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Investigation of amplitude of accommodation among Ghanaian school children

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Background: Deficient amplitude of accommodation is the most frequently used criteria in an optometric practice in diagnosing whether a patient has accommodative insufficiency. This deficiency is determined based on an age-related expected finding calculated using Hofstetter's equation derived from Donder's and Duane's data. The aim of the present study was to investigate the amplitude of accommodation among Ghanaian school children and to compare the findings with age-expected norms predicted by Hofstetter's equation.

Methods: The amplitude of accommodation was measured using the push-up method in a random sample of 435 school children from the Cape Coast Municipality. The mean amplitude of accommodation was compared with the age-expected amplitude of accommodation as predicted by Hofstetter's equation for average amplitude of accommodation.

Results: The mean amplitude of accommodation was 16.86 ± 3.07 D (95% CI = 16.57, 17.15). This is significantly higher than age-expected norms calculated using Hofstetter's equation. The amplitude of accommodation showed the characteristic decline with age.

Conclusion: From the results, we conclude that the age-expected norms for amplitude of accommodation using Hofstetter's equation might not be accurate for Ghanaian children.

Key words: accommodation, accommodative insufficiency, amplitude of accommodation, Ghanaian children, myopia, myopic progression

The amplitude of accommodation defines the maximum amount of accommodation the visual system can elicit and is one of the commonly assessed visual functions during an eye examination. It is valuable when investigating the accommodative status of a patient. Clinically, it is used to diagnose accommodative anomalies, as well as estimating the additional power required to correct presbyopia. In these instances, the predicted average amplitude of accommodation (AOA) is calculated for a patient by using Hofstetter's equation[1] (AOA = 18.5 - 0.3 × age in years). This equation was derived from the original work of Duane and is routinely used in determining whether a patient has sufficient AOA, and this is often combined with other accommodative findings to diagnose accommodative anomalies.[2–6] The reliability of the norms for children aged eight to 12 years has been discussed.[7,8] Both Wold[7] and Turner[8] queried the reliability of Duane's norms because only 35 of the 1,000 subjects in Duane's study were aged eight to 12 years. The indiscriminate application of Duane's norms derived from a Caucasian population has also been queried on the basis of race,[9] as race might influence AOA.[10,11] Sterner, Gellerstedt and Sjöström[12] have also remarked that the AOA using Duane's norms is flawed in

predicting the accommodative amplitude for children of a younger age.

We investigated AOA of junior secondary school children in Ghana. The aim of the study was to determine if there is a difference between the AOA predicted by Hofstetter's equation and the actual AOA of Ghanaian children. The data from this study would lead to better assessment of the accommodative function of school children in Ghana.

METHODS

Ethical consideration

The protocol for the study was approved by the Department of Optometry, University of Cape Coast. Approval was also obtained from the Metropolitan Directorate of Education of the Ghana Education Service, Cape Coast. The study was conducted in accordance with the Declaration of Helsinki. School principals gave consent for the children, while each child was required to give consent to participate in the study. Children were informed that they could elect not to participate in the study or withdraw at any time without penalisation. They were assured that the procedure was safe and would not pose any significant risk to their eyes.

Subjects

The study subjects comprised school children aged eight to 14 years attending school within the Cape Coast Municipality of Ghana. Schools in the municipality are grouped into six circuits. A multi-stage sampling technique was used to select participants. In the first stage, three circuits were randomly selected by ballot. One publicly funded and one privately funded school were selected randomly from each selected circuit. This gave a total of three publicly funded and three privately funded schools with access to 1,288 children, all of whom were eligible to participate in the study.

Selection criteria

Data relating to AOA were analysed only for children with emmetropia (spherical equivalent equal to or between +0.50 DS and -0.50 DS) and no apparent ocular abnormality at the initial examination. The refractive status of the children was estimated from their present spectacle prescription. Hyperopia was checked by measuring visual acuity with a +2.00 D lens. A visual acuity cut-off point of 6/5 was used to ensure that patients had no significant refractive error.

Examination

All children underwent eye examinations comprising visual acuity using Tumbling E Snellen charts at six metres, AOA, ocular health examination with a penlight and direct ophthalmoscopy. All children were examined at school during school hours.

