

Original Article

Exophthalmometry value distribution in healthy Lithuanian children and adolescents



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Abstract

Purpose: To determine absolute and relative ocular protrusion values for healthy Lithuanian children and adolescents and analyze the data according to the age, gender, weight, height, and outer orbital distance.

Methods: A total of 397 children and adolescents were included in this study. Measurements for the right and left eyes protrusions were done with Hertel exophthalmometer in healthy subjects aged from 5 to 18 years old. Height, weight, age and gender of subjects were recorded.

Results: The mean age for all children and adolescents was 11.5 ± 3.6 years. For all subjects, the mean (\pm SD) absolute ocular protrusion value of both eyes (OU) was 14.91 ± 1.68 mm. There was no significant difference in measurements between male and female subjects although female eye protrusion was higher. No individual had more than 2 mm of asymmetry between eyes. Mean exophthalmometric values for right eye were greater than the values of the left eye, and the mean relative protrusion for all participants was 0.2 mm. The mean distance between the lateral rims of the orbits was 98.7 ± 5.2 mm for all subjects. Proptosis measurements significantly correlated with the age, weight and height of children and adolescents and base measurements.

Conclusions: In the present study, we have established ocular proptosis values according to the age, gender, weight and height of healthy Lithuanian children and adolescents. The eye protrusion significantly correlated with the age, weight and height of subjects and the distance between the lateral rims of the orbits. The gender did not play significant role on the eye projection data. We believe that larger, well-design studies are necessary in future to assess the distribution of proptosis in healthy Lithuanian children and adolescents.

Keywords: Exophthalmometry, Ocular protrusion, Children, Adolescents, Hertel measurement, Proptosis

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Introduction

Exophthalmometry is simple, routine clinical examination technique for the quantitative measurement of the globe position in the orbit.^{1–3} It allows the examiner to assess the abnormal protrusion of the eye and is used for the early diagnosis of suspected orbital or related diseases or it may be used to monitor changes of orbital diseases in dynamics.

Protrusion of the eyeball in pediatric age may be one of the early signs of congenital craniofacial abnormalities (craniosynostosis), neurofibromatosis, ocular and orbital tumors (optic nerve glioma, rhabdomyosarcoma and retinoblastoma), inflammation (orbital cellulitis, panophthalmitis or pseudotumor), Graves' disease, trauma (blowout fracture) and other space-occupying lesions. The normal values of ocular protrusion in any population group are useful to

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distinguish bilateral proptosis as a sign of Graves' ophthalmopathy from other orbital diseases and syndromes.^{1,4}

The cases of unilateral proptosis may be diagnosed at early age of population using diagnostic techniques (e.g., ultrasonography, magnetic resonance tomography or computerized tomography). Clinically, in the absence of other signs, orbital disorder is suspected when exophthalmometric values are outside of the normal range or when there is more than 2 mm difference between the eyes.

Normal level of protrusion could vary according to the ethnic origin, age, sex, height, weight of subjects. These variations require the determination of a normal proptosis upper and lower range and correlations for given population. The current pediatric ophthalmologic studies show a wide variation of eye position values and their correlations with the age and gender in healthy children and adolescents of different geographic locations and race. There is no exact opinion in medical studies about normal and pathological proptosis values in these age groups.

To our knowledge, there are several international studies about proptosis in healthy under-age persons. However, a review of the literature did not reveal any study where these values were presented for Lithuanian children and adolescents. We believe it is important to define a normal distribution of proptosis data and their relation to the age, gender, inter-orbital distance, height and weight in Lithuanian pediatric age population.

The purpose of this study was to determine absolute and relative ocular protrusion values for healthy Lithuanian children and adolescents and analyze the data according to the age, gender, weight, height, and outer orbital distance. Furthermore, we wanted to compare the eye protrusion values in pediatric age subjects with those obtained from other European and world countries.

