 Turkiye Klinikleri J Ophthalmol. 2023;32(3):137-43

ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.5336/ophthal.2022-94363

The Association of Body Mass Index with Refraction and Anterior Segment Parameters in Primary School Children: Prospective Clinical Study

İlkokul Çocuklarında Beden Kitle İndeksinin Refraksiyon ve Ön Segment Parametreleri ile İlişkisi: Prospektif Klinik Çalışma

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ABSTRACT Objective: To determine the association of weight, height, body mass index (BMI) with refractive errors and anterior segment parameters in primary school children. **Material and Methods:** Complete ophthalmologic examinations of 108 primary school children aged 6-11 years were performed. Central corneal thickness, corneal volume, aqueous depth (AD), keratometry (K) values were obtained with the Sirius topography device. Participants' weight, height, BMI, right eye spherical equivalent (SE), and anterior segment parameters were recorded. Participants were divided into groups as myopic, emmetropic, and hyperopic according to SE values. Data were compared between groups and genders. **Results:** The mean age of the participants, consisting of 54 boys and 54 girls, was 8.42±1.63 years, BMI 17.33±3.39 kg/m^2, and SE mean 0.18±1.57 diopters (D). There was a significant difference between the groups regarding age, weight, height, SE, and aqueous depth ($p<0.05$). There was no significant difference between the groups in terms of BMI (p=0.083). There was a negative correlation between SE and age, weight, height, and AD ((r=-0.275, p=0.004; r=-0.262, p=0.006; r=-0.254, p=0.008; r=-0.402, p<0.001, respectively). There was a negative correlation between SE and BMI, but it was not significant (r=-0.193, p=0.046). There was a significant difference between boys and girls in terms of AD and K values ($p<0.05$). **Conclusion:** Significant differences were found between the groups in terms of age, weight, height and AD. Our study showed that myopic children had heavier weights, higher heights, and deeper aqueous depth. These findings suggest that school-aged children with rapid height growth and weight gain should be followed more closely regarding refractive errors.

Keywords: Body mass index; height; myopia; refraction error; school-age children;

ÖZET Amaç: İlkokul çocuklarında kilo, boy, beden kitle indeksi (BKİ) ile refraksiyon kusurları ve ön segment parametreleri arasındaki ilişkiyi belirlemektir. **Gereç ve Yöntemler:** İlkokul çağında 6-11 yaşları arasındaki 108 çocuğun tam oftalmolojik muayeneleri yapıldı. Sirius topografi cihazı ile santral kornea kalınlığı, korneal volüm, aköz derinliği (AD), keratometri (K) değerleri alındı. Katılımcıların kilo, boy, BKİ ile sağ göz sferik ekivalan (SE) ve ön segment parametreleri ölçümleri kaydedildi. SE değerlerine göre katılımcılar miyop, emetrop ve hipermetrop olarak gruplara ayrıldı. Veriler, gruplar ve cinsiyetler arasında karşılaştırıldı. **Bulgular:** Elli dört erkek ve 54 kız çocuktan oluşan katılımcıların yaş ortalamaları 8,42±1,63 yıl, BKİ ortalaması 17,33±3,39 kg/m^2, SE ortalaması 0,18±1,57 diyoptri idi. Gruplar arasında yaş, kilo, boy, SE, AD açısından anlamlı fark mevcut idi (p<0,05). BKİ açısından gruplar arasında anlamlı fark bulunmadı (p=0,083). SE ile yaş, kilo, boy, AD arasında negatif korelasyon vardı (sırasıyla r=-0,275, p=0,004; r=-0,262, p=0,006; r=-0,254, p=0,008; r=-0,402, p<0,001). SE ile BKİ arasında anlamlı olmamakla birlikte negatif korelasyon mevcut idi (r=-0,193, p=0,046). Erkek ve kız çocuklar arasında AD ve K değerleri açısından anlamlı fark vardı (p<0.05). **Sonuç:** Gruplar arasında yaş, kilo, boy ve AD açısından anlamlı fark bulundu. Çalışmamızda, miyopik olan çocukların daha ağır kilo, daha uzun boy ve daha derin AD'ye sahip oldukları gösterildi. Bu bulgular, okul çağı döneminde hızlı boy uzaması ve ağırlık artışı olan çocukların refraksiyon kusuru açısından daha yakın takip edilmesi gerektiğini düşündürmektedir.

