camera from the cornea surface, and the corneal curvature radius computes the corneal refractive power, corneal astigmatic power, and corneal astigmatic axis angle. (6,7)

[3] CCD - Charge-Coupled Device Camera

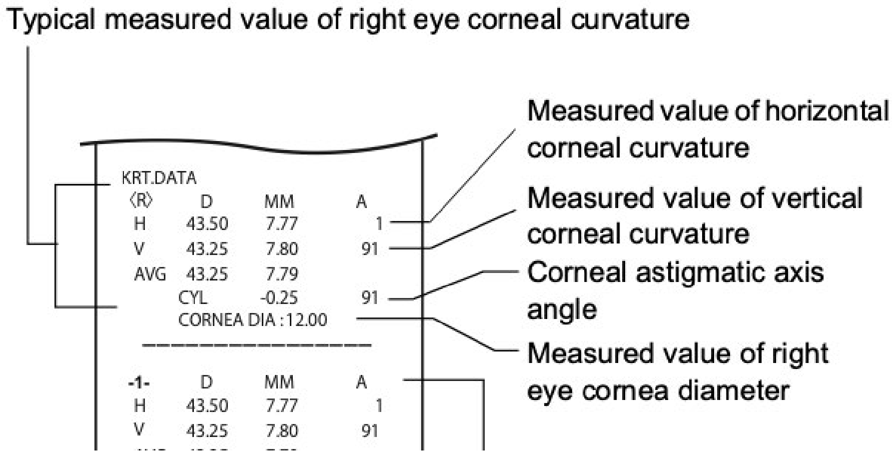

Figure 8 KRT TOPCON TRK-2P printer output(6)

Average corneal radius can also be calculated from horizontal and vertical corneal radius with the average corneal radius formula. For this master thesis, I used calculated data from KRT TOPCON TRK-2P printer output.

$$Ravg = \frac{Rh + Rv}{2}$$

Equation 2 The average corneal radius formula

Ravg – Average corneal radius
Rh – Horizontal corneal radius
Rv – Vertical corneal radius

2.1.3 Central corneal thickness

Corneal pachymetry is a process of measuring corneal thickness. The average corneal thickness is 0,550mm. Precise measurement is needed in decision making and planning for refractive surgery, diagnosis of corneal ectasia and accurate assessment of the intraocular pressure with special importance in glaucoma suspect and normal tension glaucoma. (8)

Topcon TRK-2P has a measuring range from 0,400mm to 0,750mm (Display unit: 0,001mm step display). (6)

2.1.4 Pupillary distance

Binocular pupillary distance is the distance between the center of pupils of your two eyes. Different techniques are used for PD[4] measurements, such as photographs, Viktorin's method, pupilometers, and auto refractometer. The average PD in the adult population is 63.7 ± 3.5 mm. (9)

TOPCON TRK-2P measures PD or IPD[5] with movement from measuring objective refraction of one eye to another. It has a range to measure PD from 20-85mm in 1mm step. (10)

2.2 MYAH

MYAH is a corneal analyzer with an integrated pupillometer and optical biometer. The instrument is made to be used in eye-care-related facilities and operated by qualified persons: eye specialists, ophthalmologists, optometrists, and opticians. MYAH's main applications are the following:

- Corneal topography for diagnostic purposes

[4] PD – Pupillary distance
[5] IPD – Interpupillary distance

- Measurement of Eye Axial thicknesses
- Fluorescence imaging for contact lens fitting
- Pupil measurements
- Dynamic analysis of tear film stability and blink time
- Assessment of the Meibomian glands
- Tear meniscus measurement
- Store and generate overviews of historic data of ocular properties for easy observation of changes over time. (2)

Figure 9 TOPCON MYAH

The following table is showing measurements, measuring range, display resolution, and in vivo repeatability.

Measurements		Measuring range	Display resolution	In vivo repeatability
Keratometry	Curve radius	5.00 – 12.00 mm	0.01 mm	±0.02 mm
	Curve Radius in Diopter (D) (n=1.3375)	28.00 - 67.50 D	0.01 D	±0.12 D
Axial Length		15.00 – 36.00 mm	0.01 mm	±0.027 mm
Pupil dimension		0.50 – 10.00 mm	0.01 mm	N/A
Limbus (White-To-White)		8.00 – 14.00 mm	0.01 mm	±0.05 mm
IBI Index		0.2 - 20.0 s	0.1 s	N/A
Break-Up Time (TBT)		0.5 - 30.0 s	0.1 s	N/A
Meibomian Glands area of loss		0 – 100 %	1%	N/A
Tear Meniscus Height		0.10 – 1.00 mm	0.01 mm	N/A

Table 2 Topcon MYAH information of measurements (11)

2.2.1 Axial eye length

TOPCON MYAH device measure axial Length by means of repeated interferometry scans (express eye AL[6] as ultrasound equivalent value, assuming the eye is phakic). For each acquisition, six individual interferometry scans are performed. Ultrasound biometrical instruments measure the axial length as the distance between the cornea and the inner limiting membrane of the retina, because the sound waves are reflected at this membrane. To ensure that the measured values obtained with the MYAH are compatible with those obtained through acoustic axial length measurement, the system automatically adjusts for the distance difference between the inner limiting membrane and the RPE[7]. The displayed axial length values are thus directly comparable to those obtained by immersion ultrasound, and no re-calculation or correction factors are necessary. MYAH has a range of measuring axial eye length from 15,00 to 36,00mm with a display resolution of 0,01mm and repeatability of ±0,027mm. (11)

2.2.2 Horizontal corneal diameter

The White to White section in TOPCON MYAH device allows to view the value of the corneal diameter measured from limbus to limbus. The measuring range of horizontal corneal diameter (White-to-White) is 15,00 – 36,00mm in repeatability ±0,05mm. (11) According to the White-to-white corneal diameter distribution in an adult population study: "Mean WTW corneal diameter in this study was 11.80 mm (confidence interval: 11.78–11.81), and based on two standard deviations from the mean, the normal range for this index was from 10.8 to 12.8 mm. WTW corneal diameter strongly correlated with corneal radius of curvature (r = 0.422) and axial length (r = 0.384)."(12)

Figure 10 WTW - White to White

[6] AL – Axial (eye) length
[7] RPE – Retinal pigment epithelium

2.3 Body measurements

2.3.1 Body height

No sophisticated device was used to measure body height. Body height, measured in centimeters was measured using a wall mounted tape, with 0.5cm accuracy. Measurement was taken standing straight next to a wall, barefooted.

2.3.2 Head size

No sophisticated device was used to measure head size. Head size was measured in centimeters with sewing measuring tape with 0.5cm accuracy. Head size was measured over the most prominent part on the back of the head and just above the eyebrows.

2.4 Subject criteria

All participants in this master thesis have unremarkable ocular history. This means:

- Absence of any eye diseases
- Absence of any eye pathology
- No ocular surgery history (eg. LASIK, cataract surgery…)
- Not wearing contact lenses on the day of examination

3 Results

In this master thesis was a total of 82 participants and their 164 eyes, 36 (43.9%) participants were male, and 46 (56.1%) participants were female. Participants were on average 41.46±13,19 old. The oldest person was 67 years old and the youngest was 15 years old. Both right and left eyes were included in the calculations.

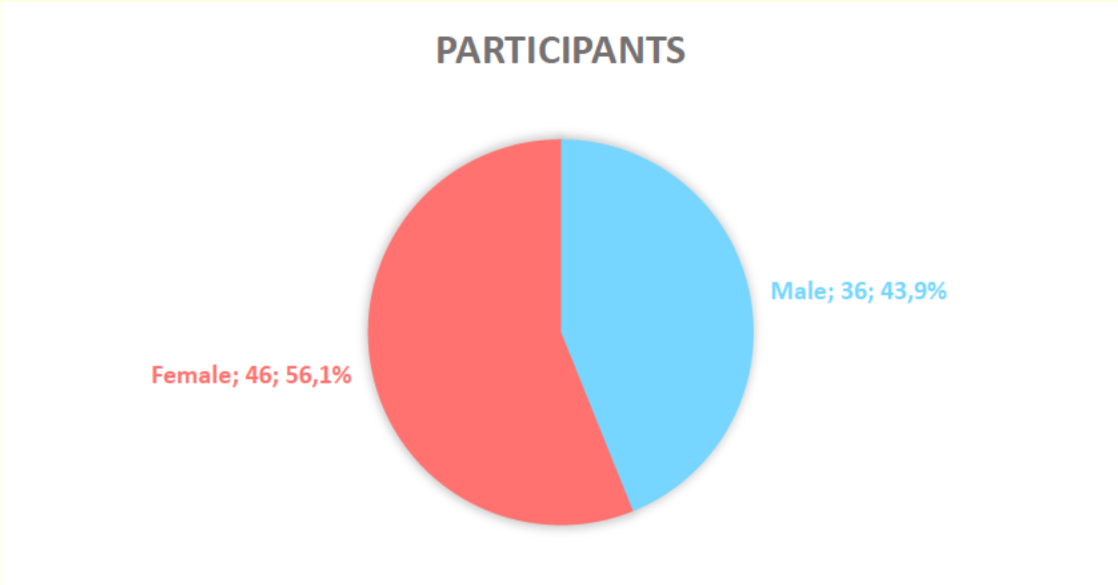

Figure 11 Sex distribution

Axial eye length was 23,91±1,02mm on average. The longest axial eye length was 26,24mm long and the shortest axial eye length was 21,20mm long.

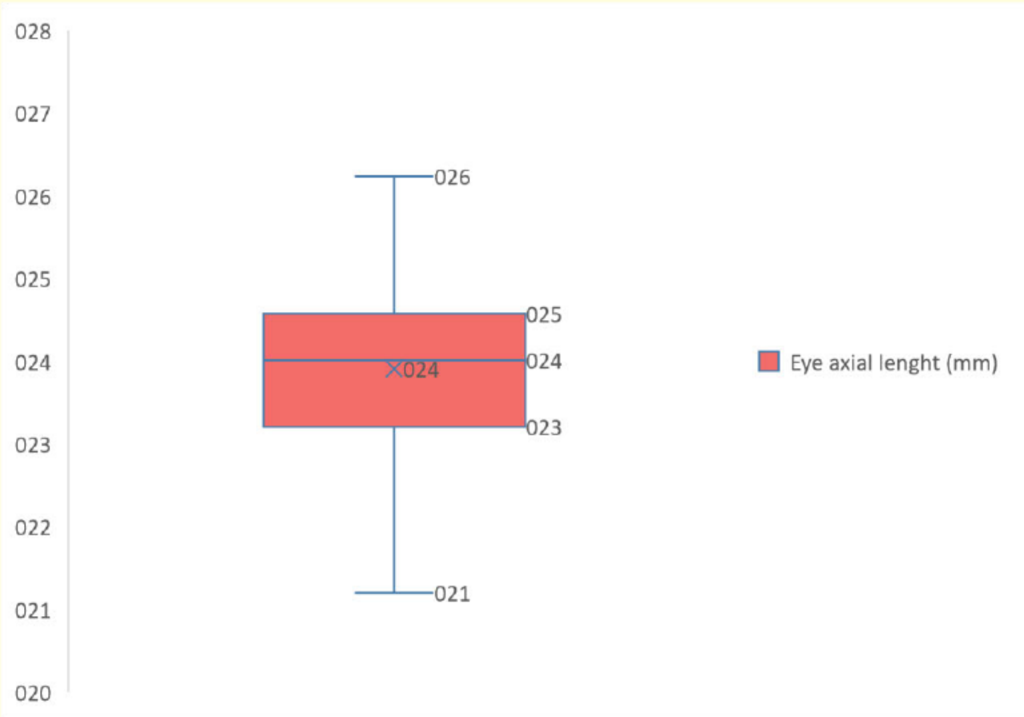

Figure 12 Axial eye length distribution

3.1 Axial eye length to body height comparison

In the comparison of axial eye length to body height comparison, all 82 participants and their 164 eyes were compared. The participant's body height mean was 172,5±8,2cm. The tallest person was 190,0cm tall and the shortest person was 156,0cm tall.

