Original article

Determination of the normal range of exophthalmometric values for Ethiopian adults at Menelik II Hospital, Addis Ababa, Ethiopia

Yilikal Adamu[1]

Abstract

Background: Many orbital diseases can cause proptosis, including thyroid-associated orbitopathy, tumors, inflammation, head and orbital trauma, and craniofacial abnormalities. In patients for whom orbital diseases are suspected, exophthalmometry is an established method of routine evaluation. The objective of this study was to establish a set of exophthalmometric values in a normal Ethiopian adult population.

Subjects and Methods: A cross-sectional study of clinically normal Ethiopians in the age range of 18 years and above, attending the outpatient department of ophthalmology in Menelik II Hospital, Addis Ababa, from May to September 2018, were included in the study. Hertel's mirror exophthalmometer was used to determine inter-orbital distance and exophthalmometric values of both eyes. Data were collected using a structured format, entered in an Excel spreadsheet, and analyzed using Stata version 14 statistical package.

Results: A total of 2,133 subjects were included in the study, of whom 1,220 (57.20%) were males and 913 (42.80%) were females. The ages ranged from 18 to 98 years (mean=40.79±16.84 years). The mean inter-orbital distance was 113.16±3.99mm. The mean exophthalmometric value for the right eye and left eye in both sexes was 115.77±2.65mm and 115.71±2.62mm, respectively. The mean inter-orbital distance was 114.33mm for males and 111.61mm for females. This value difference was statistically significant with p=0.00. The mean inter-orbital distance and mean exophthalmometric values in different age ranges, ethnic groups and sex were statistically significant, (p=0.00) and (p=0.04) respectively. The mean exophthalmometric values for left eye was 15.80mm for males and 15.58mm for females. This difference was statistically insignificant (p=0.05).

Conclusions: The normal inter-orbital distance of Ethiopian adults was found to be 113mm, and exophthalmometric values for right eye and left eye were 15.77mm and 15.71mm, respectively. The exophthalmometric values were consistent between right and left eyes, with a maximum relative difference of 2mm. Sex and ethnicity had a significant effect on inter-orbital distance while, sex, age range and ethnicity had a significant effect on protrusion of right and left eyes. *Ethiop. J. Health Dev.* 2019; 33(4):269-275]

Key words: Inter-orbital distance, exophthalmometry, ethnicity, Ethiopian adults

Introduction

Many orbital diseases can cause proptosis, including thyroid-associated orbitopathy, tumors, inflammation, head and orbital trauma, and craniofacial abnormalities (1–3). When they occur, these diseases are usually manifested as abnormal eye protrusion. In patients for whom orbital diseases are suspected, exophthalmometry is an established method of routine evaluation. The exophthalmometric values (EVs) obtained can either serve as a diagnostic basis or be used to monitor the progress of orbital disease via serial measurements (4). There are several types of exophthalmometric devices to measure EVs: Hertel and Luedde measure the distance of the corneal apex from the level of the lateral orbital rim, while Naugle measures the relative difference between each eye (5). Of these, the most used and widely accepted device at present is Hertel's exophthalmometer (6,7). It allows measurements of the distance between the two lateral orbital rims, that is inter-orbital distance (IOD) and the vertical distance of corneal apex to the frontal plane. This method can measure both eyes simultaneously using a mirror system and a superimposed millimeter scale (8).

The absolute EV represents the degree of protrusion when compared with a given standard, hence it is very useful for diagnosing bilateral proptosis (6,7,9). The relative EV reflects the asymmetry of protrusion between two eyes. Therefore, relative exophthalmometry is beneficial for the diagnosis of unilateral proptosis. The comparative EV reflects a change in the amount of protrusion in follow-up examinations, which can document the progression of the condition causing the proptosis.

The current literature clearly demonstrates heterogeneity in EV ranges and their correlates among different populations (4,8-10). Therefore, when evaluating the results of measurements, the normal EV range in a specific population must be taken into consideration.

