Article ▸ # Comparing Measurement Techniques of Accommodative Amplitude Among School Children

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ABSTRACT

Background: There is no consensus on the precise method of measuring amplitude of accommodation (AA) in routine clinical examination. In addition, studies have queried the use of Hofstetter's equation for computing the expected AA for different populations. This study was designed to compare four subjective methods of AA measurement in children and results from each method with Hofstetter's calculated average AA.

Methods: An evenly distributed sample of 103 children aged 6-17 years attending schools in Benin City participated in this study. Amplitude of accommodation measurements—push-up (PU), push-down PD), minus lens to blur (MLB), and modified push-up (MPU)—were carried out in children with emmetropia. The values obtained for each method were compared with Hofstetter's calculated average values. Agreement among each method was investigated using Bland-Altman plots.

Results: The means ± SD obtained for the right eye of subjects in Diopters (D) were: PU (12.69 ± 3.16), PD (12.50 ± 2.95), MLB (11.83 ± 2.99), and MPU (11.88 ± 2.88). Using the t-test, significant differences were found between all groups except the MLB and MPU pair. Hofstetter's calculated average differed significantly from results obtained using each method ($P<0.0001$). Bland-Altman plots showed levels of agreement between the PU and PD and the MLB and MPU methods.

Conclusion: Given the difference in results between some of the measurement techniques and with Hofstetter's calculated average AA values, caution should be taken when making decisions concerning AA measurements and accommodative anomalies in school children aged 6-17 years in Benin-city, Nigeria.

Keywords: accommodative amplitude, Hofstetter, minus lens to blur, modified push-up, push-down, push-up

Introduction

Accommodation can be defined as an increase in the refractive power of the eye for focusing near objects of regard on the retina.[1] The maximum accommodation exerted by an individual is the amplitude of accommodation (AA). It is a component of routine clinical examination to assess the accommodative function of an individual, including children.

There are several methods of measuring AA. These include subjective techniques such as the Donder's push-up, Sheard's minus lens to blur, push-down (also known as push-away), and the modified push-up method,[2] as well as objective methods. In clinical practice, subjective techniques are most commonly used to measure the AA.[3] The modified push-up involves measuring the AA through a combination of a minus lens added over the distance refractive correction. The advantage of the modified push-up over the conventional push-up procedure is that the target appears smaller when viewed through the minus lens; therefore, subjects will detect the presence of blur earlier.[4] Furthermore, the near point of accommodation will be farther away from the subject compared with the PU or PD techniques. Hence, the linear space between the diopters will increase, thus making the procedure more precise. On the other hand, the push-up has a limitation of overestimating the accommodative amplitude because of the effect of proximal convergence, while the minus lens to blur technique is thought to underestimate AA.[4-6]

Hofstetter[7] stated that measured AA decreases at a rate of 0.30 D per year until it reaches 0.50 D at the age of 60 years. In another study,[8] he estimated the average amplitude of accommodation for an individual of a given age to be 18.5 - (0.3 × patient's age in years). However, Hofstetter's[7] work was based on data from two early surveys by Duane and by Donders,[9,10] which although widely cited, have been noted by Hofstetter to include measurements obtained from children which could be inaccurate. In addition, the subjects recruited for Duane's and Donders' studies were Caucasians aged 8 to 72 years, with quite a small proportion of children in their respective studies. As such, conclusions drawn may not be applicable to the entire children population of children, as well as subjects of African descent.