Methods

A total of 397 subjects of this cross-sectional study were randomly selected from children and adolescents who arrived to the pediatric outpatient department at the Clinic of Lithuanian University of Health Sciences for prophylactic inspection. Children and adolescents come to this Clinic from over the country; therefore, evaluation of the exophthalmometric readings may reflect these data of pediatric population of the whole country. Subjects between 5 and 18 years of age without history of an orbital disease or trauma, craniofacial anomaly, thyroid disease, myopia or hyperopia of more than 3 diopters spherical equivalent and ability to tolerate the measurement were included to this study.

Hertel exophthalmometry was performed by the same physician with the same instrument in order to reduce intra- and inter-observer variations. Examiner also collected information about subjects' age, gender, weight and height.

Written consent for participation was obtained from the parents of participants or participants (according to the age). The study was conducted in accordance with the Declaration of Helsinki and the protocol of the study was reviewed and approved by the Ethics Committee of Lithuanian University of Health Sciences.

Statistical analysis was performed to describe the data of ocular protrusion and base (outer orbital distance), the mean, standard deviation (SD) using statistical software package

(version 20, SPSS Inc., Chicago, IL, USA). We used Kruskal-Wallis test to compare age groups and Mann Whitney *U* test for comparing gender groups. Also we used Wilcoxon test for evaluation of the difference between the right and left eye protrusion values. Spearman correlation coefficient was performed to determine the degree of linear relationship between exophthalmometric values and age, gender, height, weight of subjects, base (outer orbital distance). All *p* values were considered statistically significant when the values were <0.05.

Results

The mean age for all subjects was 11.5 ± 3.6 (mean \pm SD) years, and 235 (59.2%) of them were male (boys) and 162 (40.8%) female (girls). Subjects were divided into four age groups (5–7, 8–11, 12–15 and 16–18 years) and also divided by gender.

The lowest recorded exophthalmometric measurement for an eye was 8 mm, and the highest measured value was 20 mm. For all our subjects, a mean of both eyes (OU) was 14.91 ± 1.68 mm. For 5–7 year children proptosis value was 13.2 ± 1.63 mm, 8–11 year – 14.87 ± 1.7 mm, 12–15 year – 15.55 ± 1.5 mm, 16–18 year – 16.02 ± 1.9 mm (see Fig. 1).

Mean exophthalmometric measurements increased with age (the difference between groups was statistically significant, $p < 0.001$), (Kruskal-Wallis test) (Fig. 2). The proptosis measurements difference was not significant in accordance with the gender, although female eye protrusion was higher. Exophthalmometric measurements data of analyzed age and gender groups are summarized in Table 1.

Symmetrically both eyes position was in 132 (33.2%) cases. In 265 (66.7%) asymmetric cases, left eye measurements were higher than right in 96 (24.2%) individuals, and right eye measurements were higher than left in 169 (42.6%) subjects. The highest asymmetry of 2 mm occurred in 7 (1.8%) subjects. No individual had more than 2 mm of asymmetry. As the mean right eye (OD) protrusion was significantly greater than the mean left eye (OS) protrusion ($p < 0.001$) (related-samples Wilcoxon signed rank test), the mean relative protrusion for all subjects was 0.2 mm (see Fig. 3).

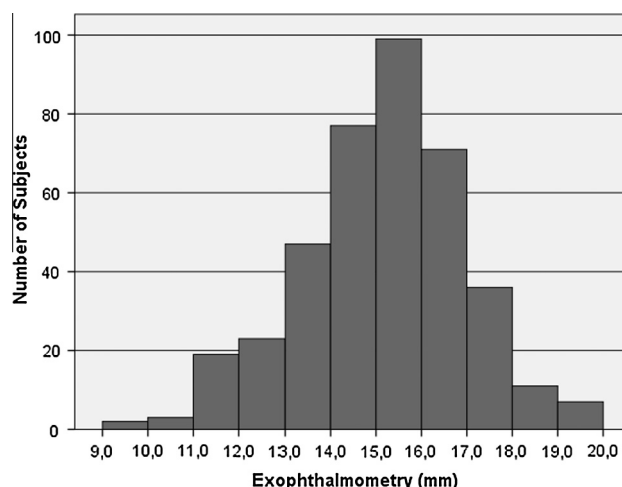


Figure 1. Distribution of mean exophthalmometry measurements of both eyes in all subjects.