However, because no published study has reported normative exophthalmometry data for Ethiopians, the diagnosis of proptosis is currently based on data from other countries and races (5,10). As a result, it is important to determine normal EVs in the Ethiopian population and compute the values with sex, age ranges and among ethnic groups, as Ethiopians are multi-ethnic, and have different shapes and statures due to varied economic status and poverty, which lead to the widespread prevalence of stunting and wasting. Thus, there is a need for a range of values for the normative exophthalmometry data of the Ethiopian population. This data will also serve as reference for future studies, while normal adult values will offer practitioners the opportunity to take appropriate action related to the exophthalmometric measurements to

[1]Department of ophthalmology, School of medicine, College of health science, AAU Email: yilikaladamu@gmail.com

their patients with orbital conditions. The objective of this study was to establish a set of EVs in a normal Ethiopian adult population and to compute these values against sex, age ranges and different ethnic groups.

Subjects and methods

This was a hospital-based, cross-sectional, descriptive study that included a total of 2,133 clinically normal Ethiopians of both sexes in the age range of 18 years and above, attending the outpatient department of ophthalmology in Menelik II Hospital, Addis Ababa, Ethiopia, from May to September 2018. Subjects with local or systemic diseases that could affect the orbital or ocular dimensions, such as ocular inflammation, endocrine abnormalities (e.g. thyroid disease), craniofacial deformities, buphthalmos, severe myopia (refractive error >5D), adnexal abnormalities or trauma, and subjects with aged under 18 years, were excluded from the study.

Measurement device: Currently, there are different techniques to determine EVs of the eyes. Radiological imaging, such as magnetic resonance imaging (MRI) and computerized tomography (CT) are considered as the most accurate methods of determining exophthalmos and are not affected by facial asymmetry and increased soft tissue volume (8,11). Even though the accuracy is high with the imaging methods, the expensive cost, exposure to radiation from CT scans, lack of sustainability and low availability in many health institutions, limits their use. In this study, an OCULUS German-made and widely used Hertel's mirror exophthalmometer was used.

The distance between the lateral orbital rim and the corneal apex served as the dimensions of measurement. Under normal conditions, the distance between the apex of the cornea and the orbital wall is approximately 18mm, as mentioned in the user manual of the instrument. This normal value was regarded as a statistical average. Physiologically, there are also certain differences in the degree of proptosis in each eye.

Measurement procedure: In a well-lit outpatient waiting hall, the IOD and degree of protrusion of both eyes were measured simultaneously. The person sat erect, with the neck straight and eyes in primary gaze. The foot plate of the instrument rested on the lateral bony orbital rim. The rest of the instrument was held parallel to the frontal plane, in line with the pupils. The exophthalmometry reading to the nearest 0.5mm was taken at the apex of the cornea from the measuring scale onto which the images of the eyes are superimposed. All the measurements were taken by the same person (investigator) using the same instrument. The readings were tabulated using a structured data collection sheet for IOD and EVs for both eyes in males and females, age ranges, and in five ethnic groups for each subject aged 18 years and above.

Statistical methods: The data were entered in an Excel spreadsheet and exported to Stata version 14 for analysis. The entries were double checked and cleaned for errors. This study has two dependent variables, including the exophthalmometry reading to the nearest 0.5mm and the IOD, both of which are continuous variables. The independent variables are sex, age group and ethnicity. The mean IOD and EVs for both eyes in both sexes for a given age range and ethnic group were computed. One-way analysis of variance with an F-test was employed to assess the mean difference of IOD and EVs across the independent variables mentioned above. One-way analysis of variance with an F-test was employed to assess the mean difference of IOD and EVs across the independent variables mentioned above. Furthermore, multiple regression equation was carried out to calibrate the association between IOD and/or EVs for right and left eye separately with sex, age ranges within 18-98 years and ethnicity, after controlling for the confounding effects of each other variable.

Ethical considerations: Ethical clearance was obtained from the Research and Publication Committee of the Ophthalmology Department, School of Medicine, College of Health Science, Addis Ababa University. Verbal informed consent was taken from each study participant.

Results

A total of 2,133 subjects were included in the study, of whom 1,220 (57.20%) were males and 913 (42.80%) were females. The ages of participants ranged from 18 to 98 years, with a mean age and standard deviation of 40.79±16.84 years. The majority of participants were within the age range 18 to 29 (32.40%) years, male (57.20%) and from the Amhara ethnic group (48.95%) (Table 1).

