

ESTABLISHING NORMATIVE VALUES FOR AMPLITUDE OF ACCOMODATION AND ACCOMODATIVE FACILITY AMONG UNIVERSITY STUDENTS IN MALAWI

ABSTRACT

Aim: The aim of the study was to examine the distribution of Accommodative Facility (AF) and Amplitude of Accommodation (AA) and compare the findings with established guidelines.

Place and duration of study: Mzuzu University, Malawi. Between May and July 2022.

Methods: This was a cross-sectional study conducted among students at Mzuzu university in Malawi. We recruited 77 undergraduate students using a stratified random sampling technique. The participants' age ranged from 16 to 35 years of age. We measured AA using the push-up method while AF was measured using +/- 1.50 Diopters (D) flippers. Both techniques utilized black reading material on white background held at 40 centimeters (cm). Next, we measured the accommodation facility by counting the number of Cycles per Minute (c/m). We utilized the Pearson correlation test and the One-way ANOVA where appropriate. The value of $p < 0.05$ was considered statistically significant.

Results: The participants comprised 44 (57.1%) males and 33 (42.9%) females. Monocular AA was 10.04D (SD=2.71) and Binocular AA was 10.51 (3.641). The difference was statistically significant ($p=0.04$). While Monocular AF and Binocular AF were 9 c/m (SD=SD=1.84) and 8.96 (SD=1.539) respectively but the difference was non-significant ($p=0.868$). According to sex, there was the difference in AF and AA were not significantly different between males and females. Based on age all the parameters decreased with age. The measured AA was significantly higher than the calculated AA using Hofstetter's formula.

Conclusion: The study provides a cut-off value for practitioners diagnosing Accommodation anomalies. However, let it be known that the indices in the study differ from the well-established guidelines hence practitioners should endeavor to perfume the clinical assessment instead of relying on equations.

Keywords: *push-up, Hofstetter's Equation, Orthoptics, Amplitude of Accommodation, Accommodative Facility, near vision.*

1. INTRODUCTION

The commonest visual disorders among young people are refractive errors and accommodative anomalies [1]. These can lead to symptoms such as blurred vision and double vision [2]. In particular, accommodation is part of the visual efficiency system, [3] hence normal binocular vision comprises an interplay between accommodation and vergence systems [4].

Specifically, Accommodation refers to the change in refractive power of the eye to focus image at the retina for various distances [4]. Clinically, Amplitude of Accommodation (AA) is the hallmark sign for diagnosing Accommodative Insufficiency, whereas, Accommodation Facility (AF) is used to diagnose Accommodative excess, insufficiency, and in the facility. The classroom environment acts as a predisposing factor for these conditions [3]. such, Students experience these symptoms more often than any other group because of the high demand for near work [5]. Accommodation anomalies mainly occur as an inappropriate response to visual demand leading to poorly sustained bi-foveal fixation [3].

Accommodation is affected by various factors eg methods of measurement, refractive status, and accommodation stimulus [6]. Moreover, age, ethnicity, sex, and race are known variables for the accommodation parameters [7]. As such, controversial results have been reported from different studies based on techniques and different study populations across and within continents [7].

Worldwide one of the commonest methods of assessing Accommodative Anomalies (BVA) involves the comparison of normative data based on studies conducted in Caucasian and Asian settings [8]. For instance, the most notably used normative data used for AA is adopted from Donder's and Duane's experiment using the Hofstetters rule[9]. However, there is a large discrepancy between normative data for accommodation parameters due to variations in measurement technique and differences in the study population [9]. Furthermore, although the Hofstetters formula is accurate for predicting maximum and minimum AA, numerous studies have questioned the accuracy for predicting average AA but it is still regarded as the guideline for prescribing presbyopia in many populations [10].