Anahtar Kelimeler: Beden kitle indeksi; boy; miyopi; refraksiyon kusuru; okul çağı çocuklar;

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Peer review under responsibility of Turkiye Klinikleri Journal of Ophthalmology.

Received: 15 Nov 2022 ***Received in revised form:*** 21 Jan 2023 ***Accepted:*** 23 Jan 2023 ***Available online***: 27 Jan 2023

Refractive errors are among the most common health problems worldwide.[1,2] The most common refractive error after birth is hyperopia. Hyperopia regresses with emmetropization mechanisms, but refraction errors occur because this process is interrupted.[3-5] Myopia increases in the school-age period. Although some risk factors are known, the mechanism that causes the refractive error has yet to be fully elucidated.

It is known that both myopia and hyperopia have various risks of complications related to vision loss. Diseases such as retinal detachment, maculopathy, early cataract formation, and glaucoma are common in myopic patients.[6] However, amblyopia and angle-closure glaucoma are more common in hyperopic patients.[1,7] All these diseases can result in permanent vision loss.

Especially in the last few decades, the age of onset of myopia has been decreasing, and its prevalence has been increasing rapidly. Approximately half of the world's population is expected to be myopic in 2050.[2,8] Parameters such as genetic factors, lack of outdoor activities, close working, parental myopia, body height, body weight, and axial length have been blamed as the cause of myopia.[9,10] Although axial length has a strong relationship with refraction, the relationship between height and weight and refraction errors has been shown with different results in studies.[11-16]

These anthropometric parameters [weight, height, body mass index (BMI)] may detect myopia early and prevent possible complications. Considering the different results in the literature and the scarcity of studies on this subject in our country, it is clear that the effects of these parameters on refractive errors should be re-evaluated.

This study aims to determine the association between refraction values and anterior segment parameters with weight, height, and BMI in primary school children.

MATERIAL AND METHODS

The study was conducted as a prospective cross-sectional study in the Department of Ophthalmology of the Hitit University Hospital. The study included one hundred fifteen right eyes of 115 healthy children of primary school age with refractive error or asthenopic complaints. Approval was obtained from the Hitit University Clinical Research Ethics Committee (date: October 12, 2022, no: 2022-88). Verbal and written consent forms were obtained from the parents of the patients. The study was carried out in accordance with the Helsinki Declaration. Seven children with unsuitable topography quality were excluded from the study, and the right eye data of 108 children were used in the study.

Patients with any history of ocular surgery or corneal disorders (scarring, nephelion, pterygium) that will affect topography, using systemic or topical drugs, best-corrected vision levels worse than 10/10, spherical refraction values greater than ≥±5 diopters (D), participants with an astigmatism value greater than ±3 D, or patients with any systemic disease (diabetes mellitus, hypertension, goiter) were excluded from the study.

Refractive measurements were taken from the participants by an autorefractometer (Topcon KR-8900; Topcon Corporation, Tokyo, Japan). Best-corrected visual acuities and anterior segment examinations were performed with a slit-lamp. Corneal topographies were taken with Sirius topography (Sirius; Costruzione Strumenti Ophthalmici, Florence, Italy) device in the children who were eligible for the study, and then 1% cyclopentolate hydrochloride (Sikloplejin, Abdi İbrahim, İstanbul, Türkiye) drops were dripped 3 times with an interval of 5 minutes. And after the last drop, waiting for 30 minutes, the refraction measurements were repeated. The children's height and weight were measured with a digital weighing device (Densi GL-150, Industrial Weighing Systems) without shoes and wearing light clothes and recorded during the break time. After dilatation, posterior segment examinations were performed with a +90 D lens.