Table 1: **Socio-demographic distribution of subjects in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018**

	Sex			
	Male	**Female**	**Total**	**%**
Age range (years)				
18-29	404	287	691	32.40
30-39	244	224	468	21.94
40-49	183	126	309	14.49
50-59	156	123	279	13.08
60-69	130	98	228	10.69
70 and above	103	55	158	7.41
Total	**1,220**	**913**	**2,133**	**100.00**
Ethnic group				
Amhara	547	497	1,044	48.95
Oromo	379	211	590	27.66
Gurage	105	88	193	9.05
Tigray	53	48	101	4.74
Others	136	69	205	9.61
Total	**1,220**	**913**	**2,133**	**100.00**

The smallest IOD measurement was 100mm and the largest was 130mm, with a mean and standard deviation of 113.16±3.99mm. The smallest EV for the right eye was 8mm and the largest was 23mm, with a mean value and standard deviation of 115.77±2.65mm, as presented in Figure 2a.

The smallest EV for the left eye was also 8mm and the largest was 23mm, with a mean value and standard deviation of 115.71±2.62mm (see Figure 2b).

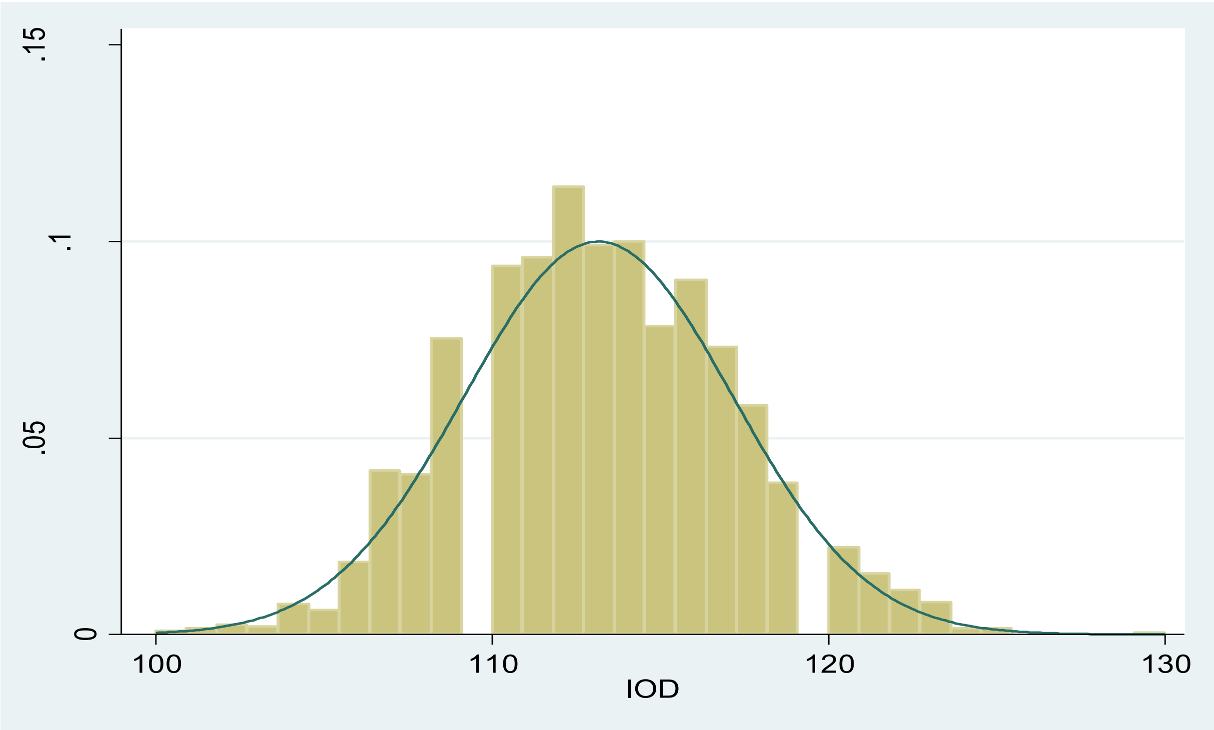
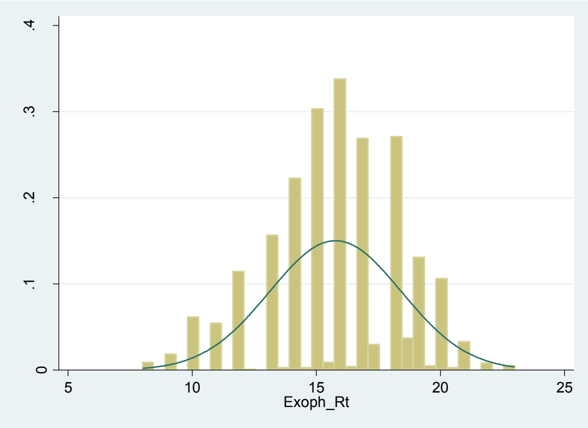
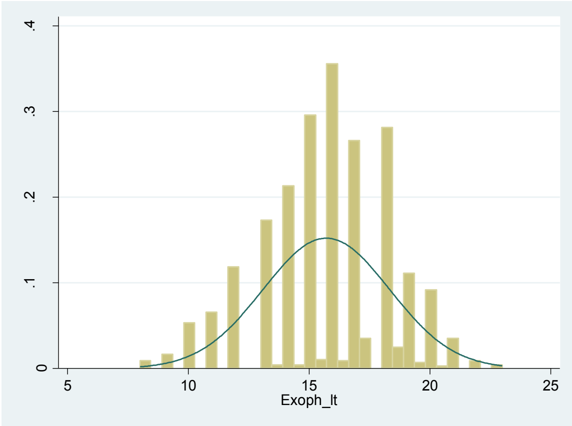