Amplitude of accommodation

The AOA was measured with the Donder's push-up method using the Royal Air Force near point rule (a rod with various scales and movable targets). The target was slowly moved towards the child along the midline while the child was instructed to keep the N5 print clear. The child reported the first sustained blur at which point the dioptric reading was recorded. To ensure accuracy of the children's report of first sustained blur, a demonstration of blur was carried out with each child prior to performing the AOA test. The procedure was performed for the right eye and then the left eye in ambient light. For comparison, the average AOA was computed using Hofstetter's equation ($18.5 - 0.3 \times \text{age}$).

Age (years)	Sex		Total (%)
	Male (%)	Female (%)	
8	26 (14.1)	26 (10.4)	52 (12.0)
9	39 (21.2)	32 (12.7)	71 (16.3)
10	14 (7.6)	31 (12.4)	45 (10.3)
11	23 (12.5)	46 (18.3)	69 (15.9)
12	32 (17.4)	37 (14.7)	69 (15.9)
13	27 (14.7)	40 (15.9)	67 (15.4)
14	23 (12.5)	39 (15.5)	62 (14.3)
Total	184 (100.0)	251 (100.0)	435 (100.0)

Table 1. The number of participants by age and gender

Data analysis

The mean AOA was computed for the right and left eyes separately. The difference between the measured AOA and expected average amplitude obtained using Hofstetter's equation was tested using the Student's t-test. The relationship between age and AOA was analysed using the Pearson's correlation coefficient. One-way analysis of variance was used to investigate the difference in mean AOA among the different age groups.

RESULTS

Study subjects

Of the total 1,288 children at all six selected schools, 511 children were initially examined. The results of 61 children were excluded from the study based on the selection criteria. The results of 435 children comprising 184 (42.3 per cent) males and 251 (57.7 per cent) females are reported. Table 1 shows the age and gender distribution of participants. The children were aged eight to 14 years with a mean age 11.11 ± 1.9 years. The mean age for the male subjects was 10.92 ± 2.02 years (95% CI: 10.62, 11.21) and for female subjects was 11.24 (95% CI: 11.00, 11.48). There was no significant difference between the mean age of male and female participants.

The AOA for each age group is shown in Table 2. The mean AOA for right and left

Age (years)	Mean amplitude of accommodation (right eye; dioptres)		
	All subjects and SD	Male and SD	Female and SD
8	19.00 ± 2.11	18.92 ± 1.79	19.08 ± 2.43
9	18.43 ± 2.45	18.79 ± 2.35	17.98 ± 2.53
10	17.08 ± 2.82	18.64 ± 1.76	16.37 ± 2.95
11	16.08 ± 3.19	17.02 ± 3.44	15.61 ± 2.99
12	16.30 ± 2.77	17.09 ± 2.33	15.61 ± 2.96
13	16.09 ± 3.38	16.17 ± 3.26	16.04 ± 3.50
14	15.47 ± 2.80	15.20 ± 2.82	15.63 ± 2.80
Entire subjects	16.86 ± 3.07	17.49 ± 2.89	16.44 ± 3.73

SD: standard deviation

Table 2. The age and gender distribution of amplitude of accommodation

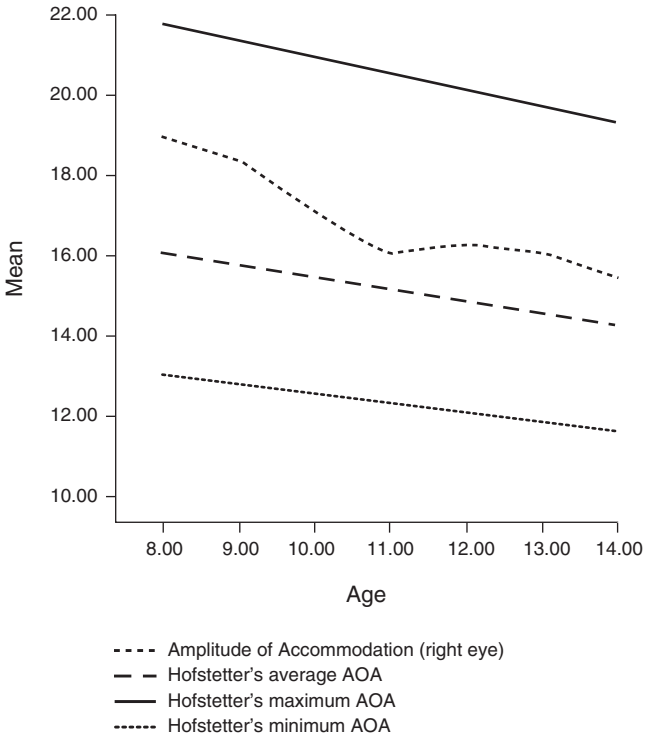

Figure 1. Decline in mean amplitude of accommodation (AOA) of the right eye with age