The Sirius topography device consists of a Scheimpflug camera and a Placido disc-based corneal topography. After the patient had placed his head and chin, he was told to blink 3 times and look straight to the opposite side. Topography shots were taken from both eyes. If an acquisition quality of >90% or better has been detected, the topography images have been saved. In this study, patients' central corneal thickness, corneal volume in a central 10 mm area (C_{vol}), aqueous depth (AD), flat keratometry value (K1), steep keratometry value (K2), and mean keratometry value (Km) were obtained. Spherical equivalent (SE) was calculated as spherical value + ½ cylindrical value. Patients with a SE value of <-0.50 D were classified as myopic, those with >0.75 D as hyperopic, and those between these 2 values were grouped as emmetropic. The participants' height was recorded in "cm" and their weight in "kg." BMI were calculated using the weight/height^2 (kg/m^2) formula. Obtained data were compared statistically according to age, gender, and SE values.

STATISTICAL ANALYSIS

Statistical analyzes were performed using the SPSS version 22 (SPSS, Inc., Chicago, IL, USA) package program. The conformity of the data to the normal distribution was evaluated with the Kolmogorov-Smirnov test. Normally distributed data were compared using a one-way ANOVA test. The homogeneity of variances was assessed with Levene's test. p<0.05 was considered significant. In cases with a substantial difference between the groups, pairwise post-hoc comparisons were made with Tukey tests. Groups were compared with the Kruskal-Wallis test for data that did not show normal distribution. Pairwise comparisons were made using the Mann-Whitney U test. Normally distributed parameters in the evaluations between genders were evaluated with the independent samples t-test, and parameters that did not show normal distribution were evaluated with the Mann-Whitney U test. Spearman correlation analysis and linear regression analysis assessed the relationship between the data.

RESULTS

One hundred eight primary school-aged children, 54 (50%) boys and 54 (50%) girls, were included in the study. The average age of the participants is 8.42 (range, 6-11 years) years, their average weight was 31.17 (range, 16.3-68.5 kg) kg, their average height was 132.91 (107.60-162.00 cm) cm, and the mean BMI was 17.33 kg/m^2 (range, 11.42-27.78 kg/m^2). The mean and standard deviations (SD) of all participants, myopic, emmetropic, and hyperopic data, are shown in Table 1. Age, weight, height, SE, and AD values significantly differed between the groups (Table 1).

There was no statistical difference in age between myopic-emmetropic and emmetropic-hyperopic groups; however, it was statistically different between myopic-hyperopic groups (p=0.178, p=0.281, p=0.007, respectively). For weight and height, there was a significant difference only be-

TABLE 1: Comparison of anthropometric and anterior segment parameters between groups.

Parameters	Overall (n=108)	Myopia (n=32)	Emmetropia (n=30)	Hyperopia (n=46)	p value
Age (year)	8.42±1.63	9.00±1.44	8.43±1.74	8.00±1.59	0.027*
Gender (M/F)	54/54	11/21	16/14	27/19	0.100*
Weight (kg)	31.17±9.98	35.13±10.93	30.47±8.80	28.88±9.38	**0.014***
Height (cm)	132.91±10.98	137.29±9.47	130.85±10.08	131.21±11.84	**0.025****
BMI (kg/m^2)	17.33±3.39	18.31±3.72	17.58±3.48	16.47±2.93	0.083*
SE (D)	0.18±1.57	-1.91±0.73	0.37±0.36	1.50±0.72	**<0.001***
CCT (µm)	559.57±34.32	563.41±34.23	554.23±35.55	560.39±33.89	0.454*
Cvol (mm^3)	59.14±3,53	59.56±3.62	58.65±3.23	59.18±3.68	0.600**
AD (mm)	3.18±0.27	3.33±0.24	3.21±0.22	3.06±0.28	**<0.001****
K1 (D)	43.31±1.27	43.52±1.22	43.45±1.26	43.06±1.29	0.223**
K2 (D)	44.32±1.38	44.64±1.34	44.46±1.43	44.02±1.33	0.117**
Km (D)	43.80±1.29	44.07±1.25	43.95±1.31	43.53±1.29	0.153**

*: Kruskal-Wallis test; **: One-way ANOVA test; bold <0.05; M/F: Male/female; D: Diopter; BMI: Body mass index; SE: Spherical equivalent; CCT: Central corneal thickness; Cvol: Corneal volume; AD: Aqueous depth; K1: Flat keratometry value; K2: Steep keratometry value; Km: Average keratometry value.

tween the myopic and hyperopic groups (p=0.005, p=0.040, respectively). There was no significant difference between the groups in terms of BMI (p=0.083). There was a significant difference in SE values in pairwise comparisons in all 3 groups (myopic, emmetropic, hyperopic) (for all, p<0.001). For AD, there was no difference between myopic-emmetropic groups, but there was a statistically significant difference between myopic-hyperopic and emmetropic-hyperopic groups (p=0.159, p<0.001, p=0.035, respectively).