Table 1. Mean and Standard Deviation Obtained for Different Ages of Subjects

Age (years)	Number of subjects	PU Mean ± SD (D)	PD Mean ± SD (D)	MLB Mean ± SD (D)	MPU Mean ± SD (D)
6	8	17.62 ± 1.48	16.61 ± 0.92	15.75 ± 1.03	15.79 ± 0.84
7	13	17.23 ± 1.13	16.99 ± 1.11	16.23 ± 0.92	16.10 ± 1.10
8	5	15.48 ± 0.70	15.48 ± 0.90	15.00 ± 0.00	14.66 ± 0.68
9	8	15.03 ± 0.86	14.47 ± 0.67	14.25 ± 0.71	14.16 ± 0.49
10	2	13.69 ± 0.76	13.51 ± 0.97	14.00 ± 1.41	13.25 ± 1.06
11	4	13.64 ± 0.43	13.28 ± 0.30	12.75 ± 0.50	12.72 ± 0.36
12	8	11.36 ± 1.11	11.67 ± 1.11	11.13 ± 1.25	11.49 ± 1.04
13	9	11.36 ± 1.88	10.98 ± 1.25	10.33 ± 1.32	10.63 ± 1.18
14	15	9.99 ± 1.30	10.35 ± 1.49	9.20 ± 1.15	9.48 ± 1.32
15	13	9.25 ± 1.07	9.04 ± 1.14	8.23 ± 1.09	8.19 ± 0.71
16	9	11.24 ± 1.05	11.01 ± 1.03	10.44 ± 1.01	10.69 ± 0.89
17	9	10.95 ± 0.70	10.69 ± 0.75	10.22 ± 0.67	10.24 ± 1.10
Total	103	12.69 ± 3.16	12.50 ± 2.95	11.83 ± 2.99	11.88 ± 2.88

Table 2. Mean and Standard Deviation for Different Measurement Techniques and Hofstetter's Calculated Average (HOF AVE= Hofstetter's average)

	N	Mean ± SD (D)	95% Confidence Interval
PU	103	12.69 ± 3.16	12.08 – 17.37
PD	103	12.50 ± 2.95	11.92 – 13.08
MLB	103	11.83 ± 2.99	11.24 – 12.41
MPU	103	11.88 ± 2.88	11.32 – 12.45
HOF AVE	103	14.52 ± 1.20	14.29 – 14.75

This study was therefore designed to compare subjective measurement techniques of accommodative amplitude in children and to compare results of each method with Hofstetter's average normative value.

Methods

Subjects

From the schools chosen, subjects were randomly selected from the list of students. One hundred and three (50 male and 53 female) subjects who met the inclusion criteria, aged 6-17 years, were recruited for the study. Ethical approval was obtained from the Department of Optometry, University of Benin, Nigeria. Permission was obtained from the Edo State Ministry of Health and the school headmaster and principal, respectively. Consent was sought from the parents, while each child gave assent to participate in the study. The study was conducted in accordance with the Declaration of Helsinki. The children were informed that they could decide not to participate in the study or withdraw at any time without punishment. They were also assured that the procedure was safe and would not pose any risk.

The right and left eye values for each of the amplitude of accommodation measurements (PU, PD, MLB, and MPU) were carried out only for children with emmetropia. All children went through eye examinations comprising the following:

Table 3. T-test to Determine the Difference between Each Measurement Procedure, including Hofstetter's Calculated Average Value (HOF AVE= Hofstetter's average)

Pair	Mean difference	Standard error	P	Lower bound	Upper bound
PU – PD	**0.19**	0.08	0.018	0.034	0.354
PU – MLB	0.87	0.10	< 0.0001	0.675	1.061
PU – MPU	0.81	0.11	< 0.0001	0.583	1.030
PD – MLB	0.67	0.08	< 0.0001	0.512	0.837
PD – MPU	0.61	0.10	< 0.0001	0.410	0.140
MLB – MPU	**-0.06**	0.10	**0.543**	-0.264	0.140
PU–HOF AVE	-1.83	0.22	< 0.0001	-2.255	-1.397
PD–HOF AVE	-2.02	0.20	< 0.0001	-2.407	-1.632
MLB–HOF AVE	-2.69	0.20	< 0.0001	-3.091	-2.297
MPU–HOF AVE	-2.63	0.19	< 0.0001	-3.008	-2.256

- distance and near visual acuity using the Snellen chart at far and N-notation card at 40cm
- cover test
- ocular health examination with a penlight and direct ophthalmoscopy to rule out any ocular disease
- non-cycloplegic static retinoscopy

Students with visual acuity of 6/6 or better and N5 in each eye at 6 m and 40 cm, respectively; those without an ocular deviation at 6 m or 40 cm; students without a refractive error in either or both eyes; and those with no history of ocular trauma, ocular disease, amblyopia, aphakia, or pseudophakia were included in the study. Using the retinoscope, subjects who had a spherical equivalent refractive error outside the range of +0.50DS to -0.50DS were also excluded from the study. All children were examined at school during school hours.

