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Research Article

The Comparison of Subjective and Objective Clinical Methods of Assessing Amplitude of Accommodation

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Abstract

This research was carried out to compare the subjective and objective clinical methods of assessing the Amplitude of Accommodation (AA). A total of 109 university students, (54 males and 55 females), with mean age of 20.2 ± 4.3 years were selected randomly. The subjective AA was measured using the push-up to blur method and minus-lens to blur method, while the objective AA was measured using the modified dynamic retinoscopy method. A test of reliability (Z test) showed that there is a statistically significant difference between the mean AA measured using push-up to blur method and minus-lens to blur method, push up to blur method and modified dynamic retinoscopy, minus-lens to blur method and modified dynamic retinoscopy with Z-calculated value of (12.9), (27.5) and (15.0) respectively. Analysis of variance at P = 0.05 level of significance showed that there is a statistically significant difference in the mean AA measured using push-up to blur method, minus-lens to blur method and modified dynamic retinoscopy with age (P-value<0.05). Also, analysis of variance at P = 0.05 level showed that there is no statistically significant difference in the mean AA measured using push-up to blur method, minus-lens to blur method and modified dynamic retinoscopy with gender with (P-value >0.05). The push-up to blur method gave the highest mean AA with 11.8 ± 2.4D followed by minus-lens to blur method and modified dynamic retinoscopy with 8.2 ± 1.9D and 5.2 ± 0.8D respectively. The subjective push-up to blur method overestimates the AA. This may affect its accuracy. The study highlights the need for more reliable AA measurement.

Keywords: Amplitude of Accommodation; Push-up-to blur; Minus-lens-to blur; Accommodation

Introduction

Accommodation refers to a temporary change in the refractive power of the crystalline lens resulting from contraction of the ciliary muscles thereby altering the location of the point in space optically conjugate with the retina [1]. This change in the refractive power enables the eye to change focus from a distant target to a closer object of regard. Accommodation is quantified in diopters (D) and in the case of an emmetropic patient, the accommodative stimulus when viewing a near object is simply the reciprocal of the target distance in meters (m). Therefore, when viewing an object at distance of 25cm, the accommodative stimulus is 1/0.25 = 4.0D [1].

Tests for accommodation

Clinically, the two primary tests for accommodation are the Amplitude of Accommodation, which is an assessment of the patient's maximum accommodative ability and measurement of accommodative response for a specific stimulus demand. Patients with reduced accommodative ability (most commonly due to presbyopia) will require a corrective lens to enable them to see clearly at near. Other clinical tests examine the interaction of the accommodation and vergence systems including assessment of relative accommodation and accommodative facility, as well as qualifying the cross-link ratios between these two functions i.e. Accommodative convergence to accommodation (AC/A) and convergent accommodation to convergence (CA/C) [2,3].

Accommodation versus Pseudo-accommodation

There is an important fundamental distinction between accommodation (i.e. The optical change in the power of the eye) and the ability of a distance corrected eye to see at near. Functional near vision in a presbyopia can be achieved through a variety of non-accommodative means such as multifocal contact lens, a multifocal intraocular lens or corneal multifocality. All of these approaches afford functional near vision through various static optical mean; however, they are clearly not accommodation. The apparent ability of some distance - corrected pseudophakic patients with fixed focal length, monofocal intraocular lenses to see at near has been called apparent accommodation or pseudo accommodation [2,4].

Pseudo accommodation facilities functional near vision, not through a change in optical power, but through an increased depth of field of the eye. An increased depth of field of the eye can be due to Ocular aberration such as astigmatism, spherical aberration, or higher order aberrations. The decrease in pupil diameter that accompanies accommodation also acts to increase the depth of field of the eye. This increase in depth of field occurs because the pupil constriction causes a decrease in the diameter of the cone of light that passes from the lens to focus on the retina. Decreasing the pupil size decreases the size of the blur circle on the retina and increases the distances over which no change in image focus can be detected [2,4].

Although an increased depth of focus provides a range of object distances over which no change in retinal image focus can be detected, this is clearly not accommodation [2-4].

Amplitude of accommodation (A.A.)

- The far point of accommodation is the point conjugate with the retina when accommodation is fully relaxed.
- The near point of accommodation is the point conjugate with the retina when accommodation is fully exerted.
- The Amplitude of accommodation is the dioptric distance between the far point and the near points of accommodation.

Accordingly, the amplitude may be calculated as the dioptric value of the far point minus the near point. If the far point of accommodation is located at optical infinity, then the amplitude of accommodation will simply be equal to the near point of accommodation or the reciprocal of the closest distance (in meters) at which distinct vision can be obtained. When measuring this parameter clinically, it simplest to measure the near point after the subject's refractive error has been fully corrected, thereby placing the far point at or close to the right eye [3-5].

The detection and management of common refractive conditions such as latent hyperopia as well as presbyopia are frequently assisted by the assessment of the amplitude of accommodation and according to Burns., *et al*. (2014), the clinical relevance of this measurement will extend to include the evolution of accommodating intraocular lenses [5]. Also, some conditions that are either pathological, recreational, or prescribed (medications) can influence accommodation and can be detected through the assessment of the Amplitude of Accommodation in routine clinical practice [5].

Factors affecting amplitude of accommodation

The magnitude of this parameter is affected by several factors such as whether the test is performed monocularly or binocularly, gaze angle, underlying refractive error, the patient's racial characteristics, the size of the target, age, adaptation to sunlight, visual and ocular comfort, intraocular pressure, down syndrome, alcohol consumption, premature birth, time of the day and systemic medications. The significance of these factors is difficult to determine or establish due to limitation encountered in the accuracy of the measurement of Amplitude of Accommodation [5].

Why measure amplitude of accommodation?

Measurement of amplitude of accommodation is a recommended component of a routine clinical eye examination. The detection and management of common refractive conditions including presbyopia and latent hyperopia are frequently assisted by determining amplitude of accommodation. The clinical relevance of amplitude of accommodation will extend to evaluate the evolution of accommodating intraocular lens (IOL) [5,6].