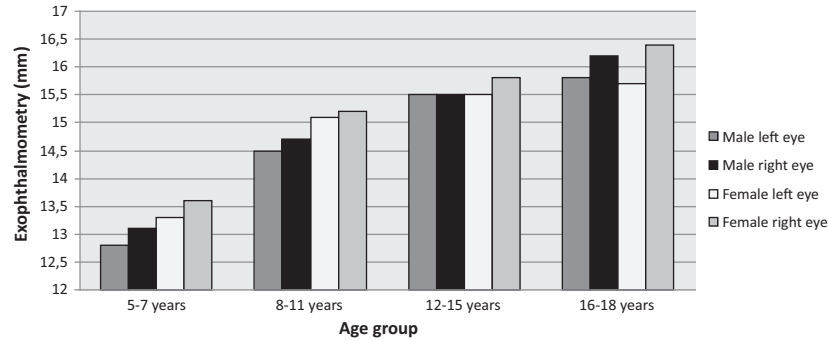


Figure 2. Mean exophthalmometric measurements for left and right eyes in different age and gender groups.

Table 1. Values of Hertel exophthalmometry in different age and gender groups.

| Age group (yr) | 5–7 (74) | | | | 8–11 (106) | | | | 12–15 (169) | | | | 16–18 (48) | | | |
|-------------------------------|-------------|------|-------|------|-------------|------|------|------|-------------|------|-------|------|-------------|------|-------|------|
| | Female | | Male | | Female | | Male | | Female | | Male | | Female | | Male | |
| Eye | OD | OS | OD | OS | OD | OS | OD | OS | OD | OS | OD | OS | OD | OS | OD | OS |
| <i>Ocular protrusion (mm)</i> | | | | | | | | | | | | | | | | |
| Mean | 13.6 | 13.3 | 13.1 | 12.8 | 15.2 | 15.1 | 14.7 | 14.5 | 15.8 | 15.5 | 15.5 | 15.4 | 16.4 | 15.7 | 16.2 | 15.8 |
| SD | 1.6 | 1.9 | 1.4 | 1.6 | 1.6 | 1.9 | 1.5 | 1.8 | 1.5 | 1.6 | 1.4 | 1.5 | 2.1 | 2.2 | 1.6 | 1.7 |
| Min | 10 | 9.5 | 9.5 | 8.5 | 11.5 | 11 | 11 | 11 | 13 | 12 | 12.5 | 12 | 13 | 12 | 12 | 11 |
| Max | 17 | 17 | 16 | 16 | 19.5 | 19 | 17.5 | 18 | 20 | 19.5 | 18.5 | 19 | 20 | 20 | 20 | 20 |
| Mean OU | 13.45 | | 12.95 | | 15.15 | | 14.6 | | 15.65 | | 15.45 | | 16.05 | | 16.00 | |
| Mean ± SD OU | 13.2 ± 1.63 | | | | 14.87 ± 1.7 | | | | 15.55 ± 1.5 | | | | 16.02 ± 1.9 | | | |
| <i>Base (mm)</i> | | | | | | | | | | | | | | | | |
| Mean | 92 | | 93.5 | | 96.7 | | 97.4 | | 100.6 | | 101.7 | | 99.4 | | 104.6 | |
| SD | 3.6 | | 3.7 | | 3.6 | | 3.9 | | 3.2 | | 4.0 | | 3.6 | | 3.5 | |

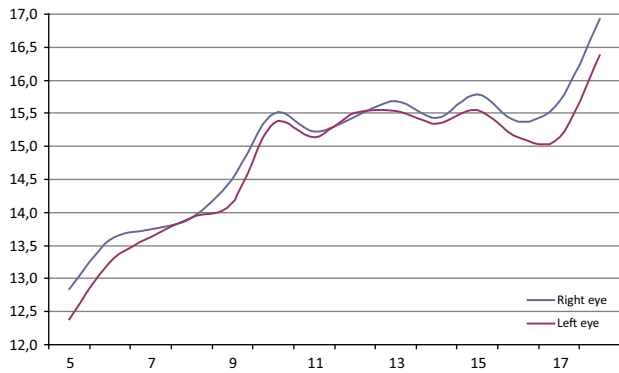


Figure 3. Comparison of mean exophthalmometric measurements for right and left eyes (vertically – exophthalmometric measurements (mm), horizontally – age of subjects (years)).