eyes was 16.86 ± 3.07 D (95% CI = 16.57, 17.15) and 16.92 ± 3.05 D (95% CI: 16.63, 17.21), respectively. There was a strong correlation between the AOA of the right and left eyes ($r = 0.985$, $p < 0.001$). Therefore, the AOA of the right eye was used in the analysis of AOA. We assumed the amplitude of the right eye was approximately normally distributed, as indicated by the Shapiro-Wilk test for normality (S-W = 0.952, $p < 0.001$).

The mean AOA showed the characteristic decline with age (Figures 1 and 2). There was a significant difference in AOA among the age groups (ANOVA $F = 13.239$, $p < 0.001$).

The mean AOA for male subjects was 17.49 ± 2.89 D (95% CI = 17.03, 17.87), while that of female subjects was 16.44 ± 3.13 D (95% CI = 16.05, 16.83). This gender difference in mean AOA was statistically significant ($t = 3.485$, $p = 0.001$).

Comparison with Hofstetter's expected AOA

The expected mean AOA computed using Hofstetter's equation (AOA = 18.5 - 0.3 × age) for the subjects in the current study was 15.17 ± 0.59 D. Using Hofstetter's equation for maximum AOA (AOA = 25.0 - 0.4 × age), the mean maximum expected AOA was 20.56 ± 0.789 D, while the minimum expected AOA (AOA = 15.0 - 0.25 × age) was 12.33 ± 0.473 D. The mean AOA obtained in the current study does not agree with the mean expected values as given by Hofstetter's equations. The mean AOA found in Ghanaian children in the present study was consistently higher than the average and minimum AOA predicted by Hofstetter's equations but lower than the maximum predicted amplitudes for all age groups (Table 3 and Figure 2).

The difference between the mean AOA obtained in the present study and the predicted mean AOA (using Hofstetter's equations) was significant (Table 4).

DISCUSSION

This is the first investigation of the AOA in Ghanaian school children, which is important in diagnosing accommodative insufficiency. As expected, amplitudes for the

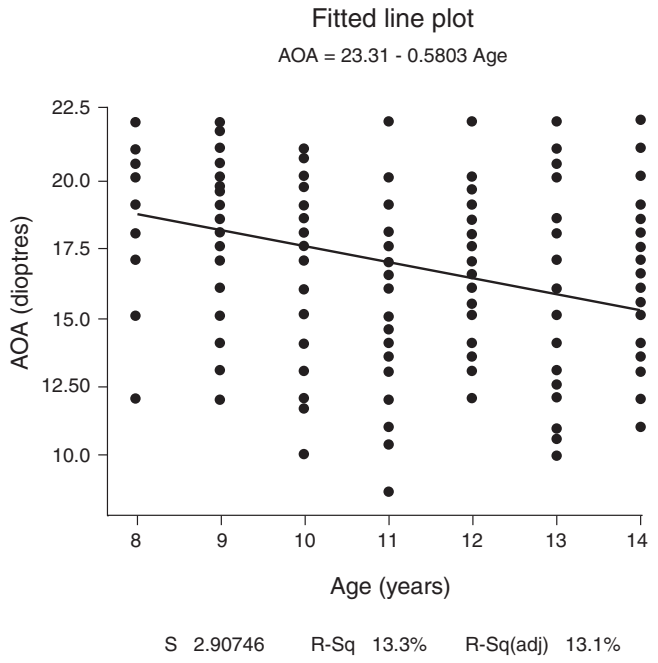

Figure 2. Scatter plot of amplitude of accommodation (AOA) shows the regression equation line

Age (years)	Number (present study)	Mean AOA (SD) (in dioptres)	Predicted Hofstetter's AOA		
			Maximum	Average	Minimum
8	52	19.00 ± 2.11	21.80	16.10	13.08
9	71	18.43 ± 2.45	21.40	15.80	12.84
10	45	17.08 ± 2.82	21.00	15.50	12.60
11	69	16.08 ± 3.19	20.60	15.20	12.36
12	69	16.30 ± 2.77	20.20	14.90	12.12
13	67	16.09 ± 3.38	19.80	14.60	11.88
14	62	15.47 ± 2.80	19.40	14.30	11.64
Mean 11.1	n = 435	16.86 ± 3.07	20.57	15.17	12.22