Some pathological conditions and recreational and prescribed medications can influence accommodation this can be detected through the measurement of Amplitude of Accommodation in routine clinical practice.

The increased use of small display screen devices such as smart phones is associated with higher levels of accommodation than conventional near-vision tasks [6]. Analysis for visual efficiency for such work would require precise measurement of amplitude of accommodation because the visual task may require maximal levels of accommodation.

Methods of determining amplitude of accommodation

There are five methods of routine clinical measurement of amplitude of accommodation, (push-up, push-down or pull-away, push-down to recognition, minus lens, dynamic retinoscopy), with four of these being completely subjective. Retinoscopy is partly objective as it relies only on the clinician's interpretation of the reflex. Fully objective clinical measurement is possible. Using an open view auto-refractor, but they are not yet widely used in optometric practice and are pupil size dependent [7].

Push up

The push up method is Ubiquitous; the commonest and simplest clinical technique to measure amplitude of accommodation. In this method, the patient optically corrected for distance vision, views a detailed test object approaching the eye and reports when there is the first slight sustained blur [1]. The test object is then said to be at the eyes' near point and its distance to the eye is measured. The measurement (in meters) is converted to its reciprocal to provide the amplitude of accommodation in diopters. This method often using an instrument known as RAF Rule, is well established in clinical practice and research. However, it has several sources of error.

Push Down/pull-away

This method can be considered as a variation on the push up method in this initial description the test object is moved away from the eye until the patient reports when it first becomes clear. Rosenfield (2009) have recommended averaging its results with the push up method [1,7,8].

Push down to recognition

This is similar to the push down method except that the end - point is when the patient first recognizes a target as it is moved away from the eye. It has been termed the modified push up method, but that term has not been widely used.

This method would be simpler for the patient because it requires the resolution of an object which may be easier than discerning clarity. The three methods so far described can all be measured under monocular and binocular conditions [5,7,8].

Minus lens

In this method, negative spherical lenses are added to the distance refractive correction until the subject cannot maintain the initial acuity at a preset viewing distance. The amplitude accommodation is given by the maximum negative lens power added while the patient maintains focus. This method, which is facilitated by using a refractor head (phoropter), should only be used under monocular conditions because it results in an excess of accommodative convergence which would be likely to disrupt binocularity [1].

Dynamic retinoscopy

In this technique, one of the methods described above is employed to induce accommodation (push-up or negative lenses) but the practitioner determines the end point by observation of the retinoscopic reflex. It requires skilled judgment by the practitioner, which may explain why it is described less often than other methods. Only monocular measurement can be made, although conditions can be monocular or binocular [7].

Sources of error in measurement of Amplitude Accommodation.

The sources of error in measurement of amplitude of accommodation are relevant because such knowledge will help to improve accuracy. The sources of error are also likely to have influenced published normative values [5].

Depth of focus

Depth of focus affects all methods of measuring amplitude of accommodation. The depth of focus error may increase with accommodation owing to pupillary constriction and because the angular size of the target will increase with proximity [1]. The magnitude of error from depth of focus is influenced by target parameters (luminance, sharpness, contrast, shape, and size), the observer's ability to perceive blur and pupil size. Pupil size changes with illumination, mental effort, accommodation itself and many other diverse influences. Error due to depth of focus also varies with the method of measuring amplitude of accommodation [7].

Reaction time

Reaction time is a source of error that influences all three of the methods that involve movement of the target. It is the sum of four reaction times that occur consecutively as the test object moves past the point where noticeable blur first occurs. The four reaction times are the time it takes for the patient to register definite blur, to vocalize this, for the examiner to register that message and then for the examiner to stop the movement. The error can be limited by reducing target velocity, but slower rates of change may make the end- Point harder to discern. Reaction time may influence push-up (detecting blur) differently to pull-away (detecting clarity) and may also influence the minus lens method if the lenses are changed fast enough [1,7].

Reference point for measurements

This affects amplitude of accommodation test methods in which a distance is measured. It has been measured to 14mm in front of the age [9], the spectacle plane [8]; the eye [10]; corneal plane [11]; and 7mm behind the anterior corneal pole [12]. Different reference points produce greater error at higher levels of amplitude of accommodation for example, if an eye had amplitude of accommodation of 3D measured to Donders' reference point, Duane would have recorded it as 3.2D. But 10D by Donders becomes 12.66D by Duane [7].

Instrumentation errors

Factors specific to the RAF rule include ambiguity about the position of the slider's index on the scale and uncertainty about the location of the scale's zero point. There is further uncertainty concerning the relevance of the zero point, due to interindividual variations in facial anatomy. A small error may occur when comparing binocular with monocular conditions owing to monocular measurements lying on one eye's visual axis, whereas binocular measurements are taken on the mid-line [7].

Practitioner bias

This is a source of error in any measurement that is not fully automatic. The practitioner examining the patient will expect approximately where the measurement endpoint should be that expectation, and inevitable differences in technique between practitioners, may influence how the measurement is taken (e.g. target speed) which may in turn influence the result. It may affect naive patients more [7].

Errors specific to dynamic retinoscopy

Dynamic Retinoscopy is typically conducted at a closer working distance than static retinoscopy and this will reduce its precision. The reliability of retinoscopy decreases when measuring away from the visual axis, which can occur dynamic retinoscopy [13].

Anomalous proximal cues

Heath (1956) proposed that accommodative effort is driven by three signals: retinal, convergence and psychological. One psychological factor that influences accommodation is awareness of the test object's nearness (proximal accommodation), which has been found to be significant. The minus lens method is an unnatural method of assessing accommodation, giving lower results because the proximal cue is avoided or reduced whilst accommodation is stimulated [14,15].

Normative values of amplitude of accommodation

Some of the key studies that provided normative values of AA at different ages are summarized in table 1 below. The most cited reference values for the normal range of AA are those of Duane (1922). In optometry reading, Donders and Duane are the most quoted reference values for AA. Duane's sample size was more than 30 times that of Donders (1864). A large sample size improves reliability and may give more information when analyzed statistically [7,9,12].

Methodological limitations are often apparent in older work, and this may explain the common reporting of curiously stable and clinically substantial residue of accommodation never lost to age.