Figure 1: **Density of IOD from the smallest to the highest value in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018**



a.



b.

Figure 2: Density of EVs in right (a) and left (b) eyes from the smallest to the highest value in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018

As it is shown in Table.2, the mean IOD for males was 114.33mm, while the mean IOD for females was 111.61mm. The IOD value difference between males and females was statistically significant at F=274.0 (p=0.00). The mean EV for the right eye was 15.88mm for males and 15.64mm for females. This difference was also statistically significant at F=4.3 (p=0.04). The mean EV for the left eye was 15.81mm for males and 15.58mm for females. This difference was statistically marginally significant at F=3.81 (p=0.05). Whereas, the mean IOD value within the age group was found to be statistically insignificant, at F=0.27 (p=0.93) (see Figure 3).

Table 2: Mean IOD and EVs of right and left eyes in males and females in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018

	Mean (mm)		
Sex	**IOD**	**EVs right**	**EVs left**
Males	114.33	15.88	15.81
Females	111.61	15.64	15.58
P-value	0.00	0.04	0.05

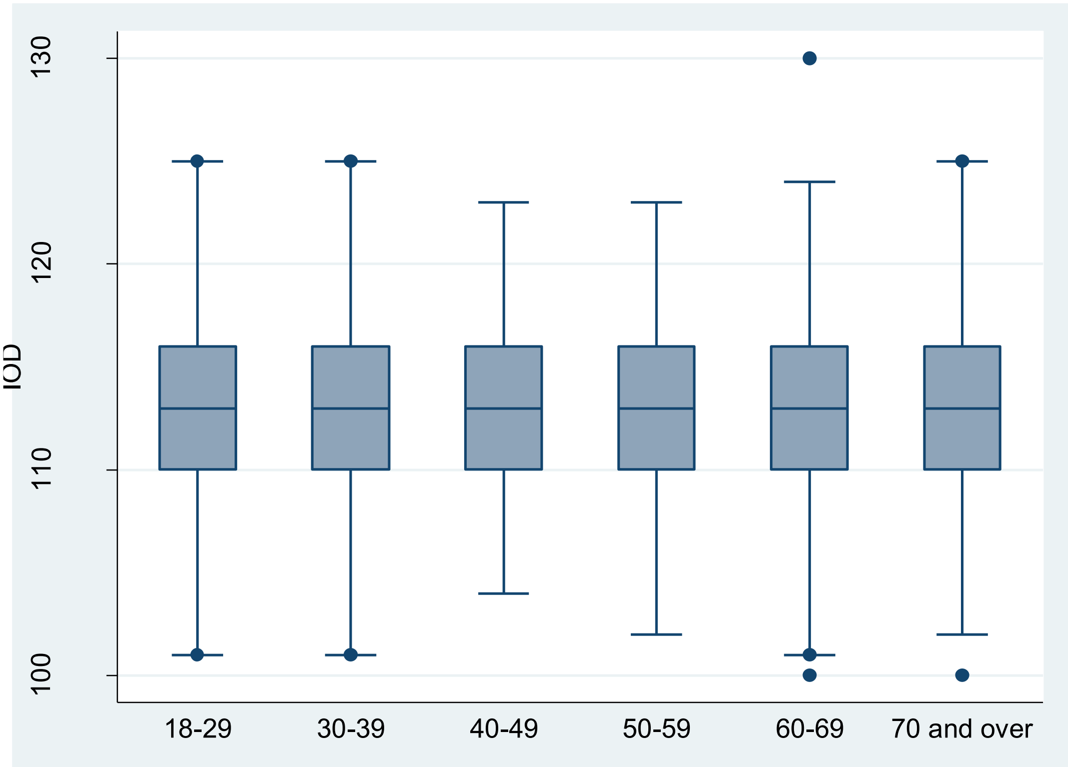