Previous studies established normative data for different geographical settings. [11, 12,13]. In Africa, authors have established normative databases for a few countries such as South Africa, Ghana, and Nigeria [7]. To the best of our knowledge, there is no normative data available for the Malawian population. Hence, the aim of the study is to investigate the distribution of accommodative parameters among university students in Malawi and compare it with the established clinical guideline. The university population is of interest since it represents a high-risk population due to a lot of near work. Prolonged near tasks could predispose students to accommodative problems and the symptoms can affect academic performance [3]. The results of the study can aid practitioners in the country in diagnosing non-strabismus visual anomalies among a similar age group[9].

2. MATERIAL AND METHODS

2.1 Study Design

This cross-sectional study was conducted among Mzuzu university students. As an inclusion criterion, we recruited subjects aged 16 to 35 years. Moreover, we included those with visual acuity of 6/6 in both eyes and participants with AA of at least 5 Diopters (D) [2]. Besides, we

excluded all those taking medications, those with a history of ocular surgery, and those with ocular conditions such as strabismus and amblyopia.

We employed a stratified random sampling method to select participants. The population was stratified by faculty and the number of participants from each faculty was calculated as a proportion of the total population. Then, we randomly selected participants from each stratum.

2.2 Procedure

Prior to the task, all the subjects underwent a comprehensive eye evaluation to determine their eligibility for participating in this study. These tests comprised of the following; Snellen visual acuity at 6 meters and near visual acuity at 40cm, cover test, slit-lamp examination, and direct ophthalmoscopy. We conducted the procedures in a standard room illumination free from distraction [14]. The distance was monitored regularly by an observer. Reading material consisted of text with black letters displayed on a white background and had a font size of N6 [15]. For monocular measurements, only the participant's right eye was included. The parameters were measured by one examiner and each measurement was conducted thrice with the average considered the final reading. Furthermore, we collected demographic data including age and sex. Next, we recorded age into age groups (16-20, 21-25, 26-30,31-35).

2.21 Amplitude of Accommodation

AA was measured using the push-up-to-blur method [13]. The measurements were converted from Centimeters to Diopters (D).

2.22 Accommodative Facility

AF refers to the ability to flexibly focus a variety of viewing distances [16]. In this review, we measured AF using +/- 1.50 D flippers [15].

2.3 Analysis

We entered the data into Microsoft Excel 2016 and Statistical Package for the Social Sciences (SPSS) version 20. Age and sex were analyzed by means of descriptive statistics (mean, standard deviation, frequency, and percent). Next, we illustrated the data diagrammatically using tables. Furthermore, an independent t-test was executed to compare means between males and females. Additionally, we used paired t-tests to compare Monocular and binocular AA. The association of age and accommodative indices was analyzed using a One-way ANOVA. We considered the value of $p \leq 0.05$ statistically significant.

2.4 Ethics

The Mzuzu University Faculty of Health Sciences Research Committee approved our study. Furthermore, the study adhered to the declaration of Helsinki, as such we obtained informed consent from each participant. In addition, we maintained confidentiality by keeping all participants anonymous.

3. RESULTS AND DISCUSSION

3.1 Demographic characteristics

Out of the 77 participants, 44 (57.1%) were male and 33 (42.9%) were females (N=77). The mean age was 25.34 years (SD=5.440). According to gender, the mean age was 25.18 years (SD=5.397) among males and 25.55 years (SD=5.574) among females. An independent t-test depicted that the difference in age with respect to gender was not significant statistically ($t(75) = -0.289, p=0.986$). The commonest age group was 22-28 years accounting for 37 (48.1%) of the participants. (Table 1)

Table 1. Distribution of age group

Age group (years)	Frequency	Percent
16-20	16	20.8
21-25	28	36.4
26-30	18	23.4
31-35	15	19.5
Total	77	100.0

3.2 Baseline Parameters

On average, Monocular AA was 10.04D (SD=2.71) and Binocular AA was 10.51D (3.641). A paired t-test showed that the mean difference between binocular and monocular AA was statistically significant ($t(76) = -2.048, p=0.04$). The mean Monocular AF and Binocular AF were 9 c/m (SD= SD=1.84) and 8.96 c/m (SD=1.539) respectively, but the difference was not significant statistically ($t(76)=0.167, p=0.868$).