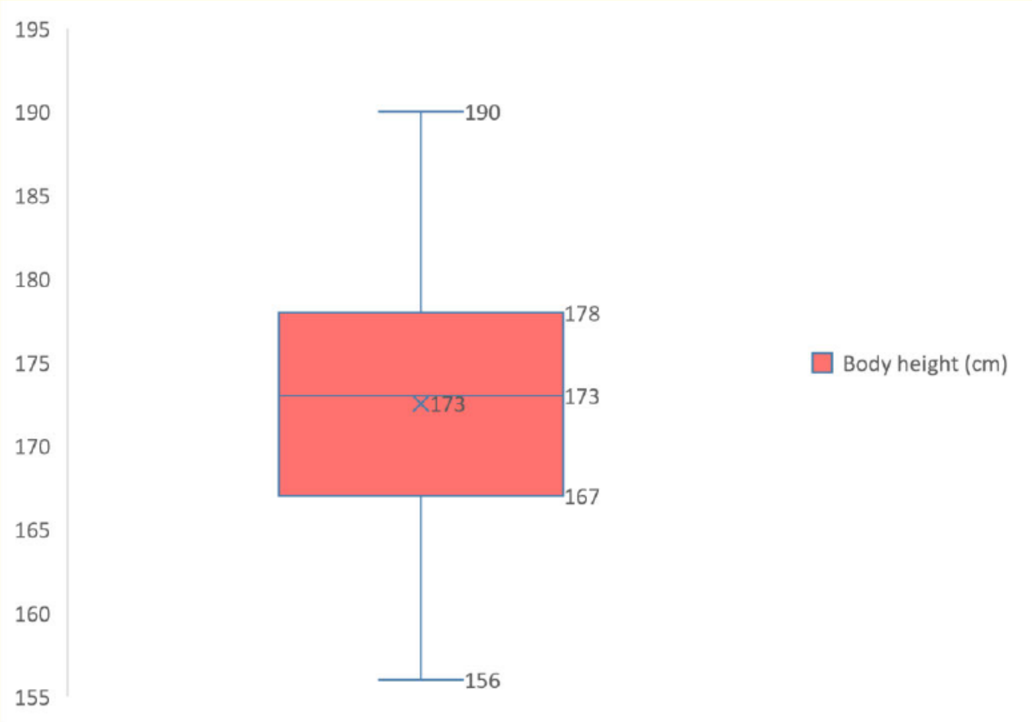

Figure 13 Distribution of body height

Pearson's coefficient of correlation is 0.14, with signification p=0,07, which is higher than 0,05. Therefore, we cannot reject null hypothesis. Therefore, we cannot claim that there is any connection between axial eye length and body height.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.140	,020	,014	,101004	,020	3,233	1	162	,074

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,033	1	,033	3,233	.074[b]
	Residual	1,653	162	,010		
	Total	1,686	163			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	2,091	,167		12,498	,000	1,760	2,421		

	Body height	,002	,001	,140	1,798	,074	,000	,004	1,000	1,000

Table 3 Statistical data between axial eye length and body height

With independent variable (body height) 2% (p=0,074) of variability of dependable variable (eye axial length) can be explained. Value of R and R Square is relatively low therefore the model is not effective enough to determine the relationship. The ANOVA analysis has shown that the regression model does not predict the dependent variable significantly. Significance is above 0,05, therefore we cannot reject the null hypothesis. There is no linear relationship between eye axial length and body height.

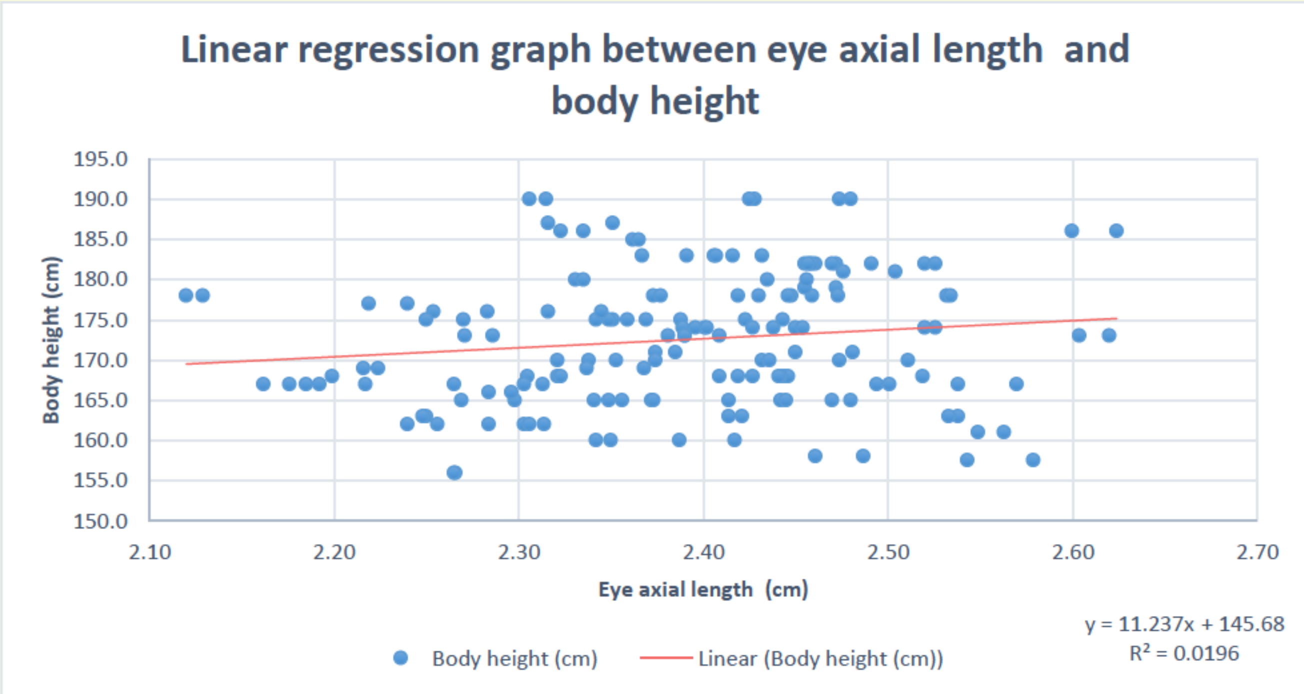

Figure 14 Graph of linear regression between eye axial length and body height

Based on the table of linear regression above, the variance of the independent variable (eye axial length) and dependent variable (body height) is 2%. (p=0,074). This data shows that the model is bad and that the further investigation is not meaningful.

3.2 Axial eye length to head size comparison

In the comparison of axial eye length to head size comparison, all 82 participants and their 164 eyes were compared. Participant's head size mean was 56,6±2,4cm. The biggest head was 61,5cm and the smallest was 47,5cm.

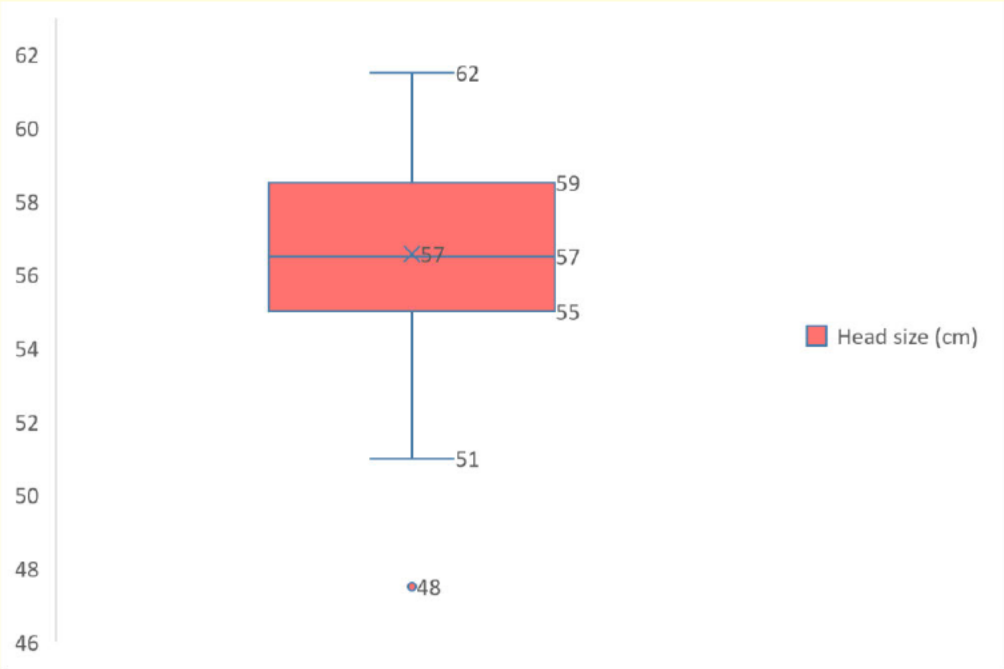

Figure 15 Distribution of head size

Pearson's coefficient of correlation is 0.128, with signification p=0,103, which is higher than 0,05. Therefore, we cannot reject null hypothesis. Therefore, we cannot claim that there is any connection between axial eye length and head size.

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.128	,016	,010	,101172	,016	2,688	1	162	,103

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,028	1	,028	2,688	.103[b]
	Residual	1,658	162	,010		
	Total	1,686	163			

Coefficients										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	2,088	,185		11,301	,000	1,723	2,453		
	Body height	,005	,003	,128	1,639	,103	-,001	,012	1,000	1,000

Table 4 Statistical data between axial eye length and head size

With independent variable (head size) 1,6% (p=0,103) of variability of dependable variable (eye axial length) can be explained. Value of R and R Square is relatively low therefore the model is not effective enough to determine the relationship. The ANOVA analysis has shown that the regression model does not predict the dependent variable significantly. Significance is above 0,05, therefore we cannot reject the null hypothesis. There is no linear relationship between eye axial length and body height.