Figure 3: Mean IOD between age ranges in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018

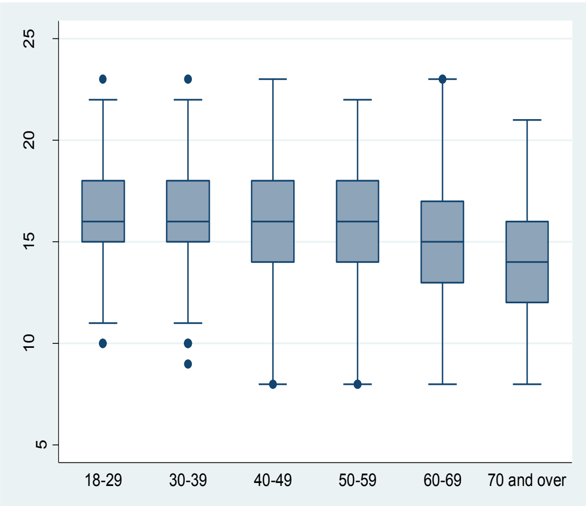
As shown in Table 3, the mean values of IOD in different ethnic groups was also found to be statistically significant at F=14.3 (*p*=0.00). Whereas, the mean EVs differences of the right and left eyes between age ranges and between ethnic groups was statistically significant at F=31.91(*p*=0.001) and F=2.72 (*p*=0.03), respectively.

Table 3: Mean IOD and EVs of right and left eyes in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018

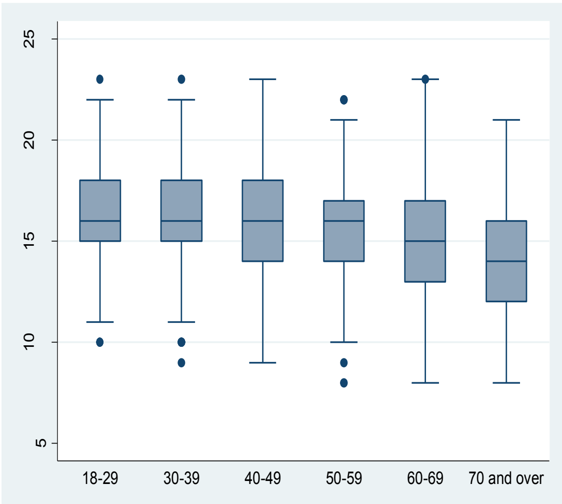
	Mean (mm)			
	IOD	**EVs right**	**EVs left**	**P-value***
Age range (years)				*p*=0.00
18-29	113.23	16.32	16.28	
30-39	113.22	16.24	16.13	
40-49	113.07	15.78	15.66	
50-59	113.23	15.50	15.46	
60-69	112.96	14.78	14.79	
70 and above	113.04	13.93	13.91	
Ethnic group				*p*=0.03
Amhara	112.73	15.80	15.74	
Oromo	113.66	15.54	15.48	
Gurage	112.92	15.87	15.83	
Tigray	112.21	15.73	15.65	
Others	114.63	16.23	16.15	

* The mean EVs differences of the right and left eyes between age ranges and between ethnic groups was statistically significant with *p*=0.00, and *p*=0.03.