The outer orbital distance (base) ranged between 80 and 117 mm, with a mean of 98.7 ± 5.2 mm for all subjects. In children and adolescents the eye protrusion statistically significantly increased with the age ($r = 0.459, p < 0.001$). Also there were statistically significant correlations between increasing age and outer orbital distance measurements ($r = 0.690, p < 0.001$). Age and base value had a significant influence on normal eye protrusion values. The ocular protrusion was positively correlated with the outer orbital distance measurements ($r = 0.583, p < 0.001$). There was statistically significant correlation between proptosis measurements and the height of healthy children and adolescents ($r = 0.382, p < 0.001$). Also linear relationship was found between exophthalmometric values and weight of subjects ($r = 0.396, p < 0.001$) (see Fig. 4).

Discussion

It is necessary to know proptosis measurements in healthy pediatric population for assessment disorders such as pediatric Graves’ ophthalmopathy and other orbital disturbances. Lithuanian ethnic population in Eastern Europe is quite homogeneous (whites) and differs from other ethnic origins. We compared our data of exophthalmometry in children and adolescents with those data of other countries (including European) which we found in the medical literature.

There is a wide variation in medical studies given by different observers about the ocular proptosis meanings in pediatric population according to the race, age and gender. These studies must be interpreted with caution for several reasons: different techniques of exophthalmometry used to

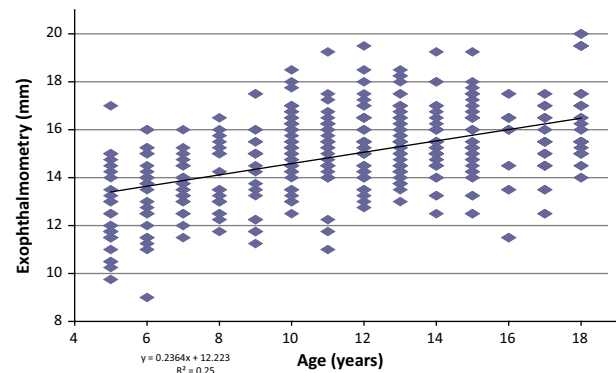


Figure 4. Correlation between exophthalmometry measurements and the age of children and adolescents.

measure their eye position, racial differences of children and teenagers population and different sample size. Research studies show that ocular protrusion is dependent, among other factors – on ethnic origin, age, gender, high refractive error, axial length, inter outer orbital distance.

To our knowledge – Lithuanian healthy children and adolescents were the first population to demonstrate this relationship between proptosis and age, gender, weight and height. Our study extends our knowledge of normal exophthalmometric references in 5–18-year-old Lithuanian children and adolescents.

There are well established data in the literature in terms of upper and lower limits of proptosis values for different anthropological groups. Studies have been carried out in the past on various countries children and adolescents: Danish,⁶ Italians⁷ Chinese,^{8,11} Arabian,⁹ Black Congolese,¹⁰ Indians,¹² Turkish,^{13,15,16} Iranian,¹⁴ American^{5,17} (Table 2).

In the clinical and research medical literature we found limited data regarding normative exophthalmometric values

in white European pediatric subjects. We wanted to compare Lithuanian children and teenagers proptosis meanings with other European pediatric population. Exophthalmometry was done in Italian children (from 3 to 10 years) and Danish children and adolescents (from 5 to 19 years). The mean exophthalmometric measurements at these studies for approximately the same ages of pediatric population varied from each other. Comparing European children and adolescents protrusion values, our exophthalmometry findings are similar to Danish exophthalmometry readings of healthy pediatric subjects.⁶ In comparison with previous European Italian studies that were performed on normal children, the mean proptosis value for Lithuanian children seemed to be slightly higher than that of the Italian healthy children.⁷ Nucci reported that the degree of Italian children ocular protrusion in 3–5 years old children of more than 14 mm, in 6–7 years old – more than 14 mm, in 8–11 years proptosis more than 15 mm should be noted during further investigation. From our study any eye protrusion of more than 15 mm for