3.3 Distribution of Accommodation parameters according to sex

According to sex, MAF was 9.07 c/m (SD= 1.860) among males and 8.91c/m (SD=1.843) among females. An independent t-test indicated that the difference between sex was not statistically significant ($t(75)=0.373, p=0.899$). Whereas MOA was 9.966D (SD=2.8074) among males and 10.148 (SD=2.6139) among females. An independent t-test showed that the mean difference in MOA between sex was not significant statistically ($t(75)=-0.291, p=0.715$). Likewise, Binocular AA was 10.193 (SD=2.7356) and 10.939 (SD=4.5947) among males and females. An independent t-test showed that statistically there was no significant difference ($t(75)=-0.889, p=0.304$).

3.4 Distribution of parameters according to age

According to age, one-way ANOVA showed that all parameters decreased significantly with advancing age. (Table 2).

Table 2 Distribution of accommodation parameters with age group

Accommodation	Age group				P value
	16-20	21-25	26-30	31-35	

parameters					
Monocular AA (diopters)	12.02 ± 2.7064	10.571±2.3829	9.583±2.4327	7.500±1.2790	<0.001
Binocular AA (diopters)	13.675±5.8579	10.525±2.1143	9.961±2.1316	7.780±1.1239	<0.001
Monocular AF	9.75±2.082	8.86±1.779	9.56±1.381	7.80±1.656	0.01
Binocular AF	9.38±1.962	8.64±1.367	9.67±1.188	8.33±1.397	0.03

3.5 Comparison between measured and calculated AA

In general, the difference between measured AA and calculated AA (43.3D) was significant for both Monocular(41.0D) and binocular AA(41.0D). Moreover, all groups had a lesser magnitude of AA compared to the expected AA determined by Hofstetter's equation. An exception was 16-20 for the binocular AA which was higher than the expected AA according to the formula. (Table 3)

Table 3.

Age distribution of measured AA and Hofstetter's average AA

Age	Measured Monocular AA (D)	Measured Binocular AA (D)	Average AA as determined by formula $18.5-(0.3 \times \text{Age})$
16-20	12	13.7	13.1
21-25	10.6	10.5	11.6
26-30	9.6	10	10.1
31-35	7.5	7.8	8.6
Total	39.7	41.0	43.4

4. DISCUSSION

In our study, Binocular and monocular AA were significantly different in contrast to previous reports [9]. We attribute the difference to methods of measurement. Apparently, Abraham et al., 2015 used a minus lens technique to measure AA while this study employed the push-up method of measurement. The results of our study are not surprising considering the effect of accommodative vergence, which manifests binocularly. Our study highlights the importance of measuring AA in both monocular and binocular settings.

The magnitude of AA in this study was similar to previous reports in South Africa [17]. However, it was lower than reported in Nigeria [13]. We attribute the difference to ethnicity and geographical position. Accordingly, previous studies have noted variations among different population groups [7]. Similar to previous results, [9,11,12] our study found that AA decreased significantly with age. Accordingly, AA decreases with age as a physiological process that is inevitable, irreversible hence regarded as normal [18]. According to sex, AA was not significantly different between males and females. In contrast, others [3] found that females have reduced AA compared to males. on the other hand, Nigeria [10] reported that males had higher AA than their age-matched female counterparts. Again differences in geographical setting can explain the discrepancies among the studies.

As previously noted, the average AA in our study was in disagreement with the data suggested using Hofstetter's equation [9]. Specifically, the formula overestimated the value of AA for the study group. In contrast, studies in Nigeria found that the pushup method did not differ from Hofstetter's expectation [10,19]. Nevertheless, In Iran [5] found that the equation generated a lower value among a young age group but it overestimated AA among older subjects beyond 30 years. Apparently, Hofstetter's equation has been discovered that correctly identifies accommodation measured using push-up methods [7]. The results of our study can be attributed to the differences in race and ethnicity [20].