Methodology developed and it is now generally accepted that most people have completely lost the ability to accommodate just after age 50 [7,16].

Statement of problem

The amplitude of accommodation is an important clinical parameter used to measure /determine the maximum amount of accommodation that can be exerted by an individual. The AA measured subjectively provides important information about the AA, but they do not accurately measure the accommodative optical change that occurs in the eye. Studies demonstrate that the sub-

Table 1: The key studies that included population data on Amplitude of Accommodation Retrieved from Burns., *et al*. (2014).

Author	Year published	Method	Number of eyes or subjects	Subject's age (yrs)	Main factors that may affect reliability
Donders	1864	Push up	130 subjects	10 - 80	No assessment of refractive error
Kaufmann	1894	Push up	400 eyes of all subjects	5 - 74	No assessment of refractive error
Jackson	1907	Push up	Most eyes of 3346 subjects	5 - 70	Retrospective, some refractive error assessment
Sheard	1920	Minus-lens	Several hundred eyes	15 - 40	Object at 33cm
Duane	1922	Push up	Most eyes of about 4000 subjects	8 - 72	
Jackson	1922	Minus lens	Unknown	10 - 65	Binocular
Clarke	1924	Push up	Most eyes of over 5000 subjects	10 - 65	Retrospective, used Duane's method
Coates	1955	Push up	3171 eyes of about 1700 subjects	10 - 80	Retrospective, no assessment of refractive error
Jurner	1958	Push down	About 1000 eye of about 500 subjects	10 - 75	Retrospective
Ayishure Study circle	1964	Push up	1,307 subjects	30 - 75	Limited details of methodology
Fitch	1971	Push up and Push down	110 subjects	13 - 67	
Anderson., *et al*.	2008	Auto refraction and minus lens	140 eyes	3 - 40	

jective methods overestimate the true AA of the eye because of depth of focus, target size, illumination end point cues, pupil size and subject variability. Objective tests of the AA can possibly differentiate true AA from pseudo-accommodation or other possible confounding factors.

Aims and Objectives

To compare the subjective and objective clinical methods of assessing the amplitude of accommodation.

- To determine if the subjective AA has age or gender variation.
- To determine if the objective AA has age or gender variation.
- To establish a relationship if any, between subjective and objective AA findings.

Scope of study

The research will be carried out in the optometry clinic in Abia State University, Uturu, on one hundred human subjects comprising of both sexes.

Materials and Methods

Ethical Consideration

Written informed consents were obtained from the subjects as the research was on healthy human subjects. Also, consent for access to the instruments used for this research was obtained from the Head, Department of Optometry, Abia State University, Uturu.

Research design

This research was designed to be a prospective study to compare the subjective and objective clinical methods of assessing the amplitude of accommodation.

Population of study

The study population is made up of 150 students in the department of optometry, Faculty of health sciences, Abia State University, Uturu, who were healthy and had their best corrected visual acuity equal or better than 6/6 and N.6.

Sample and Sampling techniques

The sample size was determined using the Slovin's (1960) formula which is as follows:

$n = \frac{N}{1 + Ne^2}$

Where: n = the sample size $n = \frac{150}{1+150\ (0.05)^2}$

N = Population size

e = Margin for error $\frac{150}{1 + 150 \times 0.0025}$

1 = Constant

$\frac{150}{1 + 0.375}$

$\frac{150}{1.375} = 109.09 = 109$

Thus, from the population of 150 students in the department of optometry, Abia State University, Uturu, a sample size of 109 subjects were selected with a margin of error 5%. The random sampling technique was used to select the 109 subjects.

Research instruments

The instrument and materials used of the research include:

- Pen torch (Riester): This was used for the examination of the eyes and its adnexa.
- Occluder: This was used for the unilateral cover test.
- Pupillary distance rule.
- Ophthalmoscope (Keeler): This was used for thorough examination of the anterior and posterior segments of the eyes.
- Distance Snellen's chart.
- Rayner's near vision test card.
- Trial lens case
- Retinoscope (Keeler): This was used for objective refraction without cyclopegia and dynamic retinoscopy.
- Phoropter head.

Validation and reliability of the instruments

Reliability refers to the degree to which an assessment tool produces stable and consistent results. Reliability of the research instrument used in this study was ensured by performing test and retest for each eye and obtaining the average value. The values obtained were consistent and repeatable for each test. Validity refers to how well an instrument or procedure measures what it is supposed to measure in this study, the validity of the research instrument was ensured as it measured the amplitude of accommodation.

Data collection procedures

Case history

The bio data of the subjects such as age, sex, birth history was collected through oral interview. The subjects' present health status was ascertained to rule out the presence of systemic health disorders. Through case history, it was made known, any type of allergic reactions experienced by the subjects. Entry was made to know if the subjects were on any type of medication in the form of drugs that would have altered the test results.

Visual acuity measurement (VA)

The visual acuity of the subjects was measured before and after refractive correction. The VA at 6m test distance was measured with the distance Snellen's chart while the VA at 40cm test distance was measured Rayner's near vision test card.

Pen light examination

Using the Reister pen light, a thorough inspection of the eyes and its adnexa was conducted. This was done to rule out the presence of external ocular pathologies. The pupils were also observed and subjects with abnormal pupillary reaction and irregular pupils were excluded.

Test for strabismus

Strabismus that was not too evident was determined using the unilateral cover test and any movement of the eye not under cover shows strabismus.

Ophthalmoscopy

Direct Ophthalmoscopy was carried out using the Keeler ophthalmoscope. This Objective method of examining the interior of the eyes was used to rule out any anterior and posterior segment pathologies.

Objective refraction

The refractive status of the subjects was determined objectively (without cycloplegia) using the Keeler retinoscope under conditions that are conducive for the relaxation of accommodation.

Subjective refraction

The refractive statuses of the subjects were determined subjectively using the phoropter. The test was done monocularly, then binocularly. The right eye was tested first before the left eye. The lens build up method was used to determine the spherical components starting with objective refraction findings. The clock dial was used to determine the cylindrical components. Binocular balancing was done using the Duochrome chart.

