Current Eye Research

ISSN: 0271-3683 (Print) 1460-2202 (Online) Journal homepage: http://www.tandfonline.com/loi/icey20

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CURRENT EYE RESEARCH
http://dx.doi.org/10.1080/02713683.2016.1220586

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ABSTRACT

Purpose: Hofstetter's equations are based on studies of Amplitude of Accommodation (AA) with methodological limitations, particularly in the case of children younger than 10 years of age. The aim of this study is to evaluate AA by age, gender, economic status, and time of day as well as accommodative insufficiency prevalence.

Methods: A cross-sectional study was conducted with 867 schoolchildren aged 6–16 years attending two public schools in the urban area of the South Brazilian city of Pelotas. Subjective refraction was performed using a monocular fogging method to standard end point of maximum plus for best visual acuity (20/25). AA was assessed using the push-up method.

Results: The median AA value was 14.3D (P25 13.3–P75 16.7) among children aged 6–16 years, being 15.5D (P25 14.3D–P75 16.7) among children aged 6–10 years, 14.2D (P25 12.5D–P75 15.4) among 11–13-year-olds, 13.3D (P25 12.5D–P75 15.4) among children aged 14–15 and 12.9D (P25 11.1D–P75 14.3) among those aged 16. AA variability was 2.4D in those aged 6–8, 3.4D in children aged 9–12, and 2.9D in those aged 13–16. There was no significant difference in median AA according to gender, time of examination, or economic status; 2.8% of children showed AA of less than 2D lower than Hofstetter's minimum reference value.

Conclusions: This study reports AA in a large sample of children and therefore may contribute to current knowledge on AA norms. In order to avoid the impact of outliers, it proposes the use of the median and percentiles to define AA standards by specific age. A set of studies using precise AA measurement and large sample size are needed to determine clinical standards for AA.

ARTICLE HISTORY
Received 11 March 2015
Revised 23 May 2016
Accepted 24 July 2016

KEYWORDS
Accommodative dysfunction; accommodative insufficiency; amplitude of accommodation; prevalence; push-up method; schoolchildren

Introduction

Assessment of visual function in school-age children places emphasis on visual acuity and refractive errors. However, accommodative insufficiency (AI) is the most common form of accommodative dysfunctions.[1] Studies with school-age children have found AI prevalence from 2.3% to 17.3%. This large variability could be related to the use of different diagnosis criteria.[2–5] Some authors have stressed the role of accommodative and binocular functions in guiding spectacle prescription and/or vision therapy.[5–12] However, consensus does not exist in the literature regarding the criteria for diagnosing AI, in particular because of the difficulty of establishing the cutoff point for normal amplitude of accommodation (AA).

In 1950, Hofstetter compared data from the studies conducted by Duane, Donders, and Kaufman and suggested three linear equations establishing minimum, expected, and maximum AA reference values by age.[13,14] Hofstetter's equations significantly contributed to improving AI diagnosis. However, these equations are based on studies with design limitations with regard to selection and sample size, low response rate, lack of information on inclusion and exclusion criteria or the use of one or both eyes (overestimating AA measurement owing to accommodative convergence).[15]

Donders evaluated the mean value for amplitude by age in children over the age of 10. Measurement was monocular, but restricted to emmetropic or nearly emmetropic subjects.[16] In addition, the low number of people aged under 30 in the sample limited the precision of maximum and minimum AA estimates.[17]

Duane assessed monocular and binocular AA and rigorously analyzed the participants' refractive status. Although he examined more than 4200 eyes, only 35 were related to children aged 8–12 years.[18,19] Kaufman assessed monocular accommodative amplitude, but the sample size was no greater than 200 individuals.[16] Hofstetter's equation estimates for those under 10 years old were calculated by extrapolation of average AA reduction. Although most studies showed an inverse relation between AA and age in children[15,20–23] this standard needs to be confirmed. Among subsequent studies, few included children under 10 years old and sample sizes were small in those covering this age group.[15,20,24,25] Only two rated monocular AA averages for specific age with a sample size of over 400 children.[21,22] The other studies show AA averages by age, but the variety of age ranges and measurement methods used makes comparison difficult.[16,20,26,27]

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Considering the limitations of the data used to build Hofstetter equations, this study aims to evaluate AA by specific age in a large sample of schoolchildren aged 6–16 years, in order to contribute to a set of studies needed to review AA standards and AI diagnostic criteria. Moreover, the study also aims to estimate AI prevalence in the same population. This is particularly important due to the lack of studies on AI in South America.