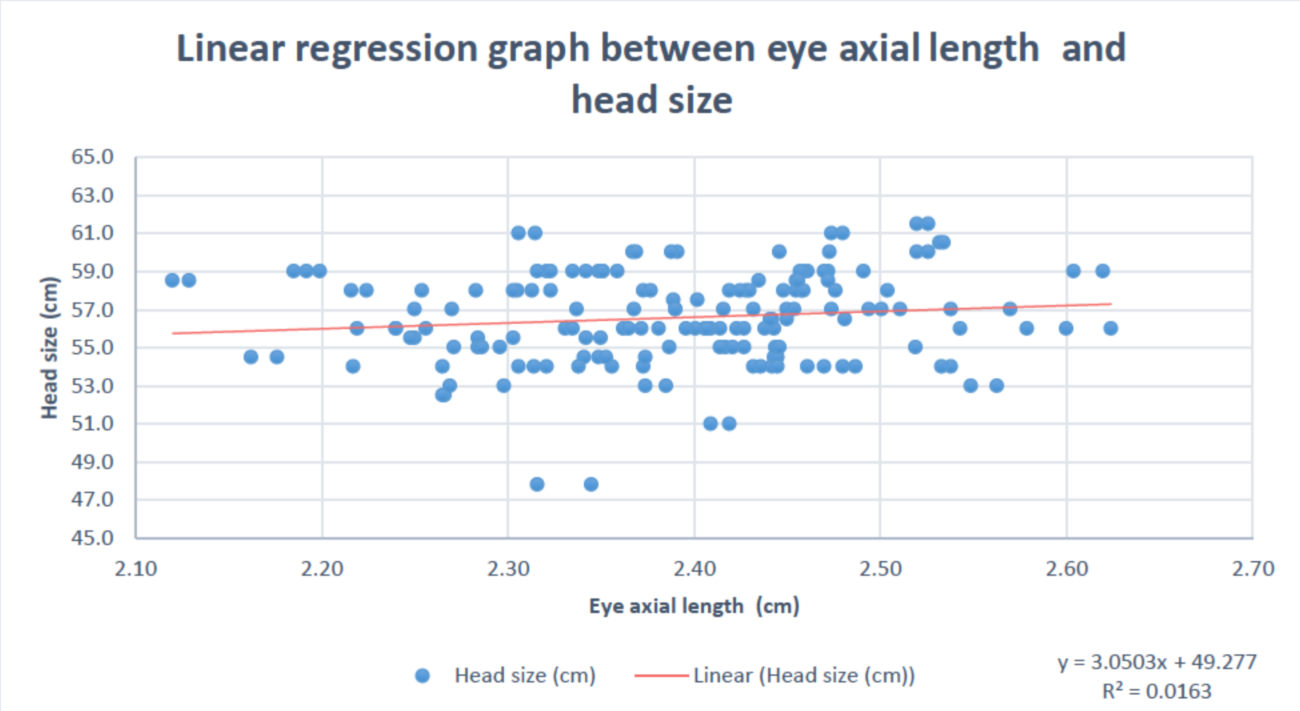

Figure 16 Graph of linear regression between eye axial length and head size

3.3 Axial eye length to objective spherical equivalent comparison

In comparison of axial eye length to objective spherical equivalent comparison, all 164 eyes were compared. The participant's objective spherical equivalent mean was -0,79±2,06D. The eye with the lowest objective spherical equivalent was -6,50D and the eye with the highest objective spherical equivalent was 4.25D.

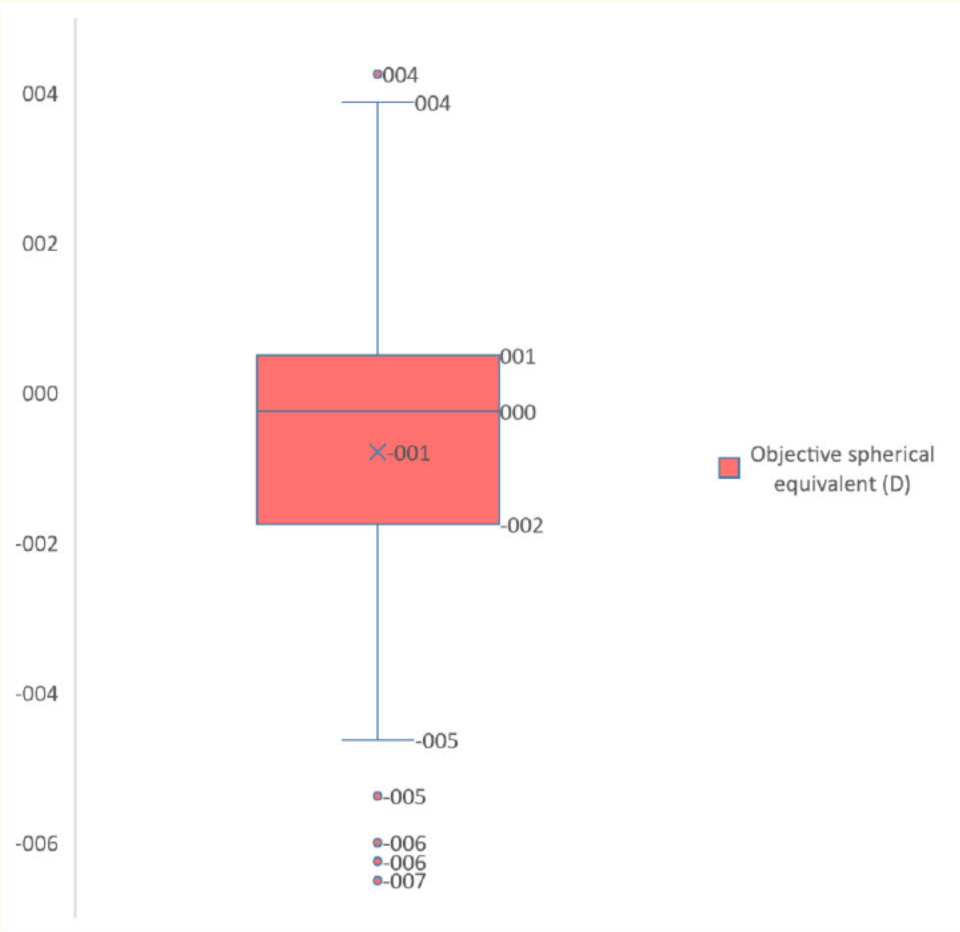

Figure 17 Distribution of objective spherical equivalent measurements

Pearson's coefficient of correlation is -0.676, signification p<0,001, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (strong) connection between axial eye length and objective spherical equivalent.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.676	,457	,454	,075155	,457	136,446	1	162	,000

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,771	1	,771	136,446	.000b
	Residual	,915	162	,006		
	Total	1,686	163			

Coefficients

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	Collinearity Statistics

		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	2,365	,006		376,062	,000	2,352	2,377		
	Body height	-,033	,003	-,676	-11,681	,000	-,039	-,028	1,000	1,000

Table 5 Statistical data between axial eye length and objective spherical equivalent

With independent variable (objective spherical equivalent) 45% (p<0,001) of variability of dependable variable (eye axial length) can be explained. Value of R is 0,676, this is above 0,4 therefore the model is suitable for further analysis. R Square is around 0,5, also the difference between R Square and Adjusted R Square is low, therefore the model is effective enough to determine the relationship. ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length and objective spherical equivalent because of sig. (p<0,001) is less than 0,05. We can reject the null hypothesis and accept the alternative hypothesis that claims that there is a linear relationship between eye axial length and objective spherical equivalent.

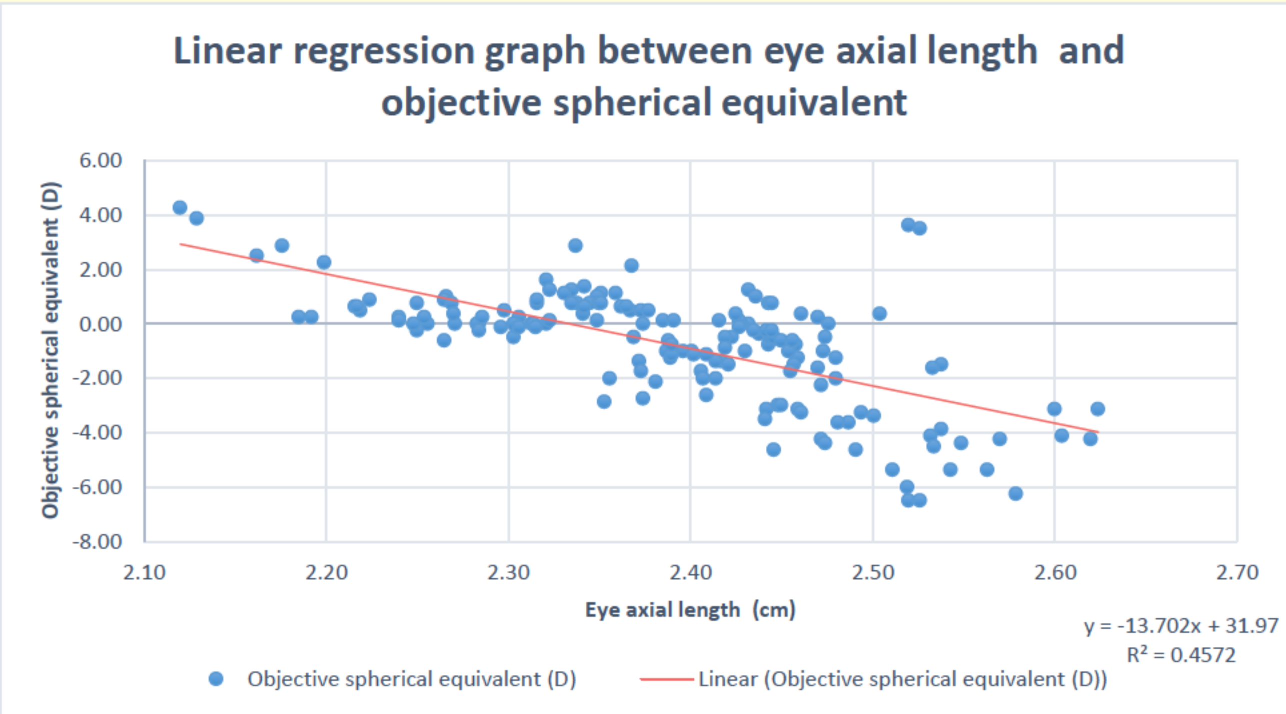

Figure 18 Graph of linear regression between eye axial length and objective spherical equivalent

3.4 Axial eye length to average corneal radius comparison

In comparison of axial eye length to average corneal radius comparison, all 164 eyes were compared. The participant's average corneal radius mean was 7,81±0,22mm. The eye with the flattest average corneal radius was 8,44mm and the eye with the steepest corneal radius was 7,34mm.