Table 2. Comparison of absolute ocular protrusion values (Hertel exophthalmometry) in children of different ethnic groups.

| Ethnic group | Age (yr) | Gender | Ocular protrusion, mm, Mean \pm SD | Base Mean \pm SD |
|---|----------|----------------|--|--------------------|
| White European (Lithuanians) D. Jarusaitiene et al. (resent study) | 5–7 | M | 13 \pm 1.5 | 93.5 \pm 3.7 |
| | | F | 13.5 \pm 1.7 | 92 \pm 3.6 |
| | 8–11 | M | 14.6 \pm 1.6 | 97.4 \pm 3.9 |
| | | F | 15.2 \pm 1.7 | 96.7 \pm 3.6 |
| | 12–15 | M | 15.5 \pm 1.4 | 101.7 \pm 4 |
| | | F | 15.7 \pm 1.5 | 100.6 \pm 3.2 |
| 16–18 | M | 16.0 \pm 1.6 | 104.6 \pm 3.5 | |
| | F | 16.1 \pm 2.1 | 101.7 \pm 4 | |
| European (Danish) (Fledelius and Stubgaard) ⁶ | 5–7 | M | 13.7 | |
| | | F | 12.6 | |
| | 8–10 | M | 13.6 | |
| | | F | 14.1 | |
| | 11–13 | M | 14.5 | |
| | | F | 14.4 | |
| 14–16 | M | 14.9 | | |
| | F | 15.7 | | |
| European (Italian) (Nucci et al.) ⁷ | 3 | | 9.1 \pm 1.5 | 78.7 \pm 1.0 |
| | 5 | | 9.9 \pm 2.0 | 82 \pm 1.0 |
| | 7 | | 11.3 \pm 1.3 | 85.8 \pm 0.98 |
| | 10 | | 11.7 \pm 1.3 | 89.1 \pm 0.61 |
| Arabic (Osuobenian Al-Harbi) ⁹ | 6–12 | M | OD 15.4 \pm 1.6; OS 15.2 \pm 1.6 | 95.7 \pm 3.4 |
| Turkish (Kurtoglu et al.) ¹⁶ | 7–18 | M | OD 14.81 \pm 1.68; OS 14.65 \pm 1.67 | |
| | | F | OD 14.95 \pm 1.68; OS 14.75 \pm 1.67 | |
| Iranian (Kashkouli et al.) ¹⁴ | 6–12 | | 14.2 \pm 1.8 | |
| | 13–19 | | 15.2 \pm 1.9 | |
| American (Gerber et al.) ⁵ | 10–14 | M | 17.00 | |
| | | F | 16.8 | |
| American (Dijkstal et al.) ¹⁷ | 1–4 | M | 12.9 | 84.9 |
| | | F | 13.6 | |
| | 5–8 | M | 14.4 | 89.7 |
| | | F | 14.3 | |
| | 9–12 | M | 15.2 | 93.7 |
| | | F | 15.2 | |
| 13–17 | M | 16.1 | 95.7 | |
| | F | 16.3 | | |
| Indian (Sodhi et al.) ¹² | 3–10 | M | OD 13.02; OS 13.09 | |
| | | F | OD 13.09; OS 13.03 | |
| | 11–20 | M | OD 12.63; OS 12.46 | |
| | | F | OD 12.75; OS 12.65 | |
| Black (Congolese) (Kaimbo et al.) ¹⁰ | 2.5–6 | | OD 14.4 \pm 2.2 | 100.0 \pm 4.4 |
| | 7–10 | | OD 15.4 \pm 3.2 | 106.5 \pm 4.6 |
| | 11–14 | | OD 16.6 \pm 1.8 | 111.7 \pm 6.8 |
| | 15–18 | | OD 17.6 \pm 2.2 | 118.5 \pm 6.4 |
| Chinese (Zhang et al.) ¹¹ | 5–17 | | 14.48 \pm 1.71 | 95.55 \pm 5.32 |

Lithuanian healthy children and 16.0 mm – for teenagers should be investigated in future in order to suspect orbital pathology.