Push up method

In this method, the patient, optically corrected for distance vision views a detailed test object approaching the eye and reports when there is the first slight sustained blur. The test object is then said to be at the eyes near point and its distance to the eye is measured. The measurement (in meters) is converted to its reciprocal to provide the amplitude of accommodation in diopters.

Minus lens method

This method is facilitated by using a phoropter. The subjects were seated comfortably behind the phoropter, while looking with the lenses as determined through distance subjective refraction, the Rayner's near vision chart was introduced at 33cm from the eye to compensate for accommodative micropsia. Negative spherical lenses were added to the distance refractive correction until the subject cannot maintain the initial acuity at the distance of testing. The amplitude of accommodation was determined as the maximum negative lens power added while the patient can maintain focus.

Dynamic retinoscopy

The test was performed monocularly in a dimly illuminated room and with the subject wearing the distance refractive correction. Each subject looked at the front-Illuminated near point card with paragraph text as an accommodative stimulus attached to the front of the streak retinoscope at 40cm. Each subject was instructed to read the letter and keep them clear. The vertical streak was used for the test. When a with movement (lag of accommodation) was observed, the retinoscope was moved until neutral reflex was first observed.

Once the neutrality was achieved, the distance between the spectacle plane and retinoscope was measured with a pupillary distance rule. The AA was taken as the reciprocal of the distance in meters. The test was performed similarly for the other eye.

Data analysis techniques

All data were analyzed by a statistician using the statistical package for social sciences (SPSS) version 21. The distribution of variables was presented using tables. The analysis of variance (ANOVA) was used to analyze if there were differences among group means. Z test was used to analyze if the results from the test were valid or repeatable.

Data presentation, interpretattion and analysis

Data presentation and interpretation

Data for the research was collected on one hundred and nine (109) subjects who were properly examined, fifty-four (54) (49.5%) males and fifty-five (55) (50.5%) females. The ages of the subjects examined ranges between 15 - 25 years with a mean age of (MeanSD).

Table 2: Distribution of Subjects according to their Age and Gender.

Age (yrs)	Male	(%)	Female	(%)	Total	(%)
15-18	16	(14.7)	13	(11.9)	29	(26.6)
19-22	29	(26.6)	31	(28.4)	60	(55.1)
23-26	9	(8.3)	11	(10.1)	20	(18.3)
Total	54	(49.5)	55	(50.5)	109	(100)

Table 2 showing the age and sex distribution of the subjects. The 19-22 age group showed the highest number of male and female subjects with 26.6% and 28.4% respectively while the 23-26 age group showed the lowest number of male and female subjects with 8.3% and 10.1% respectively.

Table 3: Mean Distribution of AA measured using Push-up to Blur, Minus-lens to Blur and Modified Dynamic Retinoscopy.

	Push-up to Blur (D)	Minus-lens to Blur (D)	Modified Dyn. Ret. (D)
Mean ± SD	11.8 ± 2.4	8.2 ± 1.9	5.2 ± 0.8

Table 3 showing the mean AA measured using push-up to blur, minus-lens to blur and modified dynamic retinoscopy. The push up to blur method gave the highest mean AA with 11.8 ± 2.4D while the modified dynamic retinoscopy method gave the lowest mean AA with 5.2 ± 0.8D.

Table 4: Mean Distribution of AA measured using Push-up to Blur with Age.

Age (yrs)	n	Push-up to Blur (D)
15-18	29	14.6 ± 1.9
19-22	60	11.3 ± 1.2
23-26	20	9.2 ± 1.8
Total	109	

Table 4 showing age distribution of the mean AA using push-up to blur method. The 15-18 age group gave the highest mean AA with 14.6 ± 1.9D while the 23-26 age group gave the lowest mean AA with 9.2 ± 1.8D.

Table 5: Mean Distribution of AA measured using Push-up to Blur with Gender.

Gender	N	Push-up to Blur (D)
Male	54	11.9 ± 2.5
Female	55	11.7 ± 2.4
Total	109	

Table 5 showing sex distribution of the mean AA measured using push-up to blur method. Males gave the highest mean AA with 11.9 ± 2.5D while females gave the lowest mean AA with 11.7 ± 2.4D.

Table 6: Mean Distribution of AA measured using Minus-lens to Blur with Age.

Age (yrs)	n	Minus-lens to Blur (D)
15-18	29	8.3 ± 1.9
19-22	60	8.4 ± 2.0
23-26	20	7.8 ± 1.3
Total	109	

Table 6 showing age distribution of the mean AA measured using minus lens to blur method. The 19-22 age group gave the highest mean AA with 8.4 ± 2.0D while the 23-26 age group gave the lowest mean AA with 7.8 ± 1.3D.

Table 7: Mean Distribution of AA measured using Minus-lens to Blur with Gender.

Gender	n	Minus-lens to Blur (D)
Male	54	8.1 ± 1.9
Female	55	8.2 ± 2.0
Total	109	

Table 7 showing sex distribution of the mean AA measured using minus lens to blur method. Females gave the highest mean AA with 8.2 ± 2.0D while males gave the lowest mean AA with 8.1 ± 1.9D.

Table 8: Mean Distribution of AA measured using Modified Dynamic Retinoscopy with Age.

Age (yrs)	N	Modified Dyn. Ret. (D)
15-18	29	5.2 ± 0.8
19-22	60	5.1 ± 0.7
23-26	20	5.3 ± 0.5
Total	109	

Table 8 showing age distribution of the mean AA measured using modified dynamic retinoscopy method. The 23-26 age group gave the highest mean AA with 5.3 ± 0.5D while the 19-22 age group gave the lowest mean AA with 5.1 ± 0.7D.

Table 9: Mean Distribution of AA measured using Modified Dynamic Retinscopy with Gender.

Gender	n	Modified Dyn. Ret. (D)
Male	54	5.1 ± 0.8
Female	55	5.2 ± 0.8
Total	109	

Table 9 showing sex distribution of the mean AA measured using modified dynamic retinoscopy method. Females gave the highest mean AA with 5.2 ± 0.8D while males gave the lowest mean AA with 5.1 ± 0.8D.