Examination

The AA measurements were carried out one eye at a time while occluding the other eye. The eye to be tested first

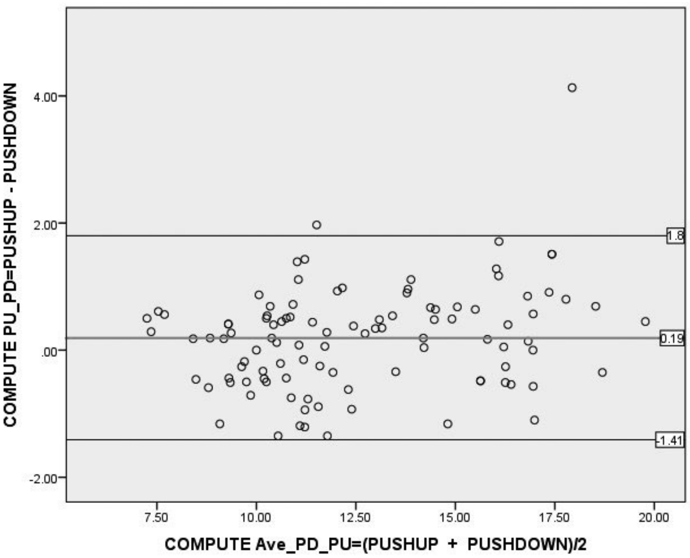

Figure 1. *Bland-Altman plot showing relationship between PU and PD method*

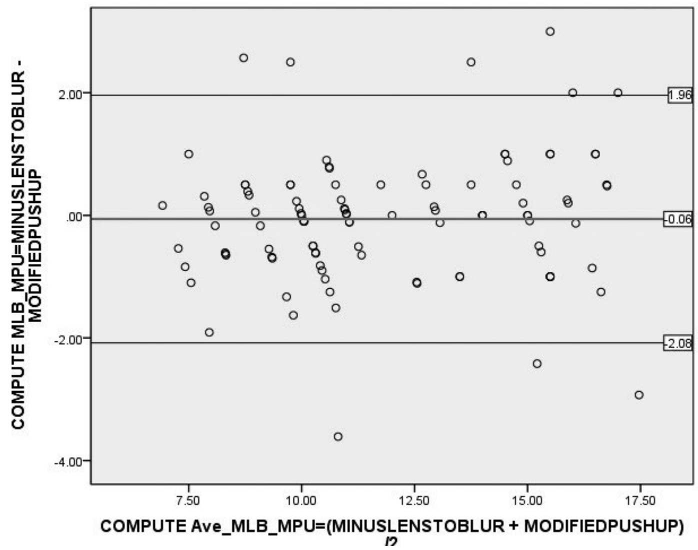

Figure 2. *Bland-Altman plot showing relationship between MLB and MPU methods*

was randomly selected. Measurements were carried out after demonstrating to each subject what the concept of blur was. They were performed in the same order as explained below. The procedures used were as follows:

Push-up-to-blur method

For this procedure, we presented a near target, which was the child's best near point visual acuity (VA) letter on the N-notation card at 40 cm. The print was moved gradually towards the child's eye until she noticed the first sustained blur. The distance between the blur point and the spectacle plane was measured using a meter rule and converted into diopters to give the AA.

Push-down method

This procedure is an inverse of the push-up-to-blur method. It required presenting the child's best near point VA letter on the N card, close to the face of the child (to the nose) and moving it gradually away until she could read the first letter on her best near point VA line. The distance between the spectacle plane and the point of clarity was measured and converted into diopters as the AA.

Minus-lens-to-blur method

This method required presenting the child's best near point VA letter on the N card at 33 cm and gradually increasing minus lenses before the child's eye until she noticed the first sustained blur. The amount of minus lens added before the eye plus the dioptric value of the target distance gave the AA.