Materials and methods

A cross-sectional study was conducted in all children attending first to eighth grades of two public schools in the urban area of Pelotas, a medium-sized city in southern Brazil, from April to December 2012. This city has 340 000 inhabitants and had 37 000 children in the 6–16 age group enrolled at elementary state schools in 2010.[28] The average monthly household income in the city is R$ 500 (US$ 164), 80% of the children are white and 50% are female.[28] The schools studied are located in a lower middle class neighborhood and their students have similar socioeconomic and cultural characteristics.

Of the 1128 children available at both schools, we were able to recruit 1022 (90.6%) for this study. Of these, 14.1% did not meet the inclusion criteria for the study. A further 11 individuals older than 17 years were also excluded. Therefore, the final sample was 867 children. This sample size enabled an estimation of AI (2.00D or more lower than the value expected for age according to Hofstetter's equation (15–0.25 × age))[15] prevalence of 2.9%, with a 95% confidence level and a margin of error of 1.2 percentage points. Schoolchildren (n = 597), accompanied by a parent or guardian, were evaluated at the Federal University of Pelotas Ophthalmology Outpatients Clinic. In order to ensure testing of all children in this age range in the sample, the other 270 schoolchildren were evaluated at school, using the same equipment and methodology as used in the Clinic.

Boys accounted for 56.5% of the studied sample. Most of the children (63.8%) belonged to economic status "C+D+E". AA was measured in the afternoon in 60% of the children, while the other 40% had it measured in the morning.

Children with best corrected visual acuity poorer than 20/25 in either eye after the fogging test[5] as well as children with distance and near tropias or stereoscopic vision worse than 100 sec/arc[29] were excluded.[5,7,8]

The following screening tests and experimental test were performed in the order they are described. Visual acuity and subjective refraction were assessed for each eye separately using a logMAR chart and a phoropter at a distance of 4 meters (Snellen optotype). Non-cycloplegic automated refraction was measured eight consecutive times with an Auto Ref-Keratometer (PRK – 5000; Potec Co. Ltd.). This was refined by a monocular fogging/unfogging method to a standard endpoint for best visual acuity.[5,30] The fogging test was performed with positive lenses (at 0.25D intervals) until the child achieved visual acuity of 20/100.[30] The plus lenses were gradually reduced (unfogged) to control accommodation until the children were able to see the 20/25[5] line, using the most positive lens possible. Following this, astigmatism was tested, without fog[30], taking the readings for the cylinder and respective axis by autorefraction. In order to limit the duration of the eye exam, the cross cylinder test was performed only in the few cases in which it was not possible to quantify astigmatism by autorefraction. Children having difficulty with far vision (13.5%) used trial frames during AA measurement.

Following refraction, the cover test was performed for distance and near and the Titmus test was used to assess stereopsis in children who showed no tropias. The Titmus test is based on contour target and therefore it might overestimate stereopsis, since children with poor stereoscopic vision may guess the right answer because of monocular cues.[31]

The AA examination was carried out in free space (without a phoropter) using Donders' push-up method.[32] Only the right eye was examined and the left eye was kept occluded. For the procedure, the children looked at a reduced single line target of 20/30[5,7,31,32] Snellen letters at a distance of 30 cm. Each child was instructed to keep the target as sharply focused as possible. While encouraging the children to pay close attention, the examiner then gradually brought the target closer to the children at a speed of around 2 cm/sec[5] until the children indicated that the target had become blurred. The distance between the chart and the children's forehead was then measured in millimeters using a ruler. The examination was repeated once more in cases of uncertainty.