Statistical data analysis

Research hypothesis one

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Push-up to Blur and Minus-lens to Blur.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Push-up to Blur and Minus-lens to Blur.

The above research hypotheses were analyzed using Z-test statistic to test for the difference in the mean AA measured using Push-up to Blur and Minus-lens to Blur.

stating the Z-test statistic: $Z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

Where.

= Mean AA using Push-up to Blur.

= Mean AA using Minus-lens to Blur.

are their corresponding variances.

n_1 and n_2 are their corresponding sample sizes.

= 11.8

= 8.2

= (standard deviation)^2 = (2.4)^2 = 5.8

= (standard deviation)^2 = (1.9)^2 = 3.6

= 109

= 109

12.9

Decision rule

Reject if does not lie within +1.96 and -1.96, otherwise accept and conclude.

Conclusion

Since does not lie within +1.98 and -1.98, we therefore accept and conclude that there is statistical significant difference between the mean AA measured using Push-up to Blur and Minus-lens to Blur.

Research hypothesis two

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Push-up to Blur and Modified Dynamic Retinoscopy.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Push-up to Blur and Modified Dynamic Retinoscopy.

The above research hypotheses were analyzed using Z-test statistic to test for the difference in the mean AA measured using Push-up to Blur and Modified Dynamic Retinoscopy.

Stating the Z-test statistic: $Z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

Where.

= Mean AA using Push-up to Blur.

= Mean AA using Modified Dynamic Retinoscopy.

are their corresponding variances.

n_1 and n_2 are their corresponding sample sizes.

= 11.8

= 5.2

= (standard deviation)^2 = (2.4)^2 = 5.76

= (standard deviation)^2 = (0.8)^2 = 0.64

= 109

= 109

27.5

Decision rule

Reject if does not lie within +1.96 and -1.96, otherwise accept and conclude.

Conclusion

Since does not lie within +1.98 and -1.98, we therefore accept and conclude that there is statistically significant difference between the mean AA measured using Push-up to Blur and Modified Dynamic Retinoscopy.

Research hypothesis three

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Minus-lens to Blur and Modified Dynamic Retinoscopy.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Minus-lens to Blur and Modified Dynamic Retinoscopy.

The above research hypotheses were analyzed using Z-test statistic to test for the difference in the mean AA measured using Minus-lens to Blur and Modified Dynamic Retinoscopy.

stating the Z-test statistic: $Z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

Where.

= Mean AA using Minus-lens to Blur.

= Mean AA using Modified Dynamic Retinoscopy.

are their corresponding variances.

n_1 and n_2 are their corresponding sample sizes.

= 8.2

= 5.2

= (standard deviation)^2 = $(1.9)^2$ = 5.76

= (standard deviation)^2 = $(0.8)^2$ = 0.64

= 109

= 109

15.0

Decision rule

Reject if does not lie within +1.96 and -1.96, otherwise accept and conclude.

Conclusion

Since does not lie within +1.98 and -1.98, we therefore accept and conclude that there is statistical significant difference between the mean AA measured using Minus-lens to Blur and Modified Dynamic Retinoscopy.

Research hypothesis four

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Push-up to Blur with age.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Push-up to Blur with age.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	363.413	10	36.341	13.088	0.000
Within Groups	272.117	98	2.777		
Total	635.531	108			

Table 10: ANOVA for Research Hypothesis four.

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value < 0.05, we therefore accept conclude that there is statistically significant difference between the mean AA measured using Push-up to Blur with age.

Research hypothesis five

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Minus-lens to Blur with age.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Minus-lens to Blur with age.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	21.879	10	2.188	0.554	0.041
Within Groups	386.883	98	3.948		
Total	408.761	108			

Table 11: ANOVA for Research Hypothesis five.

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value < 0.05, we therefore accept conclude that there is statistically significant difference between the mean AA measured using Minus-lens to Blur with age.

Research Hypothesis Six

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Modified Dynamic Retinoscopy with age.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Modified Dynamic Retinoscopy with age.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	1.264	1	1.264	0.213	0.645
Within Groups	634.267	107	5.928		
Total	635.531	108			

Table 13: ANOVA for Research Hypothesis seven.

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value < 0.05, we therefore accept conclude that there is statistically significant difference between the Mean AA measured using Modified Dynamic Retinoscopy with age.

Research Hypothesis Seven

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Push-up to Blur with sex.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Push-up to Blur with sex.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

(table 13)

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value > 0.05, we therefore accept conclude that there is no statistically significant difference between the mean AA measured using Push-up to Blur with sex.

Research Hypothesis Eight

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Minus-lens to Blur with sex.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Minus-lens to Blur with sex.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	0.427	1	0.427	0.112	0.739
Within Groups	408.335	107	3.816		
Total	408.761	108			

Table 14: ANOVA for Research Hypothesis eight.

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value > 0.05, we therefore accept conclude that there is no statistically significant difference between the mean AA measured using Minus-lens to Blur with sex.

Research Hypothesis Nine

- **Null Hypothesis** There is no statistically significant difference between the mean AA measured using Modified Dynamic Retinoscopy with sex.
- **Alternative Hypothesis** There is statistically significant difference between the mean AA measured using Modified Dynamic Retinoscopy with sex.

The above research hypotheses were analyzed using ANOVA test of significance at P = 0.05 level of significance.

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	0.514	1	0.514	0.821	0.367
Within Groups	66.979	107	0.626		
Total	67.493	108			

Table 15: ANOVA for Research Hypothesis nine.

Decision rule

Reject , if p-value <0.05 and accept , otherwise accept , if p-value >0.05.

Conclusion

Since p-value > 0.05, we therefore accept conclude that there is no statistically significant difference between the mean AA measured using Modified Dynamic Retinoscopy with sex.

Discussions

Discussion of Findings

This research was aimed at comparing the subjective and objective clinical methods of assessing the amplitude of accommodation using university students. Accommodation in the eye is one of the systems that play a significant role in the formation of a clear retinal image. Several researchers have assessed the amplitude of accommodation using various subjective and objective techniques [3].