In our study, AF was similar to a previous study in South Africa, [3] and Iran [11]. However, it is lower than reported in India [1]. We attribute the differences to differences in age composition among the studies. Hussaindeen and colleagues [1] recruited a younger age group of 7 to 17 years compared to the 16 to 35 recruited in our study. Apparently, AF is difficult and becomes invariably difficult for younger children to comprehend [3].

In our study AF decreased with age similar to previous studies [3,21] In contrast, others [1] found that AF increased with age among 7 to 17-year-olds. Again, we attribute our study results to the age composition which excluded younger participants AF.

Limitations

The study was not without drawbacks. First, using means as norms does not consider outlier variability within the dataset. In addition, participants in our review were not assessed for refractive errors which could pose a confounding factor. Moreover, we measure AA using a subjective technique that does not measure the true accommodative value. Furthermore, the study was conducted among a narrow age range as such cannot be generalized to children and the elderly.

Conclusion

The study has established the norms for AA and AF that can be used as a reference for practitioners diagnosing non-strabismic binocular visual anomalies among the study population. Additionally, our study affirms the previous assertion that AA predicted with Hofstetter's equation is inaccurate and highlights the significance of clinical assessment over Hofstetter's formula.

CONSENT (WHERE EVER APPLICABLE)

We obtained informed consent.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

We confirm that the authors have obtained all necessary ethical approval from suitable Institutional Committee.

REFERENCES

1. Hussaindeen JR, Rakshit A, Singh NK, Swaminathan M, George R, Kapur S, Scheiman M, Ramani KK. Binocular vision anomalies and normative data (BAND) in Tamil Nadu: report 1. *Clin Exp Optom*. 2017 May;100(3):278-284. doi: 10.1111/cxo.12475. Epub 2016 Oct 30. PMID: 27796049.
2. Narawi et al., 2020. The Effect of Smartphone Usage on Accommodation Status
3. Wajuihian SO. Normative values for clinical measures used to classify accommodative and vergence anomalies in a sample of high school children in South Africa. *J Optom*. 2018;12(3):143–160. <https://doi.org/10.1016/j.optom.2018.03.005>
4. Kang, J.W., Chun, Y.S. & Moon, N.J. A comparison of accommodation and ocular discomfort change according to display size of smart devices. *BMC Ophthalmol* 21, 44 (2021). <https://doi.org/10.1186/s12886-020-01789-z>
5. Hashemi H, Pakbin M, Ali B, Yekta A, Ostadimoghaddam H, Asharlous A, Aghamirsalim M, Khabazkhoob M. Near Points of Convergence and Accommodation in a Population of University Students in Iran. *J Ophthalmic Vis Res*. 2019 Jul 18;14(3):306-314. doi: 10.18502/jovr.v14i3.4787. PMID: 31660110; PMCID: PMC6815340.
6. Kaphle D, Varnas SR, Schmid KL, Suheimat M, Leube A, Atchison DA. Accommodation lags are higher in myopia than in emmetropia: Measurement methods and metrics matter. *Ophthalmic Physiol Opt*. 2022 Sep;42(5):1103-1114. doi: 10.1111/opo.13021. Epub 2022 Jul 1. PMID: 35775299; PMCID: PMC9544228.
7. Darko-Takyi C, Moodley VR, Boadi-Kusi SB. A review of normative data for parameters of functional non-strabismic binocular vision. *Afr Vision Eye Health*. 2020;79(1), a507. <https://doi.org/10.4102/aveh.v79i1.507>
8. Yammouni R, Evans BJW. Is reading rate in digital eyestrain influenced by binocular and accommodative anomalies? *J Optom*. 2021 Jul-Sep;14(3):229-239. doi: 10.1016/j.optom.2020.08.006. Epub 2020 Oct 25. PMID: 33115619; PMCID: PMC8258174.
9. Abraham NG, Srinivasan K, Thomas J. Normative data for near point of convergence, accommodation, and phoria. *Oman J Ophthalmol*. 2015 Jan-Apr;8(1):14-8. doi: 10.4103/0974-620X.149856. PMID: 25709268; PMCID: PMC4333536.
10. Akujobi AU, Vincent CL, Ekenze CJ, Obioma-Elemba JE, Vincent CC. Assessment of amplitude of Accommodation (AA) in Owerri Municipal Council, Southeast, Nigeria. *W J*