Each child was examined by one or other of the two orthoptic technicians who performed visual function and AA tests. They were trained by a third more experienced orthoptic technician and supervised by an ophthalmologist. For quality control, the third orthoptic technician (gold standard) repeated the push-up test in 10% of the examined children. The mean differences between the examiners' measurements and the gold standard were evaluated using the Bland–Altman statistical method.[33] Furthermore, the kappa statistic assessed the agreement between AI as evaluated by the examiners and AI as evaluated by the orthoptic technician who repeated the push-up, considering AI as AA < 2.00D lower than Hofstetter's equation for minimum amplitude by age.[15,31]

Gender (male or female) and age (in complete years) were studied as demographic variables. Economic status was classified according to the criterion of the Brazilian Association of Research Companies (ABEP), replacing the data on the formal education of the head of the family, as required by the ABEP criterion, with maternal education level, since this was the data available to the study.[34] The ABEP classification indicates Brazilian household ownership of durable goods and potential consumption, whereby classification A is the highest level and E the lowest level. The socioeconomic/demographic questionnaire was administered by a trained interviewer to the person responsible for each child. AA was evaluated according to the time of the day the examination was performed (morning/afternoon) and according to the two examiners (orthoptic technicians).

The push-up values were converted into meters and used in the equation to determine AA expressed in diopters. Medians, means, and standard deviation as well as the 10th, 25th, 50th, 75th, and 90th percentiles (P) were calculated for specific ages. The AA medians and percentiles are very useful for establishing

AA standards by specific age because they are not affected by outliers. Differences among gender, examination time, economic status, and examiner were evaluated using the Median test. Observed values (means) were compared to those predicted by Hofstetter's formula for expected amplitude by age using the t-test for unequal variances. Hofstetter's lines representing the maximum and minimum reference values by age were used for comparison. The following criteria were used to evaluate AI prevalence: AA lower than 2.5D by Duane's table for each age; AA below Hofstetter's equation for minimum amplitude by age; and AA 2.00D below Hofstetter's equation for minimum amplitude by age.[15,22,30] The study was approved by the Federal University of Pelotas School of Medicine Research Ethics Committee. Both the schoolchildren and their parent/guardian signed the informed consent form. For those children tested at school, informed consent was obtained by interviewers who visited their parents at home, before testing took place. The study guaranteed the subjects' right to refuse to participate, as well as the confidentiality of the collected information. When refractive errors were diagnosed, the study benefited these subjects by providing them with eyeglasses prescriptions, taking into account the subjective examination (fogging/unfogging) and those who needed follow-up were treated at the Federal University of Pelotas Ophthalmology Outpatients Clinic. The study met the requirements established by the Helsinki Declaration.[35] We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

Results

For children aged 6–16 years, the median AA value was 14.3D (P25 13.3–P75 16.7). It was 15.5D (P25 14.3D–P75 16.7) among those aged 6–10. For children aged 11–13, the median AA value was 14.2D (P25 12.5D–P75 15.4), and among those aged 14–15 and 16 years old, it was 13.3D (P25 12.5D–P75 15.4) and 12.9D (P25 11.1D–P75 14.3), respectively (Table 1).

The difference in variability between the 25th and 75th percentiles (P25 and P75) in the 9–12 age group was almost 4.00D (Figure 1) In the 6–8 and 13–16 age groups this difference was approximately 3.00D (Table 1).

Mean AA was 15.5D ± 3.5D and, on average, it was 0.34D lower for each year age range (Table 1). There was no statistically significant difference between mean AA for age found in this study and the expected value proposed by Hofstetter, with the exception of the values found at 10 and 16 years ($p < 0.05$) (Table 1).

The greatest standard deviation of estimated mean AA was ±4.5D at 10 years old (Table 2). Examiner 1 evaluated 51.4% of the children, and the AA median values by age were similar to those found by examiner 2, with the exception of children aged 6 years old (Table 2).

No significant difference was found in the AA median between genders, examination time (morning or afternoon), or economic status (Table 2).