There was a positive correlation between age and BMI and a negative correlation between age and SE (r=0.260, p=0.007; r=-0.275, p=0.004, respectively). There was a negative correlation between SE and weight, height, and AD (r=-0.262, p=0.006; r=-0.254, p=0.008; r=-0.402, p<0.001). There was a negative correlation between BMI and SE, although it was not significant (r=-0.193, p=0.046).

Figure 1 shows the regression analysis of SE between weight, height, BMI, and AD. A 10 kg increase in weight causes a 0.4 D decrease in SE, a 10 cm increase in height causes a 0.3 D decrease in SE, a 10-unit increase in BMI causes a 0.9 D decrease in SE, and an increase in AD by 0.1 mm SE causes a decrease of 0.23 D (Figure 1).

Table 2 shows the comparison of parameters between genders (Table 2). There was a statistically significant difference in AD, K1, K2, and Km values (p=0.026, p=0.026, p=0.014, p=0.017, respectively).

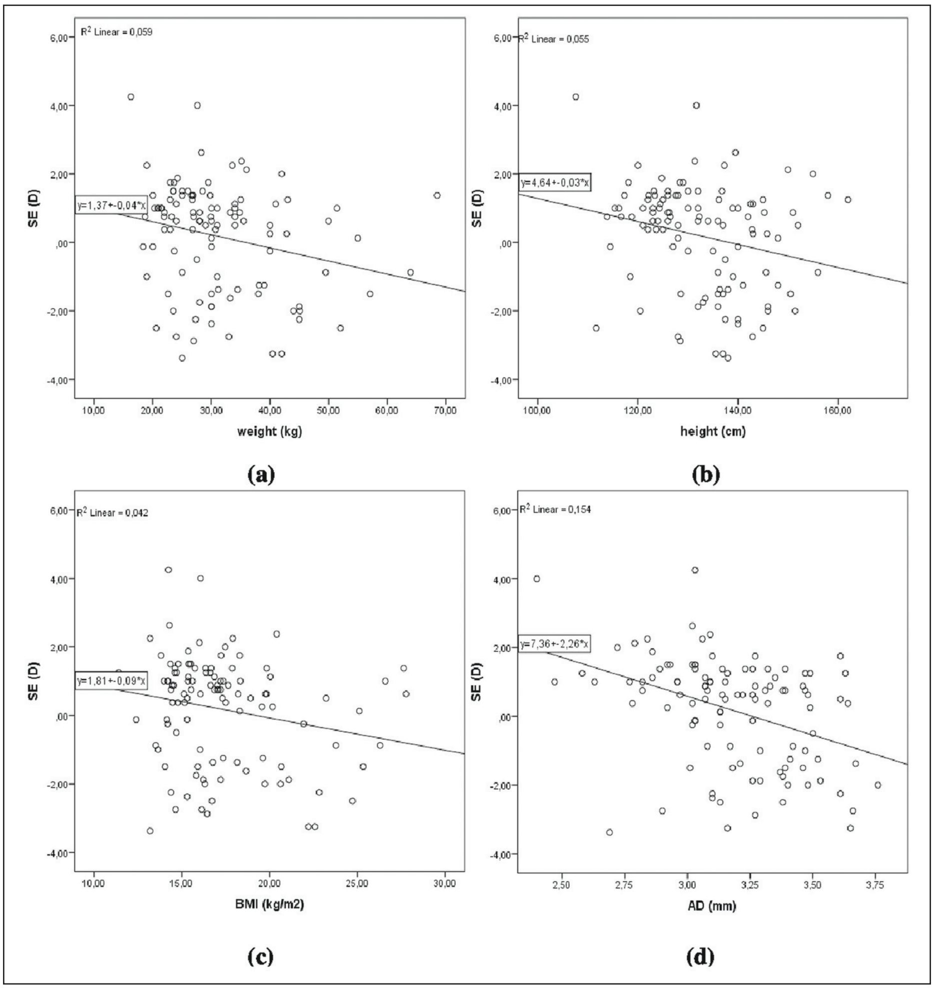

FIGURE 1: Correlation plot and linear regression line between **a)** weight and SE, **b)** height and SE, **c)** BMI and SE, **d)** AD and SE.
SE: Spherical equivalent; BMI: Body mass index; AD: Aqueous depth.

TABLE 2: Comparison of anthropometric and anterior segment parameters between genders.

Parameters	Male	Female	p value
Age (year)	8.37±1.63	8.46±1.65	0.754*
Weight (kg)	29.91±9.72	32.44±10.17	0.127*
Height (cm)	131.90±11.61	133.93±10.32	0.339**
BMI (kg/m^2)	16.85±3.18	17.81±3.55	0.144*
SE (D)	0.52±1.45	-0.17±1.63	0.058*
CCT (μm)	563.32±38.50	555.83±29.45	0.319*
Cvol (mm^3)	59.49±3.99	58.80±2.98	0.310**
AD (mm)	3.24±0.26	3.12±0.28	**0.026****
K1 (D)	43.04±1.18	43.58±1.30	**0.026****
K2 (D)	44.00±1.20	44.65±1.47	**0.014****
Km (D)	43.51±1.17	44.10±1.36	**0.017****

*: Mann-Whitney U test; **: Independent samples t-test; bold <0.05; M/F: Male/female; D: Diopter; BMI: Body mass index; SE: Spherical equivalent; CCT: Central corneal thickness; Cvol: Corneal volume; AD: Aqueous depth; K1: Flat keratometry value; K2: Steep keratometry value; Km: Average keratometry value.

There was no significant difference between genders in terms of BMI (p=0.144).

DISCUSSION

In this study, there was only a difference between the myopic-hyperopic groups in terms of age between the groups. The myopic group had higher age values. Likewise, there was a significant difference between myopic-hyperopic groups in weight and height. Both weight and height values were higher in the myopic group. There was no significant difference between groups for BMI and a significant difference between the emmetropic-hyperopic and