In this study, the highest mean amplitude of accommodation was obtained using the push up to blur method (11.8 ± 2.4D). Also, the minus lens to blur method gave the lowest mean subjective amplitude of accommodation (8.2 ± 1.9D), while the modified dynamic retinoscopy method showed the lowest mean objective amplitude of accommodation (5.2 ± 0.8D) (Table 3). Findings from this study agree with that of Mathebula., *et al*. (2018), where they compared the amplitude of accommodation determined subjectively and objectively in South African University students whose ages ranged from 21 - 27 years. They found that the highest mean amplitude of accommodation was obtained using the push up to blur method (10.25 ± 1.67D), while the minus lens to blur method gave the lowest mean subjective finding (8.43 ± 1.68D), and the modified dynamic retinoscopy method gave the lowest mean objective amplitude of accommodation of approximately (6.50 ± 1.40D) [17].

The slight variations in the mean AA obtained in this study when compared to Mathebula., *et al*. (2018) may be because of the different age range and number of subjects used for this study. In this study, the objective method underestimated the amplitude of accommodation. The objective method evaluates the actual increase in the refractive power of the eye. The difference between the objective and subjective methods can be explained by the lag of accommodation. The lag of accommodation increases with the accommodative stimulus. This could probably be because of pupillary miosis and the depth of focus [7,18].

This subjective push up method may be adequate for routine use to measure AA, but it is inadequate for measuring true AA as it overestimates the AA. The higher values seen when measuring AA with the push up method in comparison with other methods have been documented. This has been attributed to the depth of focus, target size, illumination, proximal cues, pupil size, end point criteria and subject variability. When performing the push up method, there is an increase in the angular size of the retina image corresponding to the decrease in the target distance and the proximal stimulation to the accommodation increases and leads to a higher value compared to other methods. The increase in angular subtense may result in a delay in subject's ability to report the endpoint which is blur. The endpoint of sustained blur can also be a difficult concept for some patients to appreciate. Illumination can also affect measurements. Excessive illumination can greatly increase the depth of focus for some patients and result in false high AA measurements [7,18].

The results of this study showed that the minus lens method had the lowest mean subjective AA (8.2 ± 1.9D) among the subject methods. This result agrees with Mathebula., *et al*. (2018). In the minus lens method, unlike the push-up method, there is minification of the retinal images because of the optical properties of the higher powered minus spherical lens while there is no relative distance magnification, and the proximal stimulation of the accommodation remains constant. This explains why the push up amplitude result is higher than the minus-lens amplitude [17]. Based on the factors affecting the subjective AA measurement, the minus-lens method may be a better (or appropriate) and accurate method to measure the AA. However, the push-up method is faster and more widely used than the minus-lens to blur method (table 3) [17].

The modified dynamic retinoscopic findings showed the lowest mean objective AA of the three methods used in this study (5.2 ± 0.8D). This agrees with Mathebulla., *et al*. (2018) [17]. However, Rustein., *et al*. (1993) compared AA determined objectively and subjectively in a sample of fifty-four (54) students aged between 6 and 35 years using the push-up method and modified dynamic retinoscopy. They found that the modified dynamic retinoscopy consistently gave higher mean values than the push-up method [18]. The reason for a higher finding of AA measured objectively could be the end-point criterion. Rustein., *et al*. (1993) defined the endpoint when the width of the retinoscopy reflex became narrow, its color became dimmer, and its speed became slower. This endpoint criterion could be the cause of the higher values in modified dynamic retinoscopy. In his study, the more commonly adopted neutral reflex for endpoint was used (Table 3) [18].

In line with findings from this study and previous studies discussed above, statistical analysis of data using the Z-test statistics showed that there is a significant variation in the AA measured using push-up to blur and minus-lens to blur, push-up to blur and modified dynamic retinoscopy, minus-lens to blur and modified dynamic retinoscopy.

Amplitude of accommodation is not a fixed quantity; it varies primarily with age. Various researchers have studied amplitude of accommodation in various populations and have observed that amplitude of accommodation diminishes steadily with the advancement of age. Donders (1864) found that AA diminishes from 14.0D at the age of 10years to 0 at the age of 70 years [12]. Also, Chattopadhyay and Seal (1984) found that the mean AA in 6-10 years age group is 14.5D and it diminishes regularly so that in the 61-65-year age group, it comes down to 0.8D [19]. In this study, the push-up to blur method showed a decrease in AA with age from (14.6 ± 1.9D) in the 15-18 age group to (11.3 ± 1.2D) in the 19-22 age group and (9.2 ± 1.8D) in the 23-26 age group which agrees with Donders (1864) and Chattopadhyay and seal (1984) (Table 4). Analysis of variance (ANOVA) at P = 0.05 level of significance showed that there is a statistically significant variation in the AA measured using the push-up to blur with age (Table 10) [19].

Also, in this study, the highest mean AA measured using the minus lens to blur method was obtained in the 19-22 age group with 8.4 ± 2.0D which diminished to 7.8 ± 1.3D in the 23-26 age group. However, the mean AA of the 15-18 age group was lower than that of the 19-22 age group with 8.3 ± 1.9D. This slight variation could be because of the different age range used in this study when compared to previous studies.

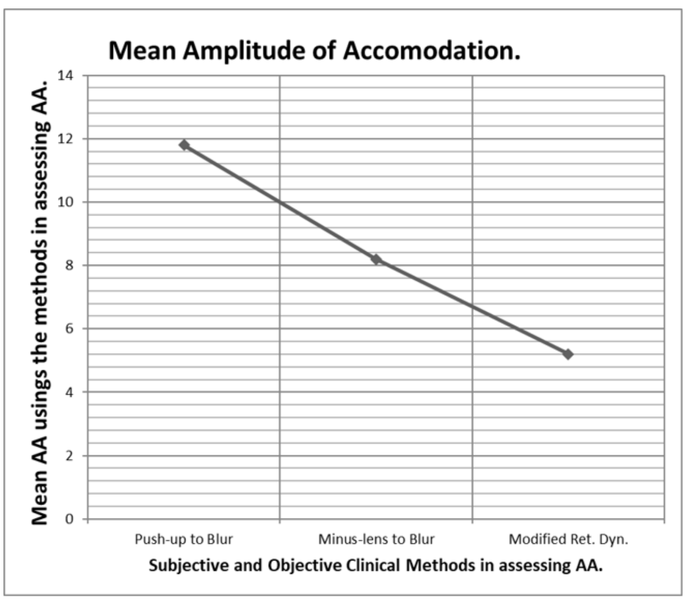
Chattopadhyay and Seal (1984) used age range 6-65 while in this study 15-26 age range was used (Table 4) [19].

