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Comparison of optometric extension program's test #19 to Hofstetter's formulas

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Abstract

This is a study to determine how well Hofstetter's Formulas predict accommodative amplitude in the clinical setting when using the Optometric Extension Program's Test #19 (O.E.P. #19) as the method of measurement. O.E.P. #19 findings were recorded from 150 Pacific University College of Optometry clinic files of patients ages 10 to 60. Scatter grams, regression lines and slope formulas were created to show the age vs accommodative amplitude correlations (see Results and Discussion). The results of my study show that using the Optometric Extension Program's Test #19 method produces accommodative amplitudes that are generally lower than Hofstetter predicts. This leads me to conclude that more suitable formulas need to be established when using the O.E.P. #19 method for assessing accommodative faculity.

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COMPARISON OF
OPTOMETRIC EXTENSION PROGRAM'S TEST #19
TO
HOFSTETTER'S FORMULAS

BY

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ABSTRACT

This is a study to determine how well Hofstetter's Formulas predict accommodative amplitude in the clinical setting when using the Optometric Extension Program's Test #19 (O.E.P. #19) as the method of measurement. O.E.P. #19 findings were recorded from 150 Pacific University College of Optometry clinic files of patients ages 10 to 60. Scatter grams, regression lines and slope formulas were created to show the age vs accommodative amplitude correlations (see Results and Discussion). The results of my study show that using the Optometric Extension Program's Test #19 method produces accommodative amplitudes that are generally lower than Hofstetter predicts. This leads me to conclude that more suitable formulas need to be established when using the O.E.P. #19 method for assessing accommodative faculity.

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INTRODUCTION

We as clinicians have been introduced to Hofstetter's formulas as a standard for assessing accommodative insufficiency and amplitudes. However, Hofstetter's formulas are based on experimental data and on a method of measurement that is not done in a clinical setting. A more practical method of measuring accommodation is the Optometric Extension Program's Test #19. This raises the question of how well Hofstetter's formulas correlate with current clinical accommodative measurements (i.e. O.E.P. #19).

Optometrists have for a long time recognized that the measuring of the amplitude of accommodation is valuable for the detection of accommodative insufficiency when it is below the amount expected for the patients age and also for the prescribing of plus lenses for near work when there exists a dysfunction or for the presbyope.

The amplitude of accommodation is the maximum amount of refractive power producable by the eye. Theoretically it can be considered the absolute dioptric difference between the punctum remotum and the punctum proximum. Put another way, it is the dioptric change produced by the eye as it maintains conjugate focus of an image moved from infinity to the punctum proximum.

This value is not theoretically pure. In theory it is true only for the emmetrope when the depth of focus can be eliminated. Campbell[1] (1957) suggests that the depth of focus may be as high as .75 diopters under certain conditions. Pascal[2] (1947) found that the actual amount of accommodation produced by the eye was not the same for myopes, emmetropes and hyperopes when fixating the same stimulus target. He found that myopes accommodate less by a factor of -.03 diopters for every diopter of refractive error per diopter of stimulus and hyperopes more by a factor of +.04 diopters for every diopter of refractive error per diopter of stimulus.

Other factors that bear upon the measurable amplitude of accommodation can be divided into those affecting the function of the eyes and those affecting the stimulus to accommodation. Factors of the first catagory are: pupil size (depth of focus), poor acuity, convergence ability or inability, monocular differences, criteria for clarity, subjective interpretation of blur, inflammation of the ciliary body, presence of certain medications, recent history of trauma and the angle of gaze. Factors which affect the stimulus to accommodation are the size of the target, angular subtense if the target is movable, illumination, technique used to measure the amplitude of accommodation and the point to which the measurement is made (i.e., spectacle plane or nodal point).