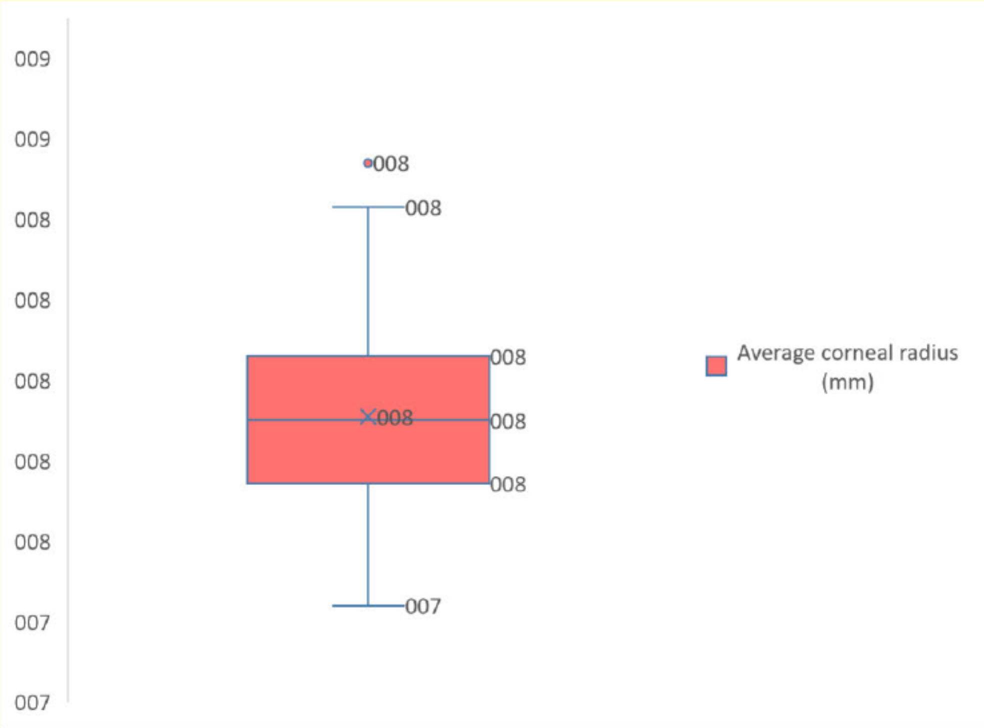

Figure 19 Distribution of average corneal radius measurements

Pearson's coefficient of correlation is 0.555, signification p<0,001, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (moderate) connection between axial eye length and average corneal radius.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.555	,309	,304	,084822	,309	72,294	1	162	,000

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,520	1	,520	72,294	.000b
	Residual	1,166	162	,007		
	Total	1,686	163			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	,428	,231		1,852	,066	-,028	,884		
	Body height	2,514	,296	,555	8,503	,000	1,930	3,098	1,000	1,000

Table 6 Statistical data between axial eye length and average corneal radius

With independent variable (average corneal radius) 31% ($p<0,001$) of variability of dependable variable (eye axial length) can be explained. Value of R is 0,555, this is above 0,4 therefore the model is suitable for further analysis. R Square is relatively low therefore the model is not effective enough to determine the relationship. Despite that ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length and average corneal radius because of sig. ($p<0,001$) is less than 0,05. We can reject the null hypothesis and accept the alternative hypothesis that claims that there is a linear relationship between eye axial length and average corneal radius.

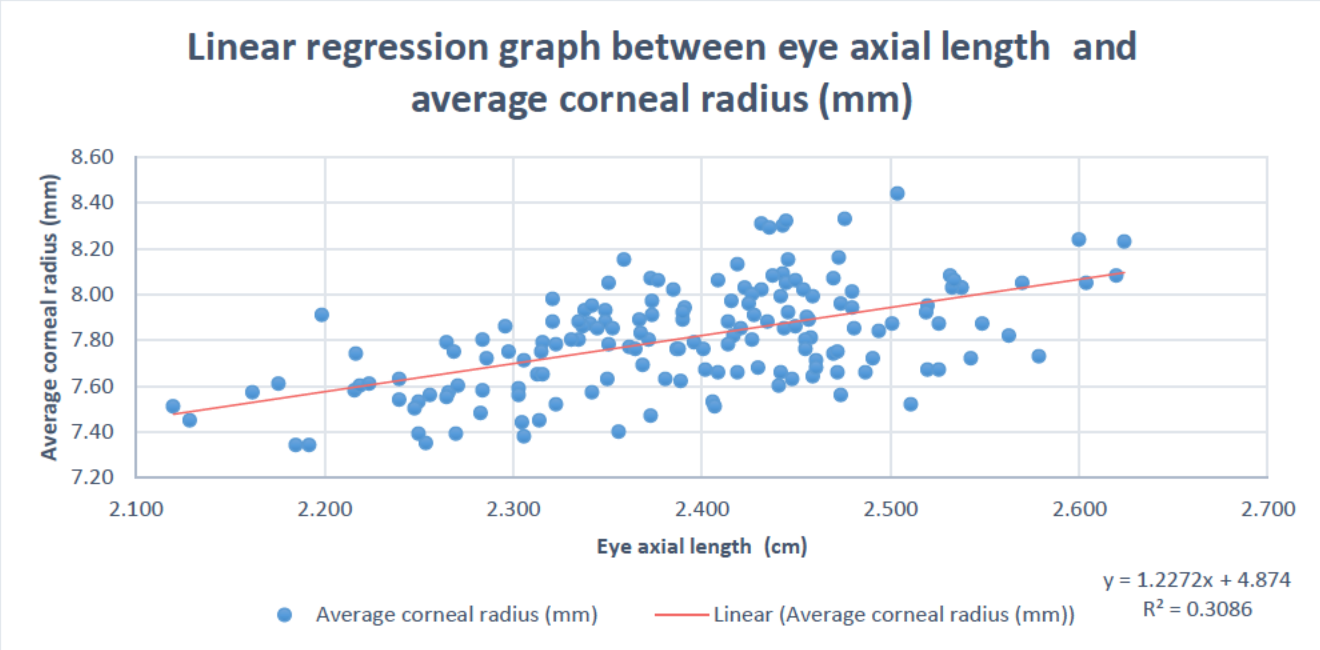

Figure 20 Graph of linear regression between eye axial length and average corneal radius

3.5 Axial eye length to horizontal corneal diameter comparison

In comparison of axial eye length to horizontal corneal diameter comparison, all 164 eyes were compared. Participant's horizontal corneal diameter mean was 1,21±0,035cm. The eye with the smallest horizontal corneal diameter was 1,13cm and the eye with the largest horizontal corneal diameter was 1,296cm.

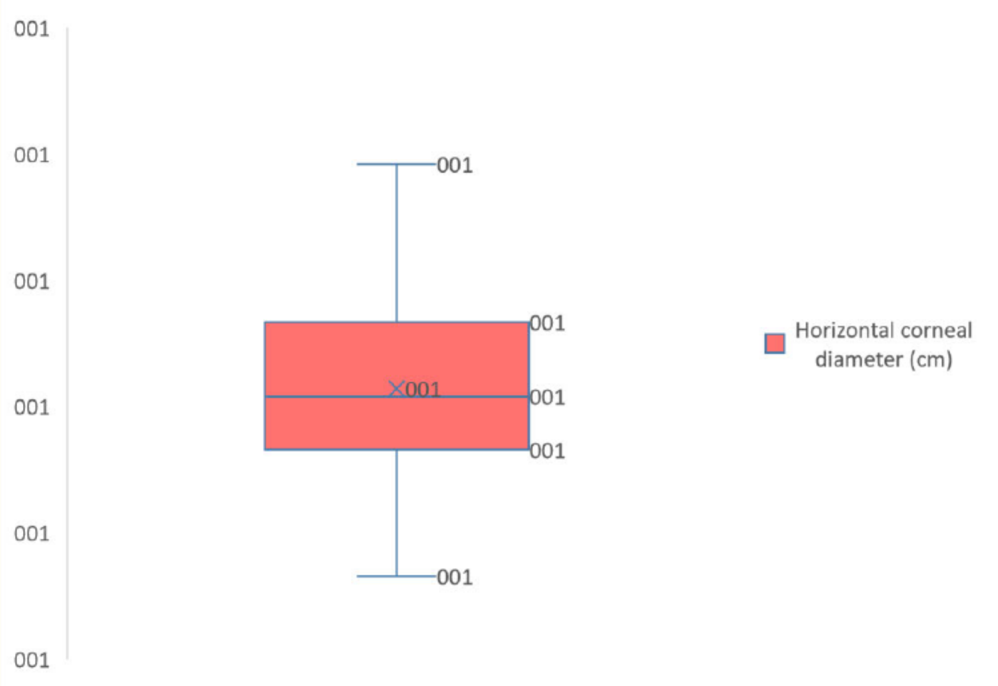

Figure 21 Distribution of horizontal corneal diameter measurements

Pearson's coefficient of correlation is 0.433, signification p<0,001, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (moderate) connection between axial eye length and horizontal corneal diameter.

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.433	,187	,182	,091970	,187	37,291	1	162	,000

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,315	1	,315	37,291	.000b
	Residual	1,370	162	,008		
	Total	1,686	163			

Coefficients										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	,889	,246		3,614	,000	,403	1,375		
	Body height	1,244	,204	,433	6,107	,000	,842	1,647	1,000	1,000

Table 7 Statistical data between axial eye length and horizontal corneal diameter

With independent variable (Horizontal corneal diameter) 18,7% (p<0,001) of variability of dependable variable (eye axial length) can be explained. Value of R is 0,433, this is above 0,4, therefore the model is suitable for further analysis. R Square is relatively low, therefore the model is not effective enough to determine the relationship. Despite that ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length and horizontal corneal diameter because of sig. (p<0,001) is less than 0,05. We can reject the null hypothesis and accept the alternative hypothesis that claims that there is a linear relationship between eye axial length and horizontal corneal diameter.