Analysis of variance (ANOVA) at P = 0.05 level of significance showed that there is a statistically significant variation in the AA measured using the minus-lens to blur method with age (Table 11).

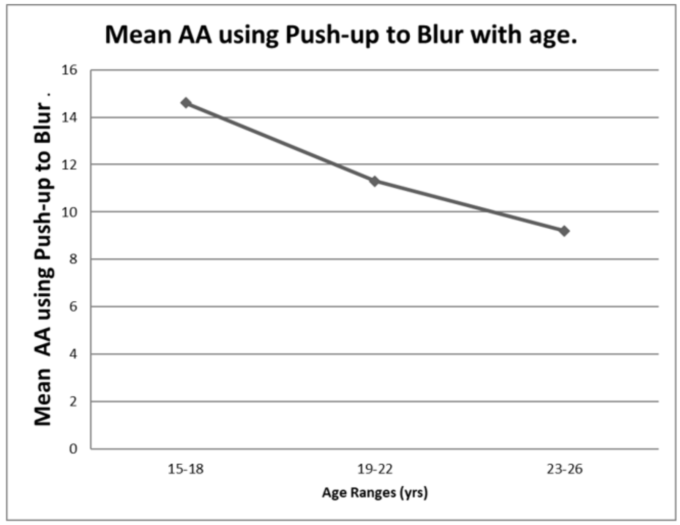
Leon., *et al*. (2016) in a study to assess the accommodative response using modified dynamic retinoscopy found no significant change between 5 and 19 years of age and between 45 and 60 years of age [20]. In this study, the highest mean AA measured using modified dynamic retinoscopy was obtained in the 23-26 age group with 5.3 ± 0.5D with the lowest mean obtained in the 19-22 age group with 5.1 ± 0.7D. The 15-18 age group showed mean AA of 5.2 ± 0.8D (Table 8). The findings from this study could be due to the close age range used for this study. However, analysis of variance (ANOVA) at P = 0.05 level of significance showed a statistically significant variation in the AA measured using modified dynamic retinoscopy with age which agrees with previous studies (Table 12) Castange., *et al*. (2017) in a study to determine the AA by age, gender and economic status found that there is no significant difference in median AA according to gender [21]. Likewise, Mathebula., *et al*. (2016) in a study that compared three methods of determining monocular Amplitude of Accommodation (subjective push-up, push down and minus lens) found no statistically significant difference between the AA in males and females (P > 0.05) [22]. Findings from this study agree with Castange., *et al*. (2017) and Mathebula., *et al*. (2016) [21,22]. In this study, males had mean AA obtained using push-up to blur as 11.9 ± 2.5D while females had 11.7 ± 2.4D (Table 5).

Also, males had mean AA obtained using minus-lens to blur as 8.1 ± 1.9 while females had 8.2 ± 2.0D (Table 7) and males had mean AA obtained using modified dynamic retinoscopy as 5.1 ± 0.8D while females had 5.2 ± 0.8D (Table 9).

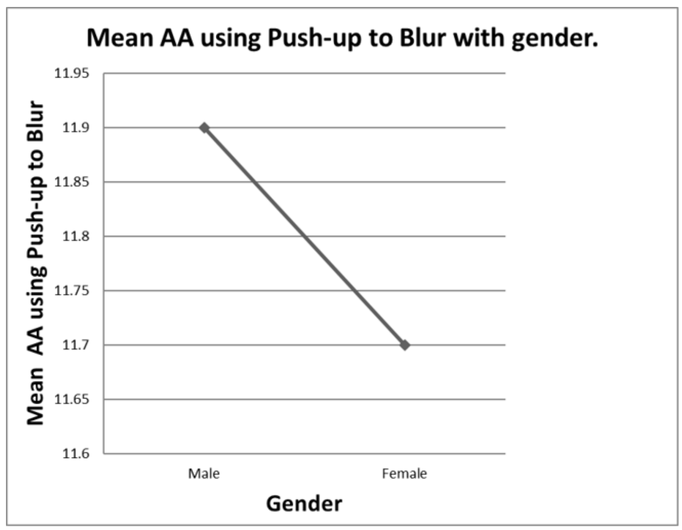
Analysis of variance (ANOVA) at P = 0.05 level of significance showed that there is no significant variation in the AA measured using push-up to blur, minus-lens to blur and modified dynamic retinoscopy with gender (P > 0.05) (Tables 13, 14 and 15).



Appendix 1: Line Graph showing the mean distribution of AA measured using Push-up to Blur with age.



Appendix 2: Line Graph showing the mean distribution of AA measured using Push-up to Blur with gender.