When investigating AI prevalence, 2.9% of children presented amplitude lower than 2.00D below Hofstetter's equation for minimum amplitude by age.[10,11,16,22] According to Duane, diagnosis of AI occurs when AA is 2.50D lower than the expected amplitude by age. In this case, 4.4% AI prevalence was found among the children. When the criterion used to diagnose AI was any value of AA lower than Hofstetter's equation for minimum amplitude by age, AI prevalence was 14.7% (Table 3).[15,36,37] The difference between examiner and gold standard AA means using the Bland–Altman method was 0.98D (95% CI 0.57D–1.45D) and the AI agreement rate was $k = 1.0$ (complete agreement) using the kappa statistic.

Discussion

Owing to its easy application, the push-up method is widely used in clinical practice and is one of the tests suggested by the American Optometric Association (AOA) for assessing AA.[32] It is therefore appropriate to develop AA standards using this method. However, when comparing push-up with more objective methods, such as dynamic retinoscopy,[21,38] push-up overestimates AA, given that the small distances that accompany higher amplitudes increase the angular size of the target and, consequently, the depth of focus.[21,31,38,39] The push-up method was validated by Rose in children aged 10–12 but only 20 individuals were assessed.[40] The literature does not contain knowledge about the precision of push-up test measurements in children aged under 10 years. The push-up method is known to be affected by subjective factors such as lack of cooperation on the part of children, especially at an early age. Assessments made of children of this age should take this limitation into consideration.[21,38,41]

Table 1. Median and percentiles (P) 10, 25, 75, and 90 of the amplitude of accommodation in diopters (D). Mean and SD of the amplitude of accommodation in diopters (D) and a comparison with expected values, according to Hofstetter's equation for expected amplitude by age.

Age	N	P10	P25	Median	P75	P90	Mean (95% CI)	±SD	Mean difference in observed vs. expected values (95% CI)	p-value
6	55	12.5	14.3	15.5	16.7	20.0	15.9 (15.2; 16.5)	2.9	−0.8 (−1.6; 0.0)	0.053
7	74	12.5	14.3	15.5	16.7	20.0	16.2 (15.6; 16.7)	2.9	−1.7 (−0.9; 0.5)	0.616
8	99	12.5	14.3	15.5	16.7	18.2	15.1 (14.6; 15.5)	2.9	−0.3 (−0.9; 0.3)	0.336
9	96	11.8	13.3	15.5	18.2	25.0	16.3 (15.5; 17.0)	4.2	0.4 (−3.7; 1.3)	0.250
10	99	11.7	13.3	15.5	18.2	25.0	16.8 (16.0; 17.5)	4.5	1.3 (0.4; 2.2)	0.004
11	103	11.8	12.5	14.2	16.7	18.2	14.9 (14.3; 15.4)	3.1	−0.3 (−0.9; 0.3)	0.297
12	93	11.1	12.5	14.2	16.7	22.2	15.3 (14.6; 15.9)	3.9	0.4 (−0.4; 1.2)	0.351
13	108	11.1	12.5	14.2	15.4	16.7	14.2 (13.7; 14.6)	2.7	−0.3 (−0.9; 0.1)	0.169
14	90	11.1	12.5	13.3	15.4	16.7	13.9 (13.4; 14.3)	2.7	−0.4 (−1.0; 0.1)	0.151
15	32	10.0	11.8	13.3	14.3	15.4	13.3 (12.6; 13.9)	2.4	−0.7 (−1.6; 0.1)	0.118
16	18	9.1	11.1	12.9	14.3	15.4	12.5 (11.6; 13.3)	2.2	−1.2 (−2.3; −0.1)	0.032
6–16	867	11.8	13.3	14.3	16.7	20.0	15.5 (15.0; 15.5)	3.5	-	-

N, sample size; SD, standard deviation; CI, confidence interval; expected amplitude, ¼ 18.5–0.3 (age).