Modified push-up-to-blur method

In this method, AA was measured using the PU technique through a minus lens power of 4.00DS. The amount of minus lens placed before the eye plus the dioptric value of the distance between the blur point and the spectacle plane gave the AA.[11]

Data Analysis

The data obtained was analyzed with the Statistical Package for Social Sciences (SPSS) version 21 software. A correlation analysis was initially used to compare results of the four techniques for the left and right eye. The paired t-test was used to ascertain any differences in results for each measured pair, at a 95% confidence interval. The Bland-Altman plot was used to determine the degree of agreement among the methods and thus ascertain whether each method can be used interchangeably. Using the paired t-test, the values obtained in each method were compared with those obtained using Hofstetter's equation for average AA.

Results

The study population was made up of 103 healthy children aged 6-17 years (mean age ± SD; 11.94 ± 3.61), comprising 50 males and 53 females. A correlation analysis was run among the different tests conducted for both eyes, and results showed a high correlation between results obtained for both eyes (<0.0001), hence results from only the right eye are presented. The mean and standard deviation for the different age groups, measurement technique, and Hofstetter's calculated average are given in Tables 1 and 2. An analysis using the t-test among all pairs showed a statistically significant difference except between the MLB and MPU methods. This finding is shown in Table 3.

Given that AA measurements are recorded to the nearest 0.25D, Bland-Altman plots showed that the PU and PD, as well as the MLB and MPU, methods gave a mean difference of less than 0.25; hence, these methods fairly agree and can be used interchangeably. The Bland-Altman plots are shown in Figures 1 and 2, respectively.

The paired t-test showed a significant difference between the values obtained in each method and that obtained using Hofstetter's equation for average AA ($P < 0.0001$).

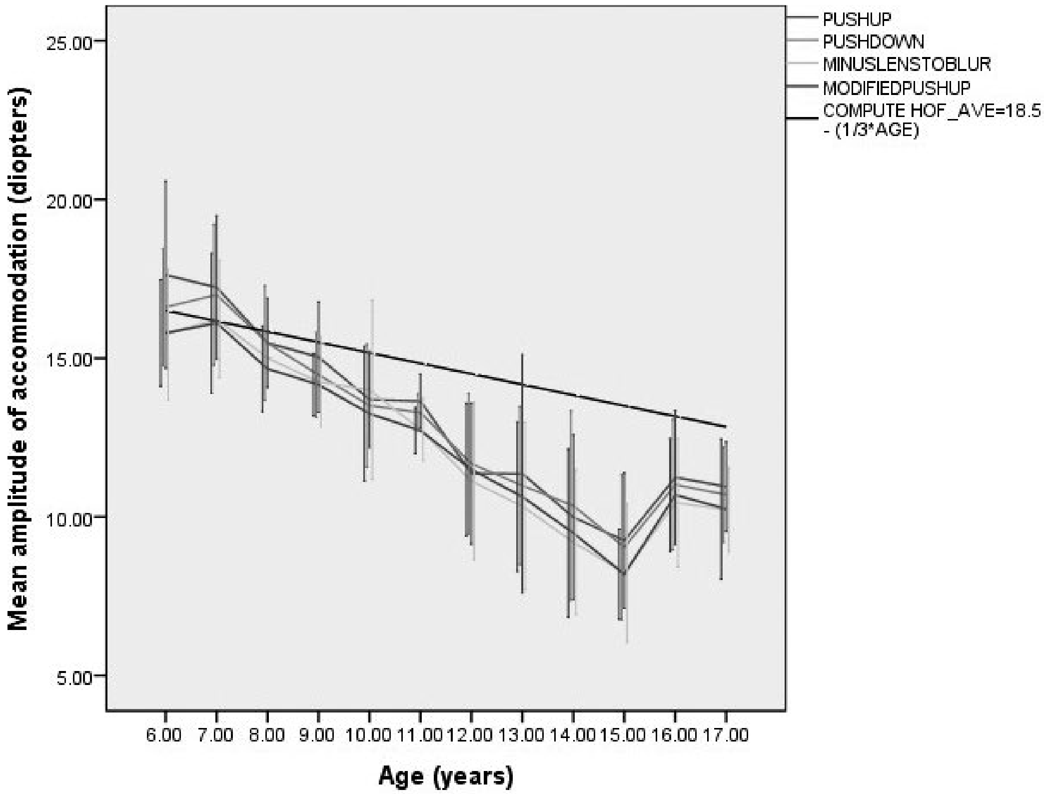

Figure 3. *Measured accommodative amplitude and Hofstetter's calculated average value (Error bars: +/- 2SD)*

The variations between age and the four methods of AA measurements as they relate to Hofstetter's average normative values are represented in Figure 3.