Methods for establishing normalcy of accommodative amplitude have always been based on different techniques and under different conditions. Understanding that Duane's data, upon which Hofstetter's formulas are based, and the O.E.P. method of measuring accommodation are different, it would not be surprising to find a difference in measurable amplitudes. If the Hofstetter's formulas show little correlation with findings taken from the Pacific University College of Optometry (P.U.C.O.) clinic, perhaps further investigation is needed to develop a table or formula of norms for comparison and prediction of amplitude more suitable to clinically accepted methods of measuring accommodative amplitudes.

METHODS OF MEASURING THE ACCOMMODATIVE AMPLITUDE

There are essentially two methods of measuring accommodative amplitude. Both have advantages and disadvantages. One method used in the laboratory is locating the punctum proximum by moving a target from far to near (once the refractive error has been corrected) until the object is perceived to blur. This approach is referred to as the Push-Up-To-Blur Method. When the point of blur is located the inverse of the object distance to the spectacle plane or to the nodal point of the eye is considered the accommodative amplitude. The other method, more commonly used in the clinical setting, is the addition of concave lenses in front of the patient while he/she fixates on a stationary object. The accommodative amplitude is determined by the lens power added until clear vision of a target at a specific distance can no longer be sustained.

Both of these methods can be used under either a binocular or monocular condition. Neither of them attempts to control for conjugate point focus as it traverses the depth of focus.

HISTORICAL BASIS

Clinicians have for a long time realized that the accommodative amplitude decreases with age. Investigation of this has been done by several authors: Donders, Duane, Kaufmann, Jackson, Sheard, and many others.

Donders is credited as being the first to document the declining amplitude with age in 1864. He also devised a table of normal values correlated to age so that it could be used in the clinical setting for assessing the accommodative amplitude or insufficiency thereof. Donders'[3] table is based on measurements of 130 subjects. He used a bench optometer with five small vertical black wires as his target. The target was brought nearer to the eye until the subject perceived blur. Plus lenses were also used when the target came within eight parisian inches (2.55 cm per inch). All measurements were performed monocularly and only on emmetropic people. Subjects ranged from 10 to 80 years of age. Donders calculated his findings from the nodal point of the eye.

Kaufmann[4] in 1894 attempted to duplicate Donders' study. He used 400 eyes (200 subjects) ranging in age from 5 to 68 and again calculated from the nodal point of the eye. Kaufmann confirmed what Donder had found.

Duane[5] attempted to refine Donders' measurements by using over 400 eyes of subjects ranging in age from 8 to 72. He first used cycloplegia to determine the static refraction in all subjects under 47 years of age. Duane also performed his study under monocular conditions. His target was constructed of a velvet disc with a white section 3 x 1.25mm. On the white disc was placed a fine vertical line of 3 x .02mm. The target was moved towards the eye on a rule graduated for dioptric stimulus. First blur was considered the end point. Duane used a -3.00 D or -4.00 D lens for many of his younger subjects to keep the measurement far enough away to make it more accurate. The most considerable difference of methodology in Duane's study is that he measured accommodative amplitude from the spectacle plane whereas Donders measured from the nodal point. Duane found that there existed a .30 D loss in accommodation per year until the age of 60. His data is published in many texts, in tabular form, as expected values to which the clinician can compare his/her measurement of amplitude.

Hofstetter[6] (1944) made a comparison of Duane's and Donders' tables. He corrected Donders values to the spectacle plane and found them to be generally higher than Duane's. Referring to his comparison, Hofstetter states that "the analysis at hand does not justify the use of any specific curve to represent the trend of amplitude with age". Although a curve representing the amplitude for age was not clear, Hofstetter agreed that for clinical purposes, a decline of .30 D per year for any given patient could be assumed.

Sheard[7] (1917) and Jackson[8] (1922) used minus lenses at 13 inches with a .62 M font test card. This method was an attempt to negate the angular size magnification as an object is brought closer to the eye. The larger target size is used to oppose the minification produced by the addition of minus spheres. It is this method which was adopted by Skeffington in the O.E.P. and is now widely used in many clinics and practices. The difference between the method of Sheard and Jackson is that Sheard measured using a monocular approach and Jackson a binocular.