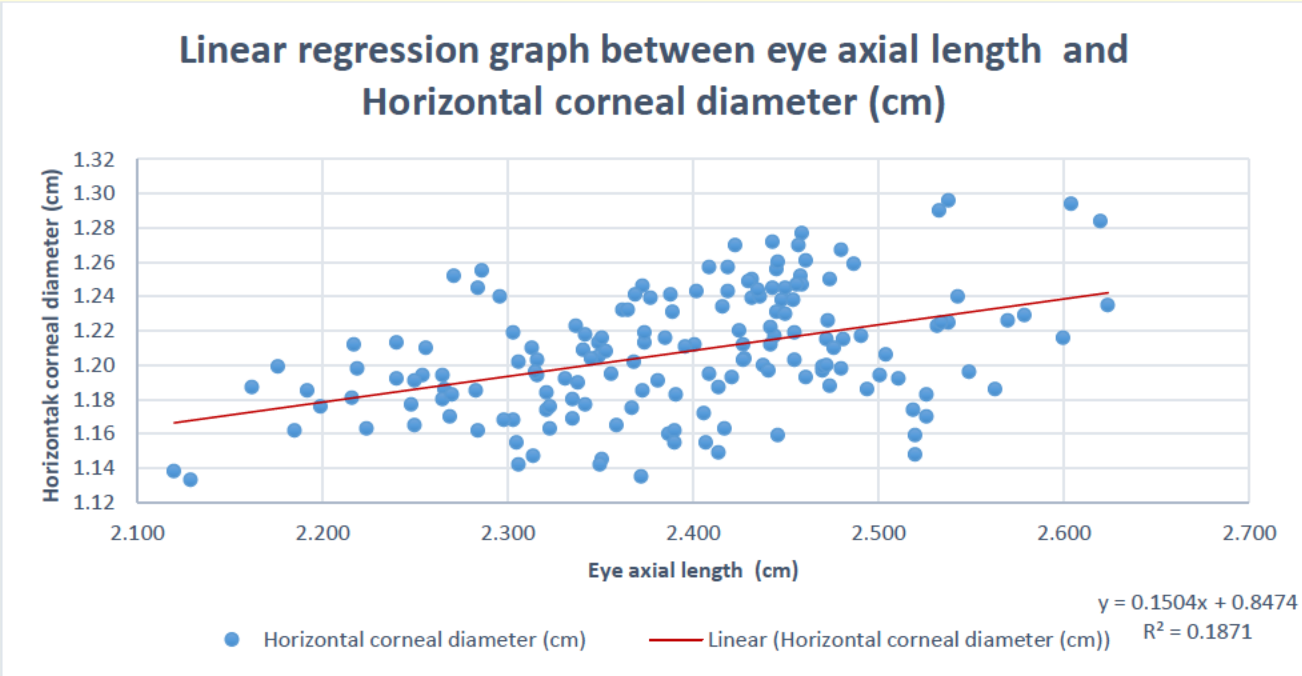

Figure 22 Graph of linear regression between eye axial length and horizontal corneal diameter

3.6 Axial eye length to central corneal thickness comparison

In comparison of axial eye length to central corneal thickness comparison, 131 eyes were compared. Measurements of 33 are missing or invalid due to errors in measuring. Mean of 131 eyes were 532±0,36µm thick. The thickest cornea was 673µm and the thinnest cornea was 474µm.

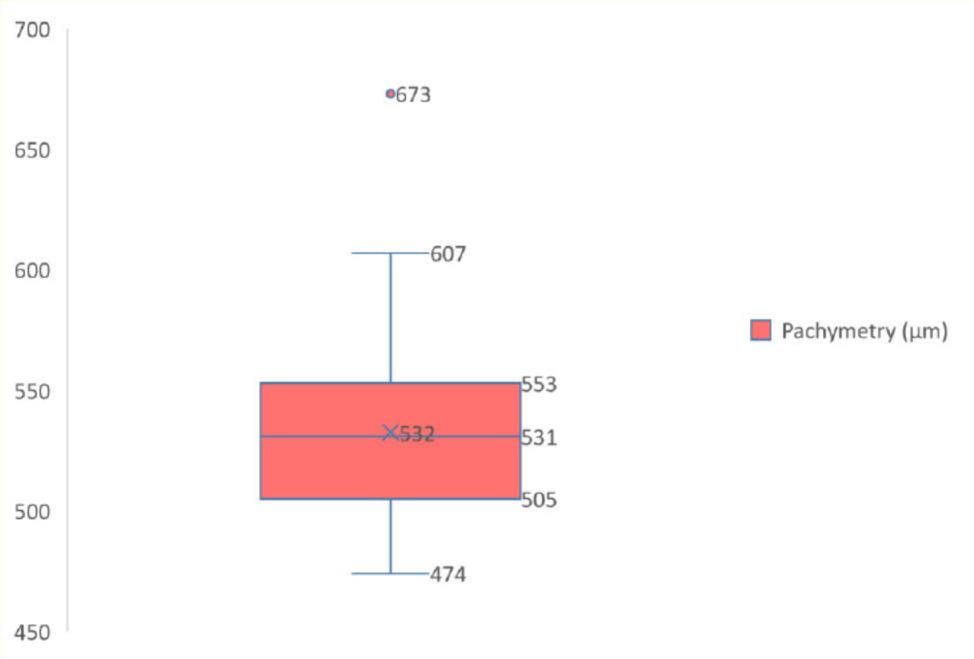

Figure 23 Distribution of central corneal thickness measurements

Pearson's coefficient of correlation is 0.248, signification p=0,004, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (weak) connection between axial eye length and central corneal thickness.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.248	,061	,054	,099752	,061	8,435	1	129	,004

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,084	1	,084	8,435	.004[b]
	Residual	1,284	129	,010		
	Total	1,368	130			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	2,008	,131		15,357	,000	1,749	2,266		

	Central corneal thickness	711,491	244,972	,248	2,904	,004	226,807	1196,175	1,000	1,000

Table 8 Statistical data between axial eye length and central corneal thickness

With independent variable (central corneal thickness) 6% (p=0,004) of variability of dependable variable (eye axial length) can be explained. Value of R and R Square is relatively low, therefore the model is not effective enough to determine the relationship. Despite that ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length and central corneal thickness because of sig. (p=0,004) is less than 0,05. We can reject the null hypothesis and accept the alternative hypothesis that claims that there is a linear relationship between eye axial length and central corneal thickness.

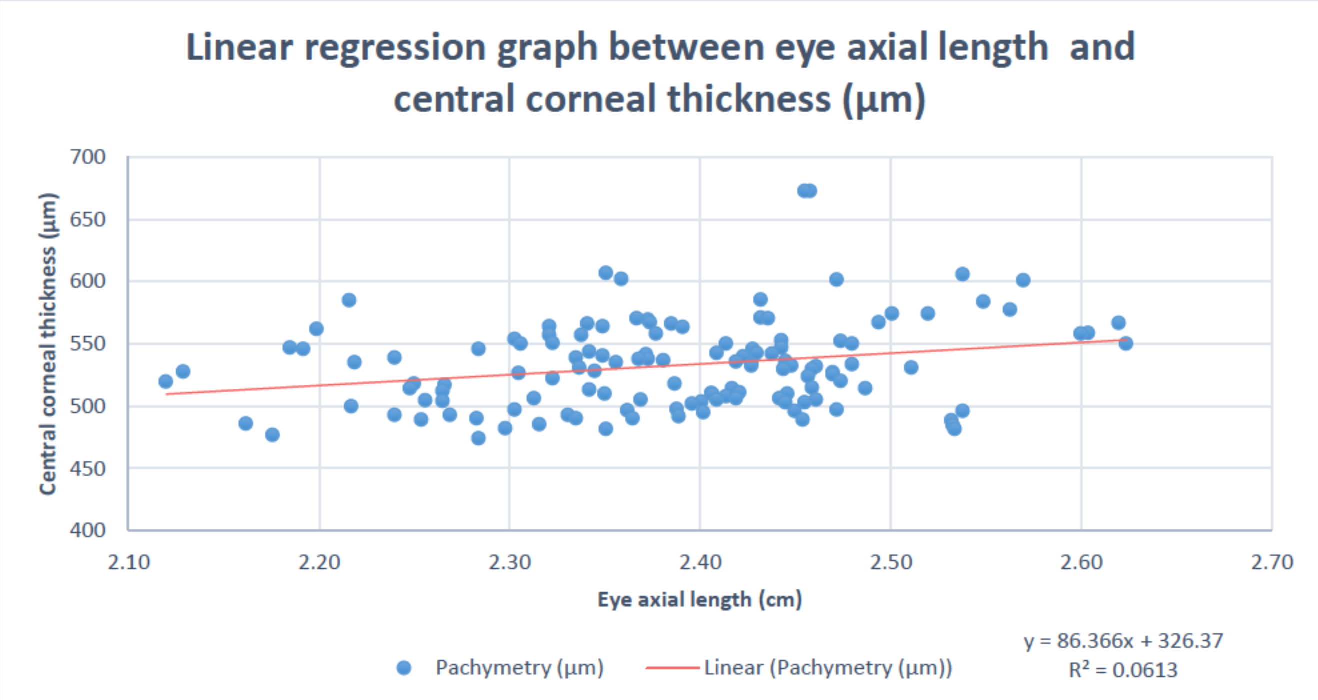

Figure 24 Graph of linear regression between eye axial length and central corneal thickness

3.7 Axial eye length to pupillary distance comparison

In comparison of axial eye length to pupillary distance comparison, 82 measurements were compared. Participants' pupillary distance mean was 63,94±3,30mm. A participant with the longest pupillary distance was 75,0mm and the participant with the shortest pupillary distance was 56,00mm.

Figure 25 Distribution of pupillary distance measurements

Pearson's coefficient of correlation is 0.161, signification p=0,039, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (very weak) connection between axial eye length and pupillary distance.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.161	,026	,020	,100671	,026	4,329	1	162	,039

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,044	1	,044	4,329	.039b
	Residual	1,642	162	,010		
	Total	1,686	163			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	2,073	,153		13,562	,000	1,771	2,375		

	Body height	,050	,024	,161	2,081	,039	,003	,097	1,000	1,000

Table 9 Statistical data between axial eye length and pupillary distance

With independent variable (pupillary distance) 2,6% (p=0,039) of variability of dependable variable (eye axial length) can be explained. Value of R and R Square is relatively low, therefore the model is not effective enough to determine the relationship. Despite that ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length and pupillary distance because of sig. (p=0,039) is less then 0,05. We can reject the null hypothesis and the accept alternative hypothesis that claims that there is a linear relationship between eye axial length and pupillary distance.

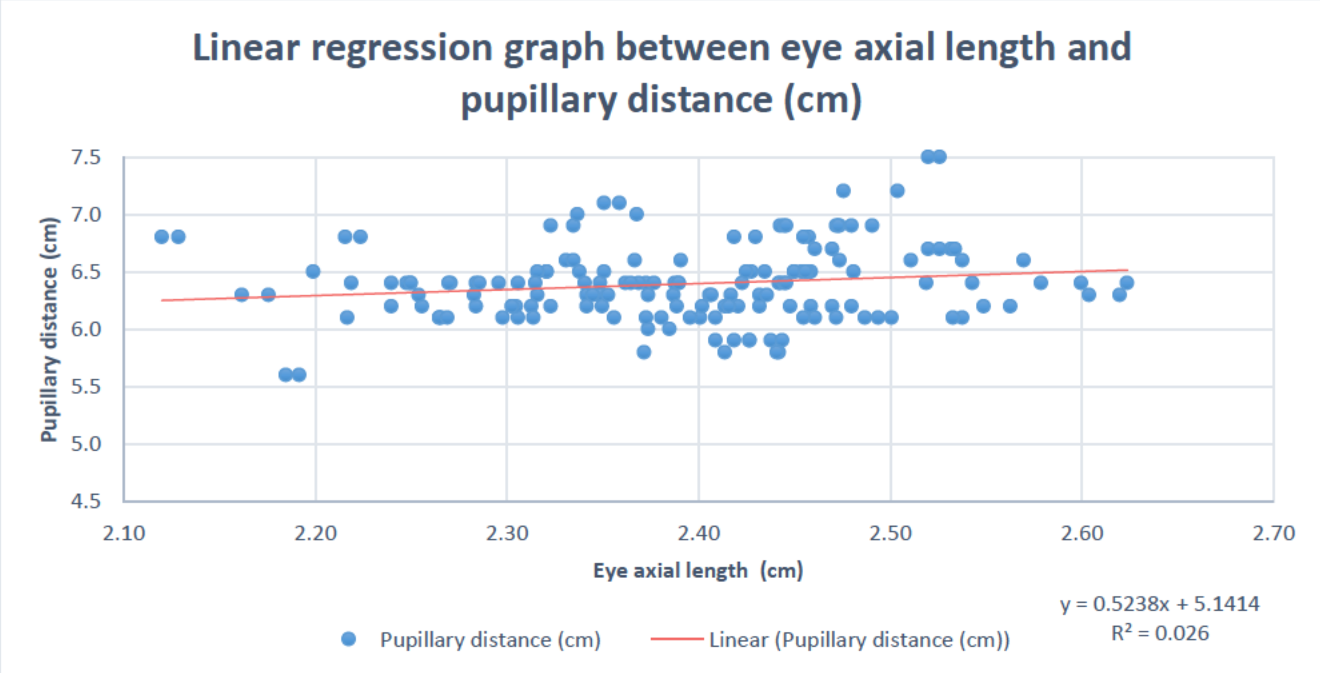

Figure 26 Graph of linear regression between eye axial length and pupillary distance

3.8 Multi linear regression model of axial eye length

Pearson's coefficient of correlation is 0.857, signification p<0,001, which is lower than 0,05. Therefore, we can with 95% probability reject null hypothesis and accept the alternative hypothesis, which claims that there is a (strong) connection between axial eye length and objective spherical equivalent and average corneal radius.