Ophthalmol & Vision Res. 1(2): 2018. WJOVR.MS.ID.000509.
<http://dx.doi.org/10.33552/WJOVR.2018.01.000509>

11. Yekta A, Khabazkhoob M, Hashemi H, Ostadimoghaddam H, Ghasemi-Moghaddam S, Heravian J, Doostdar A, Nabovati P. Binocular and Accommodative Characteristics in a Normal Population. *Strabismus*. 2017 Mar;25(1):5-11. doi: 10.1080/09273972.2016.1276937. Epub 2017 Jan 17. PMID: 28095087.
12. Yekta A., Hashemi H., Ostadimoghaddam H., Jafarzadehpur E., Salehabadi S., Sardari S., Norouzirad R., Khabazkhoob M. Amplitude of accommodation and add power in an adult population of Tehran, Iran. *Iranian Journal of Ophthalmology*. 2013;25(3):182–189.
13. Ugwoke, G.I., Esenwah, E.C., Ikoru, N.C. et.al. Effects of ingested fresh palm wine on pupil diameter and amplitude of accommodation in young adults. *Int J Health Sci Res*. 2021; 11(9): 203-208. DOI: <https://doi.org/10.52403/ijhsr.20210932>
14. Park M, Ahn YJ, Kim SJ. Changes in accommodative function of young adults in their twenties following smartphone use. *J Korean Ophthalmic Opt Soc* 2014; 19: 253–260. <http://dx.doi.org/10.14479/jkoos.2014.19.2.253>
15. Padavettan C, Nishanth S, Vidhyalakshmi S, Madhivanan N, Madhivanan N. Changes in vergence and accommodation parameters after smartphone use in healthy adults. *Indian J Ophthalmol*. 2021;69(6):1487-1490. doi:10.4103/ijo.IJO_2956_20
16. Jaiswal S, Asper L, Long J, Lee A, Harrison K, Golebiowski B. Ocular and Visual Discomfort Associated with Smartphones, Tablets and Computers: What we do and do not know. *Clinical and experimental optometry* 2019; 102. Doi:10.1111/cxo.12851
17. Mathebula SD, Ntsoane MD, Makgaba NT, Landela KL. Comparison of the amplitude of accommodation determined subjectively and objectively in South African university students. *Afr Vision Eye Health*. 2018;77(1), a437. <https://doi.org/10.4102/aveh.v77i1.437>
18. Khan, Sumera, et al. "Hofstetter's equations overestimate the amplitude of accommodation in human eye: An analyses of 5433 subjects." (2022).
19. Emmanuel K Abu, Stephen Ocansey, Joseph Yennu, Isaac Asirifi & Richmond Marfo (2018) Comparing Different Methods of Measuring Accommodative Amplitude with Hofstetter's Normative Values in a Ghanaian Population, *Current Eye Research*, 43:9, 1145-1150, DOI: 10.1080/02713683.2018.1480044 . <https://doi.org/10.1080/02713683.2018.1480044>
20. Hashemi H, Nabovati P, Khabazkhoob M, Yekta A, Emamian MH, Fotouhi A. Does Hofstetter's equation predict the real amplitude of accommodation in children? *Clin Exp Optom*. 2018 Jan;101(1):123-128. doi: 10.1111/cxo.12550. Epub 2017 May 17. PMID: 28514829.
21. Zakian A, Heydarian S, Mirzajani A, Jafarzadehpur E, Yekta A, Khabazkhoob M. Distribution of near Point of Convergence, near Point of Accommodation, Accommodative Facility and Refractive Errors in a Rural Population Living in Northern Iran. *J Binocul Vis*

Ocul Motil. 2021 Jul-Sep;71(3):104-109. doi: 10.1080/2576117X.2021.1927291. Epub 2021 May 25. PMID: 34032560.

UNDER PEER REVIEW