Discussion

This study showed that AA findings differ when four different subjective methods are used to measure, as has been reported in other studies.[12-18] Table 4 gives a summary of findings from other studies. The PU, which is the most commonly used method, gave higher values compared to other techniques. The results of this study also revealed that the minus lens to blur technique had the lowest measured amplitude among the different methods, which was in agreement with other studies.[12,13,15] The difference between these methods is attributed to the type of accommodative system stimulation. In the PU method, the effect of proximal accommodation contributes to the high AA value, as compared to the minus lens to blur, which involves a reduction of target size at a constant distance because of the optical properties of the concave lens. In this case, proximal accommodation does not come into play as noticed in the push up to blur method.[5]

From our study, it can be seen that the PU and PD averages each differed from the MLB average by almost 1.00D, closely relating to values found in previous studies.[13,14] This finding is lower than what some previous studies[12,14,15,18] reported, in which PU and PD averages differed from the MLB by a value of about 2.00D or more. One reason why this was so could be the different age group of subjects who participated. With children, apart from the speculation that their responses may not be accurate when measured subjectively,[7] it has also been proposed that the MLB may give more reliable results as age increases.[18]

Analysis between each pair showed that all groups of measurement differed statistically except the MLB and MPU pair. This finding is consistent with results obtained using the Bland-Altman plots, except with the case of the PU and PD pair. Despite the fact that the p-value indicates a significant difference in results obtained for PU and PD, our mean difference obtained was below 0.25. Several studies have reported conflicting results when PU and PD methods were compared. Some indicate a good agreement and no significant difference in results,[16,18] while others do not.[12,13,15,17] We however wish to highlight that since our mean difference of 0.19 falls below 0.25D, a value used to record AA measurements clinically, we can safely say that both methods can be used interchangeably. Although the studies highlighted used different statistical analysis methods and age groups, the similarity in the results points to the fact that the measurement procedures may be indeed similar, only differing in the direction of movement of the target, with PU measuring so-called positive accommodation (stimulation) while the PD measures negative accommodation (relaxation).

Furthermore, Momeni-Moghaddam et al.[12] reported a better agreement between the PU and PD methods than the MLB and the MPU methods. On the contrary, our study showed that the MLB and MPU agreed better. Despite this difference between the studies, which could have resulted

Table 4. Summary of Results Obtained from Previous Studies

S/N	Author(s)	Age range of subjects (years)	Number of subjects	AA average±SD (D)	Hofstetter's expected average (D)	Mean difference (D)
1	Momeni-Moghaddam et al[12]	18-25	52	PU: 11.21±1.85 PD: 10.92±1.69 MPU: 10.99±1.02 MLB: 9.31±1.61	-	PU-PD: 0.28 PU-MLB: 1.89 PU-MPU: 0.22 PD-MPU: -0.66 PD-MLB: 1.60 MPU-MLB: 1.67
2	Rosenfield and Cohen[13]	23-29	13	PU: 10.11±0.73 PD: 9.50±0.71 MLB: 9.10±0.73	-	PU-MLB: 1.01 PU-PD: 0.61 PD-MLB: 0.40
3	Kragha[14]	18-32	447	PU: 18-22yrs: 10.38±1.89 23-27yrs: 9.36±1.81 28-32yrs: 7.44±1.78 MLB: 18-22yrs: 9.18±1.77 23-27yrs: 8.13±1.70 28-32yrs: 6.52±1.81	-	PU-MLB 18-22yrs: 1.20 23-27yrs: 1.23 28-32yrs: 0.93
4	Antona et al[15]	18-32	61	PU: 13.08±2.79 PD: 11.25±1.77 MLB: 8.56±1.52	-	PU-PD: 1.83 PU-MLB: 4.52 PD-MLB: 2.69
5	Chen and O'Leary[16]	7-28	39	PU: R: 12.29±2.41 L: 12.85±2.61 MPU(PD): R: 12.06±199 L: 12.28±2.16	-	R: 0.23 L: 0.37
6	Koslowe et al[17]	7-35	79	PU: 13.55±3.67 PD: 11.05±3.68	-	-
7	Taub and Shallo-Hoffmann[18]	6-36	90	PU: 13.78±4.67 PD: 13.72±3.88 MLB: 8.41±3.01	Hof ave: 13.80±2.45	PU-Hof ave: -0.02 PD-Hof ave: -0.08 MLB-Hof ave: -5.44
8	Sterner et al[19]	6-10	76	PU R: 12.40±3.7 L: 12.50±3.8	-	PU-Hof ave R: -3.60 L: -3.50
9	Ovenseri-Ogbomo et al[20]	8-14	435	PU: 16.86±3.07	-	PU-Hof max: -3.69 PU-Hof ave: 1.67 PU-Hof min: 4.53
10	Ovenseri-Ogbomo and Oduntan[21]	6-16	688	PU: 15.88±3.46	Hof max: 20.34±0.88 Hof ave: 14.62±0.73 Hof min: 12.09±0.55	PU-Hof max: 2.16 PU-Hof ave: 1.26 PU-Hof min: -2.47