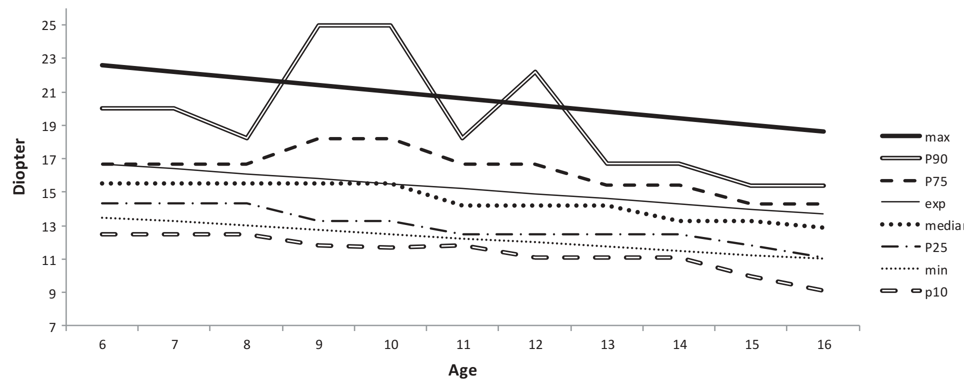

Figure 1. Comparison of median and percentiles with maximum, expected, and minimum Hofstetter's lines. max: Hofstetter's equation for maximum amplitude by age; P90: 90th percentile; P75: 75th percentile; exp: Hofstetter's equation for expected amplitude by age; P25: 25th percentile; min: Hofstetter's equation for minimum amplitude by age; P10: 10th percentile.

Table 2. Medians according to gender, socioeconomic status, time of examination, and examiner for specific age.

	Gender					Socioeconomic status (N = 838)					Time of examination					Examiner				
	Male		Female			A+B		C+D+E			Morning		Afternoon			Examiner 1		Examiner 2		
Age	(N)	(D)	(N)	(D)	*p*-value	(N)	(D)	(N)	(D)	*p*-value	(N)	(D)	(N)	(D)	*p*-value	(N)	(D)	(N)	(D)	*p*-value
6	(32)	15.4	(23)	15.4	0.87	(19)	14.3	(32)	15.4	0.98	(26)	15.4	(29)	15.4	0.38	(24)	16.7	(31)	14.3	0.01
7	(43)	15.7	(31)	15.4	0.31	(26)	15.4	(46)	15.4	0.91	(22)	15.4	(52)	16.0	0.64	(44)	16.7	(30)	14.8	0.42
8	(60)	15.4	(39)	15.4	0.79	(33)	15.4	(62)	15.4	0.39	(35)	15.4	(64)	15.3	0.39	(55)	15.4	(44)	15.4	0.77
9	(54)	15.4	(42)	16.0	0.38	(34)	15.4	(60)	15.4	0.46	(41)	15.4	(55)	15.4	0.55	(47)	15.4	(49)	15.4	0.98
10	(47)	15.4	(52)	16.7	0.60	(34)	15.7	(62)	16.0	0.83	(25)	15.4	(74)	16.7	0.45	(41)	16.7	(58)	15.4	0.80
11	(60)	14.3	(43)	14.3	0.32	(41)	14.3	(58)	14.3	0.42	(39)	14.3	(64)	14.3	0.75	(53)	14.3	(50)	14.3	0.88
12	(57)	14.3	(36)	14.3	0.45	(31)	14.3	(59)	14.3	0.57	(36)	15.4	(57)	14.3	0.16	(45)	14.3	(48)	14.3	0.94
13	(60)	14.3	(48)	14.3	0.77	(36)	13.8	(69)	14.3	0.22	(51)	14.3	(57)	14.3	0.96	(60)	14.3	(48)	13.8	0.14
14	(49)	13.3	(41)	14.3	0.70	(30)	13.3	(58)	13.8	0.50	(43)	13.3	(47)	13.3	0.98	(48)	14.3	(42)	13.3	0.51
15	(19)	13.3	(13)	13.3	0.77	(12)	13.3	(19)	14.3	0.82	(17)	13.3	(15)	13.3	0.74	(18)	13.3	(14)	13.8	0.97
16	(09)	13.3	(09)	11.8	0.35	(07)	11.8	(10)	13.3	0.43	(12)	11.4	(06)	13.3	0.14	(11)	13.3	(07)	11.1	0.33
Total	490	14.8	377	14.3	0.26	303	14.3	535	14.3	0.30	347	14.3	520	14.3	0.60	446	15.4	421	14.3	0.00

N, number of children; D, median in diopters.