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.857	,734	,731	,052733	,734	222,595	2	161	,000

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1,238	2	,619	222,595	.000b
	Residual	,448	161	,003		

	Total	1,686	163							
Coefficients										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	,503	,144		3,500	,001	,219	,787		
	Objective spherical equivalent	-,032	,002	-,653	-16,067	,000	-,036	-,028	,998	1,002
	Average corneal radius	2,385	,184	,527	12,963	,000	2,022	2,749	,998	1,002

Table 10 Multi linear regression model of axial eye length

With independent variables (objective spherical equivalent and average corneal radius) 73,4% (p<0,001) of variability of dependable variable (eye axial length) can be explained. Value of R is 0,857, this is above 0,4 therefore the model is suitable for further analysis. R Square is above 0,5, also the difference between R Square and Adjusted R Square is low, therefore the model is effective enough to determine relationship. ANOVA analysis has shown that the regression model predicts the dependent variable significantly. There is a significant change in the relationship between eye axial length, objective spherical equivalent and average corneal radius because of sig. (p<0,001) is less then 0,05. We can reject the null hypothesis and accept the alternative hypothesis that claims that there is a linear relationship between eye axial length, average corneal radius and objective spherical equivalent. Specifically, we found a -0,653 increase in objective spherical equivalent for every unit increase of axial eye length and a 0,527 increase in average corneal radius for one unit increase of axial eye length.

The following graph represents the linear relationship between axial eye length and predicted unstandardized values for Average corneal radius (cm) and objective spherical equivalent.

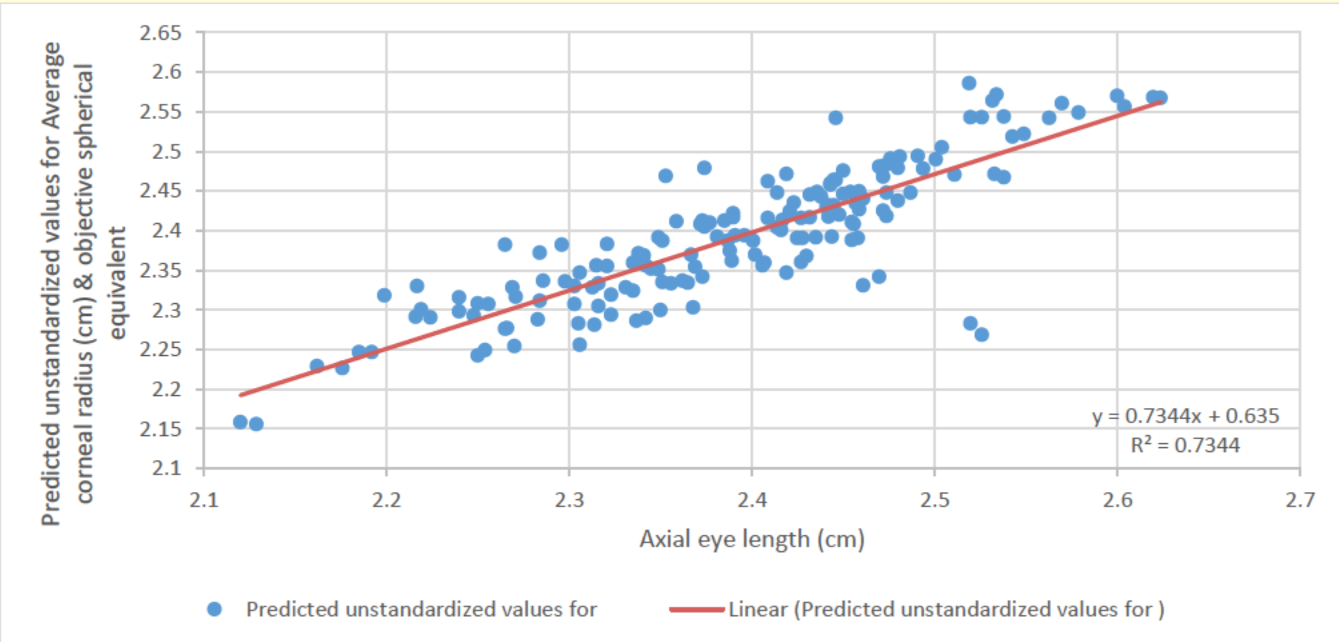

Figure 27 Multi linear regression model of axial eye length

4 Discussion

This study tried to prove a possible correlation between axial eye length and other physiological properties of the eye, body height and the head.

4.1 Axial eye length to body height comparison

The analysis of axial eye length to body height comparison revealed that there is a very weak correlation (R=0,14; P=0,074). Body height was measured using a wall mounted tape, which is not the most sophisticated way of measuring body height. An error of the examiner is possible, and results may be different if a more sophisticated device like a stadiometer was used.

Stadiometer was used to measure body height in study Axial length and its associatoins in a Russian population. Mentioned study show similar results as in this study. Axial length of the eye was measured sonographically. Mean axial length was 23,3±1,1mm, which is less compared to mean value of this study (23,9mm. Results of associations of axial eye length and body height show a very weak correlation (R=0,07; P<0,001). (13) In both studies we can see very weak correlation, but in the study, Axial length and its associatoins in a Russian population are statistically significant with a p value less than 0,05.

Study Correlations between the optical components of the eye, height and head circumference show similar results. Axial eye length was measured with a CooperVision A-mode ultrasound unit (applanation) with an accuracy of 0.1 mm. In this study. among other things, axial eye length is compared to body height. Weak correlation was found between axial eye length and body height (r=0,257; p=0,034).(14)

The correlation between axial eye length and body height is weak in both studies and this study.

4.2 Axial eye length to head size comparison

The analysis of axial eye length to head size comparison revealed that there is very weak correlation (R=0.128; P=0,103). Head size was measured with a sewing meter. Mean value of head circumference of this study was 56,57cm. The relationship with axial eye length was not statistically significant. In the study Head Circumference in Canadian Male Adults: Development of a Normalized Chart, 280 adult male participants had mean value for head circumference were 56.69 cm. (15) Results of means of the study Head Circumference in Canadian Male Adults are pretty close. Unfortunately, head size was not compared to axial eye length.

Study Correlations between the optical components of the eye, height and head circumference show similar results. Axial eye length was measured with a CooperVision A-mode ultrasound unit (applanation) with an accuracy of 0.1 mm. Among other things, axial eye length is compared to head circumference. The study found a weak correlation between axial eye length and head circumference (r=-0,01; p=0,95). Mean head circumference of this study was 54,98cm. (14) Mean head circumference of this study is less compared to study Head circumference in Canadian male adults and the results of this study.

Study Correlations between the optical components of the eye, height and head circumference and results of this study have a weak or very weak correlation and not statistically significant correlation between axial eye length and head circumference (head size).

4.3 Axial eye length to objective spherical equivalent comparison

In axial eye length to objective spherical equivalent comparison, a strong correlation was found (R=-0,676; P<0,001), which is not surprising, since the altered axial length is a major driver for refractive error, especially in myopia.

Study Axial length and its associatoins in a Russian population compared axial eye length to Refractive Error (Spherical Equivalent in diopters). Axial length of the eye was measured sonographically. Mean axial length was

23,3±1,1mm. Results of association of axial eye length and Refractive Error (Spherical Equivalent in diopters) show a strong correlation (R=-0,59; P<0,001). In both studies, we can see a strong and significant (P<0,001) correlation. (13)

Study Correlations between the optical components of the eye, height and head circumference show similar results as in this study. Axial eye length was measured with a CooperVision A-mode ultrasound unit (applanation) with an accuracy of 0.1 mm. Among other things, axial eye length is compared to refraction. Refraction was subjective and measured in non-cycloplegic condition. Axial eye length appears to be the major determinant of refraction, as can be concluded from the high regression coefficient of the correlation between axial length and refraction (r = - 0.75; p<0,001). (14)

A comparison between axial eye length and subjective spherical equivalent would be interesting to compare. A strong correlation would be expected, because in most cases in practice objective refraction is very close to subjective refraction. If we compare Study Correlations between the optical components of the eye, height and head circumference, where subjective non-cycloplegic refraction was compared to axial eye length versus results of this study where axial eye length was compared to objective spherical equivalent, show that correlation is stronger when axial eye length is compared to subjective non-cycloplegic refraction. But it would be more accurate to compare axial eye length to objective spherical equivalent and subjective spherical equivalent (non-cycloplegic refraction) within the same sample of participants.

4.4 Axial eye length to average corneal radius comparison

Results of this study of axial eye length compared to average corneal radius have a moderate correlation (R=0,555; P<0,001), which is not surprising, because in practice it is usually seen that myopic patients have a flatter corneal radius and hyperopic patients have a steeper corneal radius.

Study Axial length and its associatoins in a Russian population also compared axial eye length to Corneal refractive power (Diopters). Axial length of the eye was measured sonographically. Mean axial length was 23,3±1,1mm. Results of associations of axial eye length and Corneal refractive power (Diopters) show a moderate correlation (R=-0,41; P<0,001). Both studies show similar (moderate) correlation. (13)

In the study Relationship between Corneal Thickness and Radius to Body Height mean values of corneal radius were measured between 7,16mm to 8,49mm with a mean of 7,75±0,24mm. (16) Minimum value of the average corneal radius in this study was 7,34mm, and the maximum value of average corneal radius was 8,44mm. Mean value was 7,80±0,22mm. Mean and maximum values of corneal radius values are very close, however, minimum values have a difference of 0,18mm. Unfortunately, no statistical comparison to axial eye length was found in this study.