SD – standard deviation; Hof max – Hofstetter's maximum; Hof ave – Hofstetter's average; Hof min – Hofstetter's minimum; yrs – years; R – right eye; L – left eye

from the difference in age group, it is evident that each of these groups of methods could possibly be used interchangeably.

The PU and PD averages differ significantly from the MLB and MPU values; furthermore, the biases between each test pair were 0.87, 0.81, 0.67, and 0.61 respectively using the Bland-Altman plots (Table 3). These values are clinically significant since they are greater than 0.25D; hence, the PU and MLB, PU and MPU, PD and MLB, and the PD and MPU cannot be used interchangeably.

The difference between the measured AA in each technique and values obtained using Hofstetter's equation for average AA was found to be significant (P<0.0001). From our study, the measured AA values were lower than the average expected norm, as seen in another study among Swedish children.[19] This variation between values, however opposite, was similarly reported in the study by Ovenseri-Ogbomo et al.,[20] done to investigate the AA in Ghanaian school children using the push up to blur method. In their study, there were significantly higher values than the calculated average expected norms. However, one would expect that since their measured AA were lower than the maximum expected norms predicted by Hofstetter, maybe it would have been the same for average calculated values. If we consider that refraction to determine subjects with a refractive error was not done, this may have contributed to the difference in findings.

Looking closely at Figure 3, the PU and PD methods compared closely to Hofstetter's normative average values for younger children aged 6-7 years old. This finding was similar to that reported by Taub and Shallo-Hoffmann,[18] where among children aged 6-13 years, the PU and PD methods were not different from Hofstetter's normative calculated value, while the MLB varied significantly. In contrast, in another study,[19] measured AA values obtained using the PU method in children aged 6-10 years were lower than Hofstetter's calculated minimum expected values. The difference found in our results may be attributed to different sample size, age, race, and the fact that our studies used either minimum or average calculated value to compare results.

A striking observation in Figure 3 is the increase in AA from age 15 to 16 years. Irrespective of the method employed, this remarkable change in AA was observable ruling out the effect of measurement technique as the cause of this change. A cursory observation of the line graph further reinforced the fact that AA does not decline linearly with age as suggested by Hofstetter's equations, at least in children. The absence of linearity in AA in children has been reported by various investigators.[20-25]

It is evident that for children, the Hofstetter's average calculated age-expected value does not equate measured values using four different subjective methods as seen in previous studies.[19-21] It is imperative that we use the Hofstetter's equation with caution while working towards deriving an equation that can be applied to Nigerian children.

Conclusion

We conclude that in school children aged 6-17 years, the AA values using four subjective methods differ significantly among all methods except between the MLB and MPU methods. The PU gave the highest amplitude of accommodation, while the MLB resulted in the lowest measure. Given the agreement analysis, the PU and PD methods of measurement can be used interchangeably, and the MLB and MPU can also be used interchangeably. The Hofstetter's calculated normative values for average amplitude of accommodation were significantly higher than those obtained using the subjective techniques. These findings have clinical implications, as caution should be taken when making decisions on accommodative anomalies in school children in Benin-city, Nigeria.

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