Table 3. AI prevalence according to different criteria.

Age (y)	AI if AA lower than 2.5D predicted by Duane's Table for each age (%)	AI if AA below the minimum value for age according to Hofstetter (%)	AI if AA < 2D below the minimum value for age according to Hofstetter (%)
6–8 (n = 228)	2.6†	14.9	1.3
9–12 (n = 391)	4.8	15.3	3.3
13–16 (n = 248)	4.8	13.7	3.6
6–16 (n = 867)	4.4‡	14.7	2.9

y, years; AI, accommodative insufficiency; AA, amplitude of accommodation; D, diopters.
†Data available only for children aged 8 years or older (n = 117).
‡Data available only for children aged 8 years or older (n = 765).

This study found that median AA in those aged under 10 is 15.5D. Differently to what is proposed by Hofstetter's formula, AA appears not to decline gradually with effect from 6 years of age but, on the contrary, remains the same from 6 to 10 years of age and declines from then on (Table 1). Consistent with other studies,[21,22] it also indicates greater AA variability in the 9–12 age group (Figure 1) with a peak at 10 years. At the fourth grade of elementary school (9 years old) body posture and reading distance habits become more defined, the child interacts with longer paragraphs, and standard size fonts and reading speed gains importance.[31] Therefore, the child develops the ability to use AA in space and its variability can be better observed.

Although Hofstetter's equations are widely used in clinical practice, the methodological problems contained in the studies on which the equations are based, the absence of empirical data on children aged under 10 and the use of means and standard deviations, measures affected by outliers, suggest that these AA reference values should be better studied. [15,16,42] In this study the median was slightly lower than the expected Hofstetter values in almost all ages assessed (Figure 1). The 25th AA percentiles by specific age were similar to the minimum Hofstetter reference values, while the 75th percentiles were well below Hofstetter's maximum reference values (Figure 1).

Studies subsequent to Hofstetter show great variability in AA estimates, both in terms of age group[15,16,20,23,26,27] and in terms of specific age[21,22] (Table 4). This occurs because of the methodological variability of the different studies. Several studies used a small sample size [15,16,20,22–24,27] and different methods for measuring AA, such as the push-up method,[16–18,36,37,39] the modified push-up method,[20] minus lens,[27,43] and modified dynamic retinoscopy.[16,21] Variability in the age groups studied also makes comparisons difficult.

Table 4. Studies with AA values by different age groups.

Author (year)	Age	N	Measure	AA (D)	±SD (D)	Method	Observations
Eames (1961)[26]	5–8	899	Mean	14.3 (5 years)†	-	Push-up	Observed a decrease in AA in those aged 6–7 years, followed by an increase in those aged 8.
				13.2 (6 years)†			
				12.7 (7 years)†			
				13.7 (8 years)†			
Wold (1967)[16]	6–10	125	Mean	18.87 (6 years)	±1.0	Push-up	Identified relatively stable AA in those aged 6–7 years and a gradual increase from then until 9 years old.
				17.18 (7 years)	±2.0		
				17.87 (8 years)	±2.3		
				19.82 (9 years)	±3.4		
				18.94 (10 years)	±3.8		
Woodruff (1987)[27]	3–11	286	Mean	10.72	±0.2	Minus lens	Found low AA amplitudes at younger ages followed by a peak at 10 and 11 years old.
Chen (2000)[20]	1–17	405	Mean	16.58	-	Modified push-up	Found that mean AA does not follow a specific pattern by age among children below 10 years of age. From the age of 10, AA starts to decline.
Jimenez (2003)[21]	6–12	1.056	Mean	13.8 (6 years)	±2.7	Modified dynamic retinoscopy method	The AA showed a continual evolution with age.
				13.1 (7 years)	±2.6		
				13.0 (8 years)	±3.4		
				12.9 (9 years)	±3.3		
				12.1 (10 years)	±3.6		
				11.5 (11 years)	±3.2		
				11.5 (12 years)	±2.4		
Sterner (2004)[15]	6–10	56	Mean and median	mean: 12.4	±3.7	Push-up	AA showed much lower values than expected, especially for monocular measures. Does not agree with Duane's data as described by Hofstetter's equations.
				median: 12.0	±3.7		
Dusek (2010)[23]	6–14	308	Mean	13.29	±2.0	Push-up	-
Ovenser-Ogmobo (2012) [22]	8–14	435	Mean	19.0 (8 years)	±2.1	Push-up	AA declined between 8 and 10 years of age, followed by relatively stable AA in those aged 11–13.
				18.4 (9 years)	±2.4		
				17.1 (10 years)	±2.5		
				16.1 (11 years)	±3.2		
				16.3 (12 years)	±2.8		
				16.1 (13 years)	±3.4		
				15.5 (14 years)	±2.8		