4.5 Axial eye length to horizontal corneal diameter comparison

Measurement of corneal diameter is mostly used for contact lens fitting. In this study correlation between axial eye length and horizontal corneal diameter was moderate strong (R=0,443; P<0,001). Mean value of WTW corneal diameter was 12,10±0,35mm. WTW corneal diameter was measured with the MYAH Topcon device.

In the study White-to-white corneal diameter distribution in an adult population. Purpose of this study was to determine the normal distribution of corneal diameter and its association with other biometric components. In the study were 4787 Iranian participants, aged 40 to 64. WTW corneal diameter and biometric components were measured with the LENSTAR/BioGraph. Mean WTW corneal diameter was 11.80 mm. Correlation between WTW corneal diameter and axial eye length was strong (R=0.384; Coefficient (95% CI)=0,19; p< 0.001) as authors describe.(12)

We can see difference in the strength of correlation between White-to-white corneal diameter distribution in an adult population study and the results of this study. Opinion of strength is different. Authors of the study

White-to-white corneal diameter distribution in an adult population describe a lower pearson correlation coefficient (R=0.384) as strong compared to description of pearson correlation coefficient of this study where it is described as moderate strong (R=0,443).

It would be interesting to compare a corneal diameter to other ocular measurements (corneal radius, central corneal thickness, anterior chamber depth). Perhaps correlation between this structures would have higher correlation.

4.6 Axial eye length to central corneal thickness comparison

Results of this study of axial eye length compared to central corneal thickness show a weak correlation (R=0,248; P=0,004). Axial eye length is measured from the cornea to the retinal pigment epithelium. Interestingly, part of axial eye length is not strongly correlated with axial eye length. Because central corneal thickness is part of the axial eye length, stronger relationship was expected.

Study Axial length and its associatoins in a Russian population compared axial eye length to central corneal thickness. Study included 5899 multi-ethnic Russian individuals aged more than 40 (58,8±10,6). Axial length of the eye was measured sonographically. Mean axial length was 23,3±1,1mm. Results of associations of axial eye length and central corneal thickness show a very weak correlation (R=0,04; P<0,002). The Ural Eye and Medical Study found a very weak correlation compared to this study where correlation was significant, still weak but a little stronger. (13)

Purpose of the study Relationship Between Central Corneal Thickness, Refractive Error, Corneal Curvature, Anterior Chamber Depth and Axial Length was to determine the relationship between central corneal thickness (CCT), refractive error, corneal curvature, anterior chamber depth and axial eye length. 500 normal Taiwanese Chinese participants, aged from 40 to 80 participated in this study. The median CCT was 555±27 µm for males and 553 ± 30 µm for females. There were no significant correlation between the CCT and axial length (r =-0.053, p = 0.223).(17)

No statistically significant association between central corneal thickness and axial length (R= 0.0853; P=0.0049) was found in the study Corneal thickness and axial length, corneal thickness and axial length measurements.(18)

Difference between results of studies Relationship Between Central Corneal Thickness, Refractive Error, Corneal Curvature, Anterior Chamber Depth and Axial Length study and Corneal thickness and axial length study compared to this study results is that this study found significant, but weak correlation between axial eye length and central corneal thickness, and in the other studies significant correlation was not found.

4.7 Axial eye length to pupillary distance comparison

In this study, Topcon TRK-2P was used to measure pupillary distance. Mean value was 63,94±3,3mm, the minimum value was 56mm and the maximum value was 75mm. Pupillary distance was measured with Topcon TRK-2P. Perhaps the PD meter would give us a more precise measurement of pupillary distance because it is a device made just for measuring pupillary distance.

Same device (Topcon Auto Kerato-Refracto Tonometer TRK-2P, Tokyo, Japan) as in this study was used in another study: Assessment of Interpupillary Distance in the Azerbaijan Society. 641 male and 491 female participants, aged from 18 to 85 years were investigated for anatomical pupillary distance. Auto refractometer was used for pupillary distance measurements. Purpose of this study was to determine the normal distribution of pupillary distance in adult males and females of the Azerbaijani society and create a specific pupillary distance database. The mean pupillary was 63.7±3.5 mm. The minimum value was 51mm and the maximum value was 82mm. (9)

Unfortunately, no study or literature was found that compares pupillary distance to axial eye length. Mean values of this study and study Assessment of Interpupillary Distance in the Azerbaijan Society are very close.

4.8 Multi linear regression model of axial eye length

Multi linear regression model was made between axial eye length and two strongest variables: objective spherical equivalent ($R=-0,676$; $P<0,001$) and average corneal radius ($R=0,555$; $P<0,001$). Multi linear regression model has a very strong and statistically significant relationship ($R=0.857$; $P<0,001$). Based on analysis of data, for one unit increase of axial eye length, objective spherical equivalent increase for -0,653 and one unit increase of axial eye length a 0,527 average corneal radius increase. Based on this multi linear regression model, we can conclude that eyes with longer axial eye length will on average have flatter cornea and spherical equivalent will be more myopic.

4.9 Implications for practice

The implication of these findings might hypothetically be:

a) Contact lens manufacturers should be aware of possible necessity of altering standard back surface radii with increasing myopic power due to flatter corneas in higher myopia found in our study

b) The eye models for calculating individual spectacle lenses could consider the newly established relationships between axial eye length and corneal radii.

c) The positive (though weak) correlation between central corneal thickness and axial eye length could be considered important in myopia research, in corneal refractive surgery models and glaucoma models

5 Conclusion

The purpose of the study comprised in this master thesis was to find whether there is any relationship between axial eye length and other physiological properties of the eye (horizontal corneal diameter, average corneal radius, central corneal thickness, objective spherical equivalent, pupillary distance), body height and head size. Based on the data we obtained, we can conclude a strong correlation of axial eye length with objective spherical equivalent, moderate correlation with average corneal radius and horizontal corneal diameter, weak correlation with central corneal thickness and very weak correlation with pupillary distance. No statistically significant correlation was found between axial eye length and body height and head size. Multi linear regression model among axial eye length, objective spherical equivalent and average corneal radius show a very strong and statistically significant correlation. Based on this multi linear regression model, we can conclude that eyes with longer axial eye length will on average have flatter cornea and spherical equivalent will be more myopic. We named some possible implications of these findings: Contact lens manufacturers should be aware of possible necessity of altering standard back surface radii with increasing myopic power due to flatter corneas in higher myopia found in our study. The eye models for calculating individual spectacle lenses could consider the newly established relationships between axial eye length and corneal radii. The positive (though weak) correlation between central corneal thickness and axial eye length could be considered important in myopia research, in corneal refractive surgery models and glaucoma models.

Appendix

The following table is collected raw data.

EYE	AGE	Eye axial length (cm)	Body height (cm)	Head size (cm)	Spherical equivalent (OR)	Average corneal radius (cm)	Horizontal corneal diameter (cm)	Pupillary distance (cm)	Gender	Pachymetry (cm)
1	49	2.624	186	56	-3.125	0.823	1.235	6.4	1	0.00055
2	49	2.6	186	56	-3.125	0.824	1.216	6.4	1	0.000558
1	63	2.345	176	47.8	0.75	0.785	1.204	6.3	1	0.0005283
2	63	2.316	176	47.8	0.875	0.779	1.194	6.3	1	
1	67	2.526	174	60	3.5	0.787	1.17	7.5	1	
2	67	2.52	174	60	3.625	0.795	1.159	7.5	1	
1	50	2.526	182	61.5	-6.5	0.767	1.183	6.7	1	
2	50	2.52	182	61.5	-6.5	0.767	1.148	6.7	1	0.000574
1	53	2.396	174	56	-1.0	0.779	1.211	6.1	1	0.000502
2	53	2.401	174	56	-1.0	0.776	1.212	6.1	1	0.0005033
1	53	2.316	187	59	0.75	0.765	1.203	6.5	1	0.0004853
2	53	2.351	187	59	0.75	0.778	1.216	6.5	1	0.0004813
1	20	2.286	173	55	0.25	0.772	1.255	6.4	2	
2	20	2.271	173	55	0.00	0.760	1.252	6.4	2	
1	15	2.481	171	56.5	-3.625	0.785	1.215	6.5	2	
2	15	2.450	171	56.5	-3.00	0.786	1.230	6.5	2	
1	29	2.472	182	59	-4.25	0.766	1.215	6.9	1	0.0006017
2	29	2.491	182	59	-4.625	0.772	1.217	6.9	1	
1	46	2.39	173	57	-1.125	0.789	1.162	6.4	2	
2	46	2.39	173	57	-0.75	0.792	1.155	6.4	2	
1	20	2.579	157.5	56	-6.25	0.773	1.229	6.4	2	
2	20	2.543	157.5	56	-5.375	0.772	1.24	6.4	2	
1	43	2.303	167	58	0.00	0.756	1.219	6.2	2	0.000497
2	43	2.313	167	58	0.00	0.765	1.210	6.2	2	0.000506
1	32	2.532	178	60.5	-4.125	0.808	1.223	6.7	1	0.0004883
2	32	2.534	178	60.5	-4.50	0.806	1.225	6.7	1	0.0004813
1	46	2.321	168	59	0.00	0.788	1.174	6.5	2	0.0005643
2	46	2.199	168	59	2.25	0.791	1.176	6.5	2	0.0005617
1	49	2.470	165	54	-1.625	0.807	1.199	6.2	2	0.0005257
2	49	2.480	165	54	-2.00	0.801	1.198	6.2	2	0.0005333
1	50	2.129	178	58.5	3.875	0.745	1.133	6.8	1	0.0005277
2	50	2.120	178	58.5	4.25	0.751	1.138	6.8	1	0.0005197
1	42	2.256	162	56	0.00	0.756	1.210	6.2	2	0.0005047
2	42	2.240	162	56	0.125	0.754	1.213	6.2	2	0.0004927
1	26	2.446	168	55	-4.625	0.792	1.159	6.4	2	
2	26	2.519	168	55	-6.00	0.792	1.174	6.4	2	
1	60	2.368	169	57	2.125	0.783	1.202	7.0	2	0.0005377
2	60	2.337	169	57	2.875	0.786	1.223	7.0	2	0.000531
1	63	2.335	186	59	1.25	0.78	1.169	6.9	1	0.000539
2	63	2.323	186	59	1.25	0.778	1.163	6.9	1	0.0005507
1	20	2.432	183	57	0.00	0.802	1.239	6.2	1	0.0005857
2	20	2.416	183	57	0.125	0.797	1.234	6.2	1	