Regression analysis was conducted to assess the association between IOD and/or EVs for right and left eye separately for sex, age ranges and ethnic groups, after controlling for the confounding effects of each other variable. As is shown in Figures 4a and 4b, for both right and left eyes, the EVs decreased as age increased.



a.



b.

Figure 4: **EVs in right (a) and left (b) eyes in determination of the normal range of EVs for Ethiopian adults at Menelik II Hospital, Addis Ababa, May-September 2018**

Discussion

In this study, Hertel's exophthalmometer was selected as it is most widely used instrument for measuring globe protrusion due to its portability, easy operation and low cost (12). In studies conducted by Kashkouli and colleagues (13) and by Lam *et al.* (14), Hertel's exophthalmometer was found to be reliable and the inter-observer variation was negligible within an acceptable margin. But in the current study, all measurements were done by one physician, who was the investigator, using a single instrument to avoid inter-observer variation and variations caused by using different styles of Hertel's exophthalmometers manufactured by different companies (15).

In this study, the mean EVs of the right eye were 15.88mm for males and 15.64mm for females. These EVs were found to be less than mean EVs in the African-American normal adult population of men (18.20mm) and women (17.46mm) and white men (16.5mm). The EVs of Ethiopian women were found to be similar to those of US white women (15.4mm) (16,10).

This study showed that the EVs of clinically normal Ethiopian adults were higher than the EVs of clinically normal Iranian adults (14.7mm) (9), and higher than the EVs of clinically normal Mexican men (15.18mm) and women (14.82mm) (17). They were also higher than the EVs of the clinically normal Indian population – 14.62mm for men and 13.30mm for women (18).

The mean IOD in this study was found to be 114.33mm for men and 111.61mm for women. This finding is higher than in many studies conducted in other countries and societies (4,7-11,17,18). The mean EVs of the right and left eyes eye were 15.88mm and 15.64mm, respectively, for men, and 15.80mm and 15.58mm, respectively, for women. Compared to other studies, the EV findings in this study were lower (4,7-10). These differences are assumed to be due to racial differences in bony orbital architecture and the position and protrusion of the globe.

The result of this study confirmed that the IOD and EVs differ among ethnic groups of Ethiopians (see Table 2). This might be due to differences in facial structures and ocular anatomy. These differences should be taken heed of in the diagnosis of eye proptosis, and ophthalmologists in Ethiopia can use this data as a baseline to evaluate their patients and compare their findings.

Apart from ethnicity, sex and age were also considered as factors of variation in the normal range of IOD and EVs in this study, and in studies done on black and white Americans (10). With respect to age, studies demonstrated that there is an increasing trend of EVs during growth (in the first and second decades of life), no change during third and fourth decades, and decreases in the later decades (seventh decade onwards) (4,10,11). The present study has shown the similar trend of decreasing IOD and EVs from the sixth decade onwards (see Table 2 and Figure 4). However, a study done in Turkey by Bilen *et al.* does not confirm this finding (8).

In this study, the EVs between right and left eyes were consistent, with a minor difference of 0.5-2mm. This is similar to the majority of reports from other studies (9–11). Therefore, this study agrees with other studies that the relative difference in EVs up to 2mm in the absence of pathological findings will have little significance.

Conclusions

Based on this study, the normal IOD value of Ethiopian adults was found to be 113mm, and the EVs for the right eye and left eye were 15.77mm and 15.71mm, respectively. The EVs for the right and left eye were consistent, with a maximum relative difference of 2mm. Sex and ethnicity had a significant effect on the IOD, while sex, age range and ethnicity had a significant effect on protrusion (EVs) of right and left eyes. These values will help eye care practitioners to consider sex and ethnicity in the determination of IOD; sex, age and ethnicity in determination of EVs; and compare measurements of their patients with orbital conditions.