myopic-hyperopic groups for AD. AD was the widest in the myopic group and the narrowest in the hyperopia group. There was a negative correlation between SE and age, weight, height, and AD. The increase in these values indicates that they are associated with a negative shift of SE (myopia). In the regression analysis, a 10 kg increase in weight causes a 0.4 D decrease in SE, a 10 cm increase in height causes a 0.3 D decrease in SE, and although not statistically significant, a 10-unit increase in BMI results in a 0.9 D decrease in SE.

There are studies conducted with weight, height, and BMI in the literature. A study of 1,449 children aged 7-9 years in Singapore Chinese demonstrated a tendency to have longer axial length, flatter cornea, and myopia in taller ones. Again, in this study, weight and BMI were correlated with hyperopia.[11] A study on English children showed that children with progressive myopia grew faster in height and weight.[17] Ye et al. found that tall height and heavy weight were associated with axial length and negative refraction.[18] Terasaki et al. in their study with 122 people from 3rd grade (8-9 years old) of elementary school children, showed that body weight and parental myopia were associated with myopia in children.[19] A study recruited Korean children aged between 5-18 years by Kim et al. reported that older children and those with parental myopia were associated with myopia, and those with higher BMI were associated with higher myopia (>6 D).[20] This has been attributed to the fact that obese children participate in fewer outdoor activities and do more close work activities.[11] In our study, weight and height were negatively correlated with SE, as demonstrated in most of the above studies. Myopic children had higher values for both weight and height than hyperopia children. The fact that myopic children are on average 1 year older than hyperopic children may be responsible for this situation (myopic group 9.00±1.44, hyperopic group 8.00±1.59 years). Saw et al. reported a 10 cm increase in body length; axial length increased by 0.29 mm in boys and 0.32 mm in girls.[11] In contrast to these studies, the Finnish twin study showed that myopic ones were not heavier.[21] Anandita et al., in their study of 127 people aged 13-17 years, did not find a significant relationship between anthropometric parameters and refractive errors.[22] These different results in studies can be attributed to the fact that refraction is affected by ethnic differences, geographical location, age groups, and genetic factors.[23,24]