Among different ethnic groups Lithuanian children and adolescents have similar ocular protrusion with Chinese,^{8,11} Arabs,⁹ Iranian,¹⁴ Turkish,^{15,16} black Congolese (except for teenagers from 15 to 18 years old).¹⁰ Comparing Caucasian race of American children and adolescents group with our children and adolescents eye proptosis measurements results are quite similar.¹⁷ The ocular protrusion of children in our recent study tends to have higher exophthalmometric readings than those reported in Turkish, Indian children and adolescents.^{12,15,16} In an Indian juvenile population, the normal proptosis values were observed to be lower than other races studied.¹² When compared with a more homogeneous Lithuanian, Italian or Danish population, American children and adolescents, described by Gerber study,⁵ had higher eye position levels. This variability likely reflects the wide variety of ethnicities that contribute to the American population. The mean exophthalmometry readings in black race subjects were higher than in white race and in white race population were higher than in Orientals. The proptosis values measured in our study were lower than proptosis in Black Congolese healthy teenagers from 15 to 18 years old.¹⁰ The reasons of different ocular protrusion values should be explained by the differences in retroorbital adipose tissue, orbital, facial bony structure and globe size in children and adolescents of different ethnic origins. Some authors have proposed conventional definition of proptosis or exophthalmos using Hertel exophthalmometer and more than 20 mm should be accepted as diagnostic criteria for pediatric Graves' disease.^{1,14,17} Quant and Woo reported that readings of proptosis of Chinese children from Hong Kong were higher than children from other Chinese locations.⁸

In our study exophthalmometric values for the right and left eye in up to 34% of children and adolescents were quite similar. We have found that the mean right exophthalmometric value was significantly higher than the mean left ocular proptosis. In our study the mean relative ocular protrusion for all our subjects was 0.2 mm. Asymmetry of proptosis (mostly 0.5–1.0 mm) was in up to 67% of healthy Lithuanian under-age persons. Several authors also reported a higher exophthalmometric value of the right eye in Arabian⁹ and Iranian¹⁴ juvenile population. Other studies reported that the proptosis of both eyes in children and teenagers was similar and there was no difference between eyes.^{7,12,13} In our study the maximum relative eye protrusion meaning of our subjects was 2 mm and it was in only up to 2% of under-age persons. No individual had more than 2 mm of asymmetry. From our study asymmetric exophthalmometric measurements of more than 2 mm should be noted during further medical checkups to rule out orbital diseases. According to previous studies, in the majority of under-age persons from different ethnic origins, there was no significant difference between eyes and the relative protrusion value was below than 2 mm.^{5,7,12–16} Kara study also found that the mean relative protrusion was 0.43 mm for girls and 0.48 mm for boys.¹⁵ Therefore, the relative ocular protrusion value of up to 2.0 mm in the absence of other pathological findings could be considered as normal. Kashkouli et al. reported that relative ocular protrusion value of below than 2 mm in the absence of other orbital pathological changes may have little clinical importance.¹⁴ In Dijkstra

et al.'s study¹⁷ asymmetric measurements occurred in 14.9% of subjects, with a 2 mm maximal difference in 2 subjects. These relative exophthalmometric values are important for determining bilateral eye position in a childhood.

In our study we analyzed the relationship between the age of children and adolescents and proptosis readings. Our research study shows that eye protrusion of children and teenagers increases with the age (the difference of proptosis between groups was statistically significant). In our study the exophthalmometric values were higher in the second decade (15.55–16.02) mm as compared to the first decade (13.2–14.87 mm) of children life. In our study increasing age had a significant positive correlation with the proptosis values in children and teenagers. Accordingly to our study, we believe that the age of healthy pediatric population should be taken into account when evaluating and describing normal and pathological ocular protrusion parameters. Our study results are in agreement with other studies. Danish, Italian, black Congolese, Iranians, and White Americans studies showed that increasing age had a significant effect on the increase in eye projection.^{6,7,10,14,17} European Danish and Italian studies showed that exophthalmometry results were increased in accordance with the age.^{6,7} The increase in Hertel exophthalmometric value could be caused by the growth of the orbital bony walls and orbital width, increment of orbital adipose tissue during children growth (first two decades of life). Indian, Iranian, and Turkish researchers reported that age has no effect on proptosis.^{12–15} However, there are conflicting reports according to age and proptosis values. In Indian study the exophthalmometric values were higher in the first ten years of age of children as compared to the second ten years of age.¹² Bilen et al. noted that with increased age of juvenile population, the value of ocular proptosis was decreased.¹³