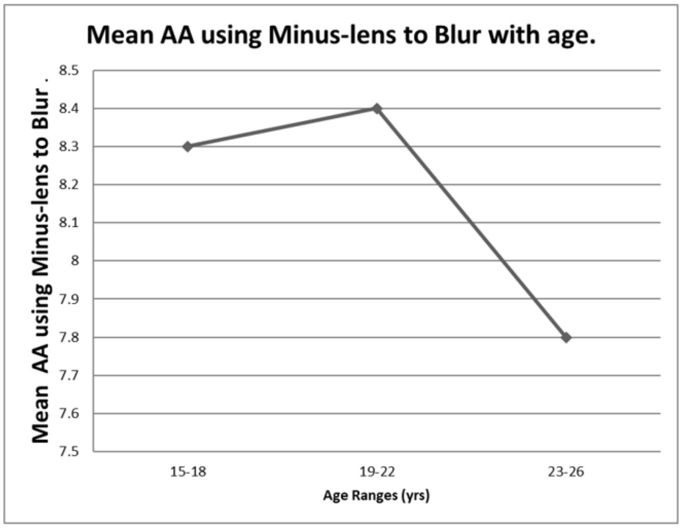


Appendix 3

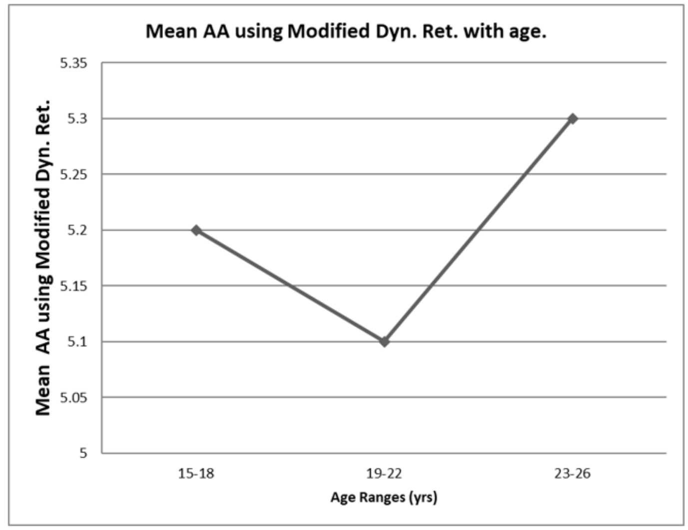
Conclusion

Based on our research findings, the following conclusions were drawn:

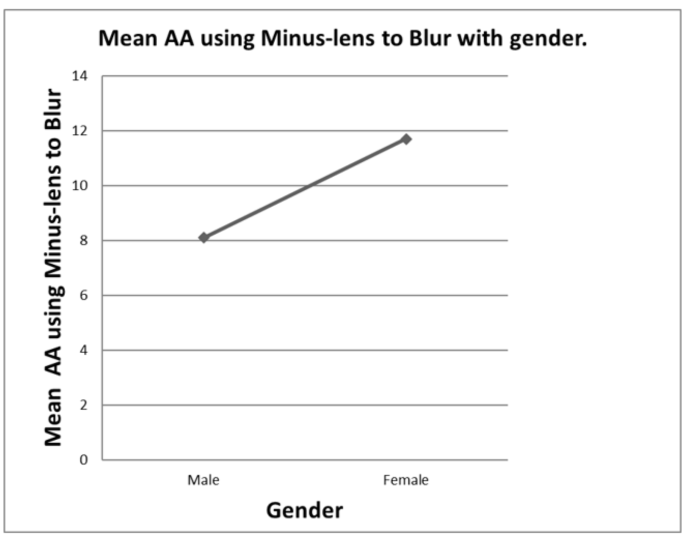
- Subjective methods showed higher mean amplitude of accommodation.
- Objective measurement of AA underestimated the subjective AA.
- There is a no significant variation in the AA measured using push-up to blur, minus-lens to blur and modified dynamic retinoscopy with gender.



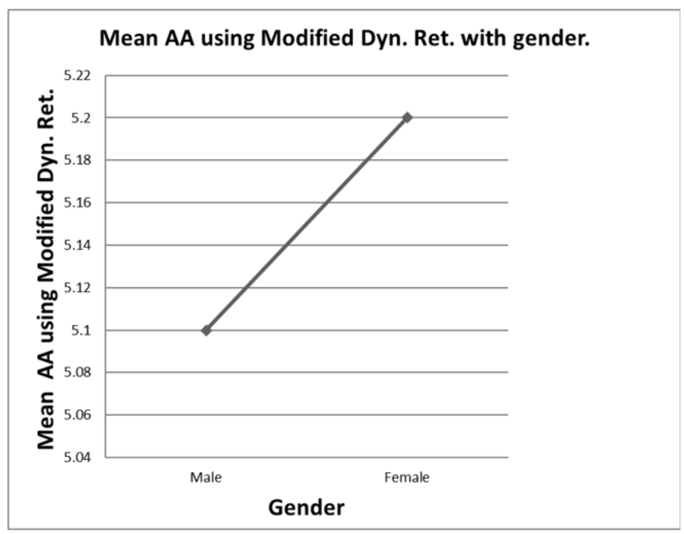
Appendix 4: Line Graph showing the mean distribution of AA measured using Minus-lens to Blur with age.



Appendix 6: Line Graph showing the mean distribution of AA measured using Modified Dynamic Retinoscopy with age.



Appendix 5: Line Graph showing the mean distribution of AA measured using Minus-lens to Blur with gender.



Appendix 7: Line Graph showing the mean distribution of AA measured using Modified Dynamic Retinoscopy with gender.

Limitations of the Study

- Only normal and healthy optometry students were included in the study. These students were more accustomed to the instrumentation and may not have yielded typical clinical responses when compared to others.
- The dynamic retinoscopy techniques took longer to perform, and the accuracy of the measurement may vary with the skills of the examiner.
- Depth of focus invariably affects the results of this study. The depth of focus errors increases with accommodation owing to pupillary construction.
- Because the measurements are not fully automated, examiner bias was a major limitation. This is due to the cause that the endpoint of the measurements was entirely at the examiner's discretion.

Suggestions for Further Studies

Further research is needed to further validate modified dynamic retinoscopy as the optimal or best possible routine clinical method to assess the true amplitude of accommodation.

Also, the clinical relevance of AA in evaluating the evolution of accommodating intra ocular lenses should be researched.

Recommendations

Amplitude of accommodation is a fundamental optometric measurement but findings from this study showed methodical sources of substantial error in its routine clinical measurement (7, 23).

Setting normative values for a clinical measurement requires research that measures it in sufficient numbers of well-specified subjects using standardized procedures. However, as shown in this study and in reviewed literature, there is marked variation in published norms of amplitude of accommodation and therefore abnormal values cannot be identified with certainty. Ideally, a standardized method should be employed by clinicians so that their results can be directly related to the published norms. In the long term, it should be useful to develop improved instrumentation to measure amplitude of accommodation.

Conflict of Interest

No financial interest or any conflict of interests.

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