N, sample size; AA, amplitude of accommodation; D, diopter; SD, standard deviation.
†Binocular AA.

Few studies have examined other factors that could be related to AA variability, such as gender, economic status, and the time of day at which the examination was performed.

The examiners did not assess the same children and difference in mean AA was only statistically significant at 6 years old. The variability between examiners in this age group may be related to the small numbers of subjects evaluated, which reduce mean AA precision.

The inexistence of AA variability between genders is consistent with a study conducted in Australia.[20] One study in Africa found that males showed greater AA than females, but attributed this to methodological problems.[22] This subject is controversial. It appears that no biological variability justifies AA gender differences. However, gender and economic status may have an effect on AA through cultural, behavioral, or nutritional aspects. Therefore, not only AA mean and median could be different between genders, but also the rate of AA reduction by age.[20]

Despite the existence of some variability in economic status, the population studied lives and attends schools in the same geographic area, which might explain the lack of association between economic status and AA. The use of maternal education may have overestimated the economic classification level of families, since women have more schooling than men. The number of children in both economic level groups allowed AA variability to be observed by economic status. Eames found that expected AA for children living in poorer urban areas was 5.00D lower on average when compared to those living in wealthy areas. He speculated that this may be due to poorer environment, malnutrition, and weaker physical development.[26]

Another author also indicates that AA would tend to decline as eyesight gradually becomes tired during the course of the day.[20] The inexistence of AA variability according to the time of day the examination was performed does not reinforce the hypothesis that visual fatigue might underestimate AA. However, more precise information about visual fatigue is needed to be able to examine this hypothesis.

AI prevalence varied greatly according to the different diagnosis criteria (Table 3). Most AI diagnosis is performed using the cutoff point of 2D below Hofstetter's minimum value[15,36,44] (Table 3). However, consensus does not exist as to which AA cutoff points or which criteria should be used to diagnose AI.

Quality control performed by using the Bland–Altman statistical test compares the AA measurements obtained by the two examiners and those obtained by the third orthoptic technician (gold standard). The test suggests that AA measurement was adequate. Moreover, the use of the push-up method is endorsed by very good intra- and inter-examiner reliability based on the intraclass correlation coefficient described by Rose validation.[40]

With regard to limitations, it must be pointed out that this study was conducted in two schools in the same neighborhood with strong representation from lower-middle income families and therefore is not representative of different economic levels. Mean AA values are slightly underestimated because no measures above 25D were obtained. AA may also have been underestimated in children who needed to correct their myopia minutes before the push-up test. Near visual acuity was not examined. This overestimated diagnosis of tropias in reading distance, thus increasing the possibility of excluding children with poor near vision due to other causes before testing AA.

Given the importance of AA in diagnosing AI, AA standards in the population need to be known in detail. This study estimated age-specific AA, thus contributing to the definition of standards based on direct estimates rather than extrapolation, especially among children younger than 10 years old, even more so because the literature is very sparse on the topic.

More studies are needed using standardized methods and sufficiently large samples to define AA profile by specific age. In order to make progress in defining AI diagnosis criteria, studies are also needed to define the AA cutoff points beyond which limitations occur.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Funding

This study was funded by the Brazilian Federal Agency for the Support and Evaluation of Graduate Education (CAPES), Ministry of Education, Brazil.

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