Studies evaluating anterior segment parameters with BMI have generally been conducted in adults. A study that compares normal weight and overweight found that BMI was positively correlated with anterior chamber depth.[25] A study on 173 Brazilian people showed a positive correlation between height and anterior chamber and vitreous cavity depth.[26] A study with a Chinese population aged 40-81 years by Wong et al. reported a strong positive correlation between height and AL, anterior chamber depth, and corneal curvature.[12] Saw et al., in their study of children aged 7-9 years, found taller and deeper anterior chamber depth in males.[11] In our study, although there was a significant difference between the groups in terms of AD, no significant difference was found in keratometry values. A negative correlation was found between SE and AD. In the regression analysis, it was seen that an increase in AD by 0.1 mm caused a decrease in SE by 0.23 D. Myopic people had a wider anterior chamber, while hyperopic people had a narrower anterior chamber. This situation coincides with the information in the literature that those with hyperopia have shorter axial lengths and narrower anterior chamber.

A study comparing girls and boys found no difference between height, weight, and BMI.[19] Li et al. showed that myopia is associated with girls in their study conducted with nursery children aged 4-6 years.[27] A meta-analysis supporting these found that myopic prevalence was higher in girls.[8] Saw et al. reported that taller Chinese school children of 7 to 9 years were more myopic, especially in girls.[11] Although not statistically significant, our study found girls to be heavier, taller, and more myopic (differences with boys are 2.53 kg for weight, 2.03 cm for height and -0.69 D for SE). We also found that girls had narrower AD and steeper keratometry values. This situation may be responsible for girls entering puberty earlier and early growth acceleration. It has been shown in previous studies that there are sex hormone receptors in the cornea.[28]

There are also limitations of our study. First, our study recruited a relatively small number of participants; the study data should be confirmed with larger populations. Second, only Turkish children were included in the study. We know that refractive errors have different prevalences in different races, so studies can be organized to include children from different races. Third, biometric parameters such as axial length and lens thickness, which were shown to be associated with height and affect refraction, have not been investigated.

The strengths of our study are that the true refraction of children with cycloplegia was evaluated, and, unlike other studies, anterior segment parameters were also evaluated.

CONCLUSION

In conclusion, a significant difference is found between myopic, emmetropic, and hyperopic groups in primary school children in terms of age, weight, height, and AD. There was no significant difference between BMI and refractive errors. Children who are myopic have been shown to have heavier weight, higher height, and a deeper aqueous depth. In the regression analysis, every 10 kg increase in weight causes a 0.4 D decrease in SE, every 10 cm increase in height causes a 0.3 D decrease in SE, every 10 unit increase in BMI causes a 0.9 D decrease in SE and every 0.1 mm increase in AD causes a 0.23 D decrease in SE. When comparing boys and girls, it was found that girls had narrower AD and steeper keratometry values. This situation makes us think that children with rapid height growth and weight gain, especially in the prepubertal and pubertal periods, should be followed more closely in terms of refractive errors.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Mustafa Duran, Gülce Gökgöz Özışık;* ***Design:*** *Mustafa Duran;* ***Control/Supervision:*** *Mustafa Duran, Gülce Gökgöz Özışık;* ***Data Collection and/or Processing:*** *Mustafa Duran, Gülce Gökgöz Özışık;* ***Analysis and/or Interpretation:*** *Mustafa Duran, Gülce Gökgöz Özışık;* ***Literature Review:*** *Mustafa Duran, Gülce Gökgöz Özışık;* ***Writing the Article:*** *Mustafa Duran, Gülce Gökgöz Özışık;* ***Critical Review:*** *Gülce Gökgöz Özışık, Mustafa Duran;* ***References and Fundings:*** *Mustafa Duran, Gülce Gökgöz Özışık.*

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