1	61	2.351	175	59	1.125	0.805	1.145	7.1	1	0.000607
2	61	2.359	175	59	1.125	0.815	1.165	7.1	1	0.000602
1	65	2.461	182	59	0.375	0.771	1.193	6.7	1	0.0005317
2	65	2.470	182	59	0.25	0.774	1.197	6.7	1	0.000527
1	49	2.224	169	58	0.875	0.761	1.163	6.8	1	
2	49	2.216	169	58	0.625	0.758	1.181	6.8	1	0.000585
1	18	2.620	173	59	-4.25	0.808	1.284	6.3	1	0.0005667
2	18	2.604	173	59	-4.125	0.805	1.294	6.3	1	0.0005587
1	50	2.473	178	60	-1.0	0.816	1.226	6.9	1	
2	50	2.446	178	60	-0.50	0.815	1.260	6.9	1	0.0005097
1	44	2.563	161	53	-5.375	0.782	1.186	6.2	2	0.0005777
2	44	2.549	161	53	-4.375	0.787	1.196	6.2	2	0.0005837
1	26	2.374	170	54.5	-2.75	0.791	1.219	6.3	2	
2	26	2.353	170	54.5	-2.875	0.785	1.208	6.3	2	
1	49	2.391	183	60	0.125	0.794	1.183	6.6	1	0.0005637
2	49	2.367	183	60	0.5	0.789	1.175	6.6	1	0.0005703
1	37	2.474	190	61	-0.50	0.796	1.250	6.9	1	0.0005523
2	37	2.480	190	61	-1.25	0.794	1.267	6.9	1	0.0005503
1	48	2.436	170	54	1.00	0.829	1.240	6.3	1	0.0005707
2	48	2.432	170	54	1.25	0.831	1.250	6.3	1	0.000571
1	23	2.459	178	58	-3.125	0.764	1.247	6.2	1	0.000515
2	23	2.448	178	58	-3.00	0.763	1.238	6.2	1	0.0005323
1	32	2.438	174	56	-0.375	0.808	1.200	5.9	2	0.0005423
2	32	2.427	174	56	-0.125	0.800	1.203	5.9	2	0.0005323
1	28	2.389	174	57.5	-1.25	0.762	1.231	6.2	2	0.0004917
2	28	2.402	174	57.5	-1.125	0.767	1.243	6.2	2	0.000495
1	49	2.377	178	58	0.50	0.806	1.239	6.4	1	0.0005583
2	49	2.373	178	58	0.50	0.807	1.246	6.4	1	0.0005693
1	62	2.314	162	54	0.00	0.745	1.147	6.1	2	
2	62	2.306	162	54	0.25	0.738	1.142	6.1	2	0.00055
1	54	2.270	175	57	0.375	0.739	1.183	6.4	1	
2	54	2.250	175	57	0.75	0.379	1.191	6.4	1	
1	46	2.349	175	59	1.00	0.788	1.213	6.3	1	0.0005403
2	46	2.342	175	59	1.375	0.795	1.218	6.3	1	0.0005437
1	32	2.192	167	59	0.25	0.734	1.185	5.6	2	0.000546
2	32	2.185	167	59	0.25	0.734	1.162	5.6	2	0.000547
1	40	2.349	165	54.5	0.125	0.793	1.205	6.4	2	0.0005643
2	40	2.341	165	54.5	0.375	0.787	1.209	6.4	2	0.0005663
1	47	2.365	185	56	0.625	0.776	1.232	6.4	1	0.00049
2	47	2.362	185	56	0.625	0.777	1.232	6.4	1	0.0004963
1	26	2.306	190	61	-0.125	0.771	1.202	6.4	1	
2	26	2.315	190	61	-0.125	0.775	1.196	6.4	1	
1	15	2.442	168	56.5	-3.125	0.766	1.222	5.8	2	
2	15	2.441	168	56.5	-3.5	0.760	1.197	5.8	2	
1	18	2.459	182	59	-1.25	0.799	1.277	6.5	1	0.000530
2	18	2.457	182	59	-1.50	0.789	1.270	6.5	1	0.0005237
1	29	2.414	165	56	-2.00	0.788	1.149	5.8	2	0.000550
2	29	2.372	165	56	-1.375	0.780	1.135	5.8	2	0.0005413
1	46	2.444	168	55	-0.50	0.785	1.217	5.9	2	0.0005297
2	46	2.427	168	55	0.125	0.780	1.212	5.9	2	0.000534

1	19	2.407	183	56	-2.00	0.751	1.155	6.3	1	0.0005093
2	19	2.406	183	56	-1.75	0.753	1.172	6.3	1	0.0005107
1	48	2.421	163	55	-1.50	0.785	1.193	6.2	2	0.000511
2	48	2.414	163	55	-1.375	0.778	1.187	6.2	2	0.000508
1	28	2.388	175	60	-0.625	0.776	1.241	6.4	1	0.0004977
2	28	2.369	175	60	-0.50	0.769	1.241	6.4	1	0.0005053
1	40	2.162	167	54.5	2.50	0.757	1.187	6.3	2	0.000486
2	40	2.176	167	54.5	2.875	0.761	1.199	6.3	2	0.000477
1	27	2.494	167	57	-3.25	0.784	1.186	6.1	2	0.000567
2	27	2.501	167	57	-3.375	0.787	1.194	6.1	2	0.000574
1	48	2.458	182	58	-0.75	0.781	1.252	6.8	1	0.000673
2	48	2.455	182	58	-0.75	0.780	1.219	6.8	1	0.000671
1	48	2.419	168	51	-0.875	0.813	1.257	5.9	2	0.000506
2	48	2.409	168	51	-1.125	0.806	1.257	5.9	2	0.000505
1	49	2.331	180	56	1.125	0.780	1.192	6.6	1	0.000493
2	49	2.335	180	56	0.75	0.788	1.180	6.6	1	0.000490
1	56	2.454	174	57	-1.0	0.802	1.238	6.5	1	0.000489
2	56	2.450	174	57	-0.625	0.806	1.245	6.5	1	0.000496
1	55	2.338	170	54	0.75	0.793	1.190	6.5	2	0.000557
2	55	2.321	170	54	1.625	0.798	1.184	6.5	2	0.000557
1	25	2.461	158	54	-3.25	0.768	1.261	6.1	2	0.000505
2	25	2.487	158	54	-3.625	0.766	1.259	6.1	2	0.000514
1	36	2.533	163	54	-1.625	0.803	1.290	6.1	2	0.0004847
2	36	2.538	163	54	-1.50	0.803	1.296	6.1	2	0.000496
1	47	2.250	163	55.5	-0.25	0.753	1.165	6.4	2	0.000518
2	47	2.248	163	55.5	0.00	0.750	1.177	6.4	2	0.000514
1	31	2.217	167	54	0.625	0.774	1.212	6.1	2	0.000500
2	31	2.265	167	54	-0.625	0.779	1.194	6.1	2	0.000512
1	48	2.283	176	58	0.00	0.748	1.185	6.3	1	0.000490
2	48	2.254	176	58	0.25	0.735	1.194	6.3	1	0.000489
1	53	2.430	178	58	-1.0	0.768	1.249	6.8	1	0.0005427
2	53	2.419	178	58	-0.50	0.766	1.243	6.8	1	0.0005357
1	24	2.385	171	53	0.125	0.802	1.216	6.0	2	0.000566
2	24	2.374	171	53	0.00	0.797	1.213	6.0	2	0.000567
1	43	2.284	162	55.5	0.00	0.758	1.162	6.2	2	0.000546
2	43	2.303	162	55.5	-0.50	0.759	1.168	6.2	2	0.000554
1	35	2.409	173	56	-2.625	0.766	1.195	6.1	2	0.0005427
2	35	2.381	173	56	-2.125	0.763	1.191	6.1	2	0.0005367
1	50	2.443	175	56	-0.75	0.809	1.272	6.4	2	0.000547
2	50	2.423	175	56	-0.50	0.803	1.270	6.4	2	0.000540
1	49	2.425	190	58	0.375	0.796	1.220	6.5	1	
2	49	2.428	190	58	0.00	0.791	1.204	6.5	1	0.000546
1	34	2.474	170	57	-4.375	0.756	1.188	6.6	2	0.000520
2	34	2.511	170	57	-5.375	0.752	1.192	6.6	2	0.000531
1	59	2.350	160	55.5	0.75	0.763	1.142	6.2	2	0.000510
2	59	2.342	160	55.5	0.625	0.757	1.177	6.2	2	0.000513
1	56	2.445	165	54	-0.25	0.805	1.231	6.4	2	0.000503
2	56	2.442	165	54	-0.25	0.799	1.212	6.4	2	0.000506
1	41	2.472	179	58.5	-2.25	0.775	1.200	6.1	2	0.000497
2	41	2.455	179	58.5	-1.75	0.776	1.203	6.1	2	0.000503

1	31	2.305	168	58	-0.125	0.744	1.155	6.2	2	0.0005263
2	31	2.323	168	58	0.125	0.752	1.176	6.2	2	0.0005223
1	40	2.417	160	55	-1.375	0.782	1.163	6.3	2	0.000514
2	40	2.387	160	55	-1.0	0.776	1.160	6.3	2	0.000518
1	46	2.265	156	52.5	0.875	0.755	1.180	6.1	2	0.000504
2	46	2.266	156	52.5	1.00	0.757	1.186	6.1	2	0.000517
1	57	2.570	167	57	-4.25	0.805	1.226	6.6	2	0.000601
2	57	2.538	167	57	-3.875	0.803	1.225	6.6	2	0.000606
1	46	2.240	177	56	0.25	0.763	1.192	6.4	2	0.000539
2	46	2.219	177	56	0.50	0.760	1.198	6.4	2	0.000535
1	45	2.456	180	58.5	-0.625	0.790	1.247	6.5	1	
2	45	2.435	180	58.5	-0.25	0.788	1.244	6.5	1	
1	44	2.298	165	53	0.50	0.775	1.168	6.1	2	0.000482
2	44	2.269	165	53	0.75	0.775	1.170	6.1	2	0.000493
1	50	2.445	168	54.5	0.75	0.832	1.256	6.9	2	0.000536
2	50	2.443	168	54.5	0.75	0.830	1.245	6.9	2	0.000553
1	47	2.476	181	58	0.00	0.833	1.210	7.2	1	
2	47	2.504	181	58	0.375	0.844	1.206	7.2	1	
1	24	2.296	166	55	-0.125	0.786	1.240	6.4	2	
2	24	2.284	166	55	-0.25	0.780	1.245	6.4	2	0.000474
1	31	2.373	165	54	-1.75	0.747	1.185	6.1	2	0.000538
2	31	2.356	165	54	-2.00	0.740	1.195	6.1	2	0.000535

EYE 1 is the right eye, EYE 2 is the left eye. GENDER 1 is male and GENDER 2 is female.

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Declaration

I declare that this thesis, which I submit to Aalen University for examination in consideration of the award of a higher degree M.Sc. Vision Science and Business (Optometry) is my own personal effort. Where any of the content presented is the result of input or data from a related collaborative research program this is duly acknowledged in the text such that it is possible to ascertain how much of the work is my own. I have not already obtained a degree at Aalen University or elsewhere on the basis of this work. Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

I would like to thank my supervisors, Prof. Dr. Anna Nagl and Dr. Matjaž Mihelčič, for providing me with the guidance and counsel I need to succeed in the program M.Sc. Vision Science and Business (Optometry).

Signed ____

Student Number [redacted]

Date May 23,2022