Acknowledgments

I would like to extend my deep hearted gratitude for Dr. Menbere Alemu for proving me the latest Hertel's mirror exophthalmometer to measure all the study participants. I would like to thank my dear friend Dr. Wubegzier Mekonnen for his unreserved help in the data analysis.

The last but not least, I am very much thankful for all study participants and staffs of the hospital for their willingness and cooperation throughout the data collection.

References

1. Grove AS. Evaluation of exophthalmos. N Engl J Med. 1975;292(19):1005-13.
2. Smolders MH, Graniewski-Wijnands HS, Meinders AE, Fogteloo AJ, Pijl H, de Keizer RJ. Exophthalmos in obesity. Ophthalmic Res. 2004;36(2):78-81.
3. Bahn RS. Graves' ophthalmopathy. N Engl J Med. 2010;362(8):726-38.
4. Chan W, Madge SN, Senaratne T, Senanayake S, Edussuriya K, Selva D, *et al.* Exophthalmometric values and their biometric correlates: The Kandy Eye Study. Clin Ex Ophthalmol. 2009;37(5):496-502.
5. Onofrey BE, Skorin L Jr, Holdeman NR (eds.). Ocular therapeutics handbook: a clinical manual. Third edition. Philadelphia: Wolters Kluwer, Lippincott Williams and Wilkins, 2011:71-2.
6. Chang AA, Bank A, Francis IC, Kappagoda MB. Clinical exophthalmometry: a comparative study of the Luedde and Hertel exophthalmometer. Aust N Z J Ophthalmol. 1995;23(4):315-8.
7. Cole HP III, Couvillion JT, Fink AJ, Haik BG, Kastl PR. Exophthalmometry: a comparative study of the Naugle and Hertel instruments. Ophthalmic Plast Reconstr Surg. 1997;13(3):189-94.
8. Bilen H, Gullulu G, Akcay G. Exophthalmometric values in a normal Turkish population living in the northeastern part of Turkey. Thyroid. 2007;17(6):525-8.
9. Kashkouli MB, Nojomi M, Parvaresh MM, Sanjari MS, Modarres M, Noorani MM. Normal values of hertel exophthalmometry in children, teenagers, and adults from Tehran, Iran. Optom Vis Sci. 2008;85(10):1012-7.
10. Migliori ME, Gladstone GJ. Determination of the normal range of exophthalmometric values for black and white adults. Am J Ophthalmol. 1984;98(4):438-42.
11. O'Donnell NP, Virdi M, Kemp EG. Hertel exophthalmometry: the most appropriate measuring technique. Br J Ophthalmol. 1999;83(9):1096.
12. Wu D, Liu X, Wu D, Di X, Guan H, Shan Z, *et al.* Normal values of Hertel exophthalmometry in a Chinese Han population from Shenyang, Northeast China. Sci Rep. 2015;5:8526.

13. Kashkouli MB, Beigi B, Noorani MM, Nojoomi M. Hertel exophthalmometry: reliability and inter-observer variation. Orbit. 2003;22(4):239-45.
14. Lam AK, Lam CF, Leung WK, Hung PK. Intra-observer and inter-observer variation of Hertelexophthalmometry. Ophthalmic Physiol Opt. 2009;29(4):472-6.
15. Sleep TJ, Manners RM. Instrument variability in Hertel-type xophthalmometers. Ophthalmic Plast Reconstr Surg. 2002;18(4):254-7.
16. Dunsky IL. Normative data for hertel exophthalmometry in a normal adult black population. Optom Vis Sci. 1992;69(7):562-4.
17. Bolaños Gil de Montes F, Pérez Resinas FM, Rodríguez García M, González Ortiz M. Exophthalmometry in Mexican adults. Rev Invest Clin. 1999;51(6):341-3.
18. Kumari Sodhi P, Gupta VP, Pandey RM. Exophthalmic values in a normal Indian population. Orbit. 2001;20(1):1-9.