We have tried to correlate the exophthalmometric meanings of our subjects with their height and weight. In our study proptosis values were statistically significant correlated with children and adolescents height and weight. The reason of increased eye protrusion may be the greater height and weight data of subjects, especially after puberty. Kashkouli et al. showed that Iranian children weight and height did not have a significant effect on eye protrusion.¹⁴ Some researchers found no difference between the proptosis readings for under-aged boys and girls, and others have noticed the difference of protrusion values in males and females.^{5,13} In our present study the change of proptosis value according to the gender of children and adolescents was not statistically significant, but in female it was higher than in male. Gerber et al. reported normal exophthalmometric value in children of 10–14 years old according to age and sex. For the reason proptosis values in healthy children more than 10 years old may not be real due to the changing of organism at onset and progression of puberty. Few studies have reported a significant difference between ocular protrusion values and gender, and the study showed higher male exophthalmometry readings.^{5,13,14} Bigger height of boys after puberty has been suggested to be a reason for the greater ocular protrusion values in boys. Kashkouli et al. reported the mean exophthalmometry reading to be greater in boys, although the gender difference was not significant except for adolescents.¹⁴ On the contrary, the ocular protrusion of Caucasian American and Turkish girls was higher than boys.^{15–17} Other authors

reported the opposite insights concerning gender effect on globe position in particular age group. In European Danish study the mean proptosis in boys from 5 to 7 years was higher than in girls, although in girls (from 14 to 16 years) was bigger than in boys after puberty.⁶ This may be because adipose tissues distribution which affects the orbital soft adipose tissue increases more than in boys in puberty. Another European author Nucci et al. found that there were no differences of exophthalmometry results between boys and girls.⁷

In order to evaluate any possible effect of smaller or larger outer orbital distance (base) on ocular protrusion readings we analyzed these measurements in girls and males. The distance in our study between the lateral rims of the orbits (base) means up to 99 mm for all individuals. Base in males (boys) was wider than in females (girls). Upper limit of the distance between the two lateral orbital rims for one race may not be the same for the others. In European Danish and Italian juvenile population the distance between orbital lateral rims was smaller than in our subjects.^{6,7} Our study results showed that the base (outer orbital distance) was wider than in White American children and adolescents.¹⁷ Few studies have shown higher base value especially in black race healthy children and adolescents.¹⁰ In our study the base of children and adolescents, using Hertel exophthalmometry, was smaller than in Black Congolese subjects.¹⁰ The reason may be the variability of orbital bony framework in our individuals comparing with Black Congolese children and adolescents. We found out in our study that the distance between the two lateral orbital rims of under-age persons was similar to Chinese,⁸ Arabs children and teenagers.⁹ Our study showed that male base (outer orbital distance) value was wider than the female. Fledelius and Stubgaard,⁶ Dijkstal et al.¹⁷ reported that mean base of Caucasian Americans boys was greater than girls. From our study the ocular protrusion also was positively correlated with wider distance between the two lateral orbital rims (base). Our results are in agreement with Arabian and Iranian studies.^{9,14}

Our data can be used as normative exophthalmometric values for the Lithuanian children and adolescents in order to compare them with the future data of juvenile population of Lithuania and other countries.

Conclusions

In the present study, we have established ocular proptosis values according to the age, gender, weight and height of healthy Lithuanian children and adolescents. The eye protrusion significantly correlated with the age, weight and height of subjects and the distance between the lateral rims of the orbits. The gender did not play significant role on the eye projection data. We believe that larger, well-design studies are necessary in future to assess the distribution of proptosis in healthy Lithuanian children and adolescents.

Conflict of Interest

The authors declare that there is no conflict of interest.

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