SD: standard deviation

Table 3. Comparison between observed and expected amplitude of accommodation (AOA) according to age

right and left eyes were similar[13] and decreased significantly with age. The mean AOA for the subjects in the present study was 16.86 D. This finding was higher than the 12.40 ± 3.7 D obtained for Swedish children aged six to 10 years[12] and the 13.29 ± 2.05 D for Austrian children aged six to 14 years[14] despite the younger age ranges of those cohorts. These studies used the push-up method for determining the AOA. It was higher than the mean AOA for Korean children,[15] among whom the mean AOA was 14.55 D in children aged six to 10 years decreasing to 12.36 D in those aged 11 to 15 years,[15] using the minus lens to blur technique. From the foregoing, it is clear that irrespective of the technique used in measuring AOA, there appears to be some racial variation in mean AOA.

From the present study, it appears that the AOA of Ghanaian children might be higher than those of European and Korean children. There could be several reasons for this observation. We could not find supporting evidence that genetic factors might influence AOA. We could infer that the environment might be a factor in this racial variation in AOA. Miranda[16] indicated that populations living in warmer regions have an earlier onset of presbyopia compared with those living in colder regions. In contrast, Edwards and colleagues[17] have also argued that the lower AOA among the Chinese population might be due to factors other than long-term environmental effects.

This higher accommodation observed for Ghanaian children cannot be conclusive until various techniques for determining the AOA including objective methods have consistently shown higher amplitudes of accommodation for these subjects.

As shown in Table 4, there was a significant difference between the expected AOA predicted by Hofstetter's equations and the measured AOA in the present study. Our values were higher than the predicted average (expected) and minimum amplitudes of accommodation but lower than the maximum amplitude. Sterner, Gellerstedt and Sjöström[12] have also demonstrated a discrepancy between

	Mean difference in observed versus expected values (95% CI)	t	p-value
Hofstetter's maximum	-3.69 (-3.96, -3.42)	-26.829	<0.001
Hofstetter's average	1.67 (1.42, 1.97)	12.193	<0.001
Hofstetter's minimum	4.53 (4.25, 4.81)	32.293	<0.001

Table 4. Comparison between observed and expected amplitude of accommodation

the predicted and actual measured amplitudes of accommodation for Swedish children aged six to 10 years; however, their values were lower than the predicted AOA.

An interesting finding in the present study was the significant difference between the mean AOA between male and female participants, although there was no difference between their ages. We found no literature demonstrating gender difference with AOA. As the procedures and the test conditions were similar for both male and female subjects and a physiological difference in ocular mechanisms is unlikely, we can only suggest that the difference might be due to a higher proportion of males in the younger age group (eight- and nine-year groups) compared with the higher proportion of females in the older age group (10-, 11-, 12- and 14-year groups). The present study also demonstrated the decline in AOA with age. In the present study, the mean AOA declined from 19.00 D at age eight years to 15.47 D at age 14 years. This represented an 18 per cent decline. Using Hofstetter's equation for expected average AOA, there would be an 11 per cent decline in AOA from age eight years to 14 years.

In the present study, refraction was not performed. This might have led to a misclassification of low-grade ametropia as emmetropia. It is possible that this misclassification could affect our conclusion. Notwithstanding, we do not expect such bias to be significant or to negate the observed findings. This is because a visual acuity cut-off point of 6/5 was used in selecting subjects. It is not likely that the low-grade refractive error of the order of say ±0.25 D would significantly negate the observed findings. The subjective method of determining the AOA (push-up technique) used in this study also has some limitations. It is thought to overestimate AOA.[18]

CONCLUSION

There appear to be no previous studies investigating the AOA among Ghanaian children. We have shown that Ghanaian children aged eight to 14 years might have higher amplitudes of accommodation than what might be predicted using Hofstetter's formula. Therefore, there is a need for practitioners to exercise some caution in applying Hofstetter's expected AOA in diagnosing accommodative insufficiency among Ghanaian children. Further studies are recommended with a larger sample and with children of varying categories including out-of-school children, with a view to establishing normative values for the AOA of Ghanaian children.

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