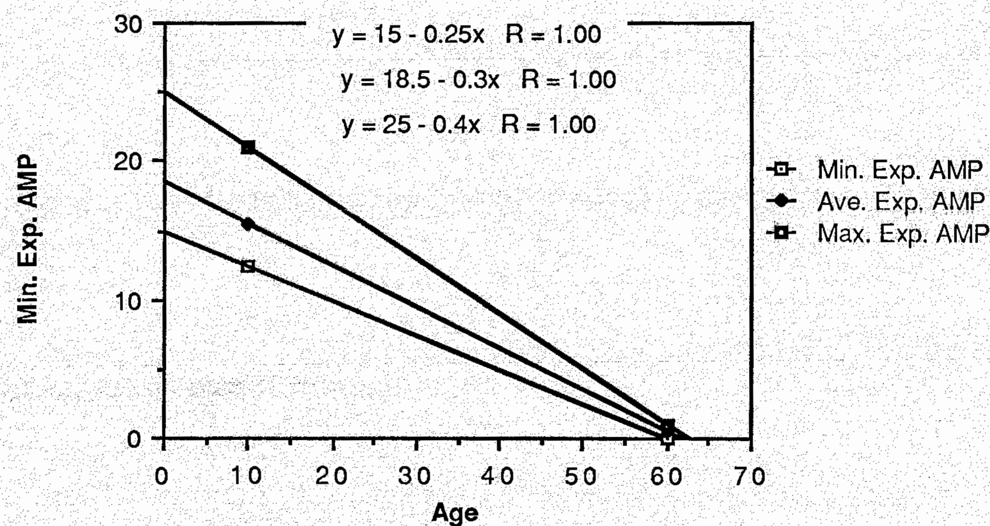
In 1950 Hofstetter[9] published a paper entitled "Useful Age-Amplitude Formula". These formulas were an attempt to give the clinician a standard to which the accommodative amplitude could be compared. Hofstetter's formulas are derived from Duane's figures based on a Push-Up-To-Blur Method and are measured from the spectacle planes.

When Hofstetter's formulas are applied, resultant lines can be drawn which include almost all of the original data from Duane's and Donders' works. Hofstetter stated that , "It shall be explained that the lines are constructed by general inspection to fit the data and at the same time to provide constants in the formulas which make computation easy". The two lines which enclose the extremes were constructed to include most of Duane's and Donders' data and are not representative of any statistical significance. He does, however, tell us that the two lines representing the extremes can be assumed to lie two standard deviations from the mean. Hofstetter's mathematical rules and Graph #1 representing the expression of these formulas by age are as follows:

HOFSTETTER'S FORMULAS

Minimum Accommodative Amplitude	= 15.0 - .25 X Age
Probable Accommodative Amplitude	= 18.5 - .30 X Age
Maximum Accommodative Amplitude	= 25.0 - .40 X Age

FIGURE #1
REGRESSION LINES OF HOFSTETTER'S FORMULAS



PROCEDURES

The data for this comparison was collected over a four week period at the Pacific University College of Optometry Clinic in Forest Grove, Oregon. To gain a completely arbitrary and randomized sample, these values were collected from files of patients that had been seen within the last 1 to 3 days and were waiting to be filed. On occasion, when no pending files were available, I simply pulled a section of files and recorded the information necessary. The initials of all patients were recorded so that the chance of duplication of one patient was eliminated by noting the repitition of the same initials within one age group. The two criteria to be met were: age (only files between the age of 10 to 60 were selected) and correctable vision to 20/20 in both eyes. Each age group is represented by three values. The total sample size is N=150 [3 x (60-10) = 150]. The values sought from the files were the #7, #19 Gross and #19 Net. It is the #7 and #19 Gross findings that Skeffington and the Optometric Extension Program suggest be used to calculate the accommodative amplitude. Also, any mathematical error that the examining clinician may have made was found as I recalculated and compared the #19 Net recorded in the files.

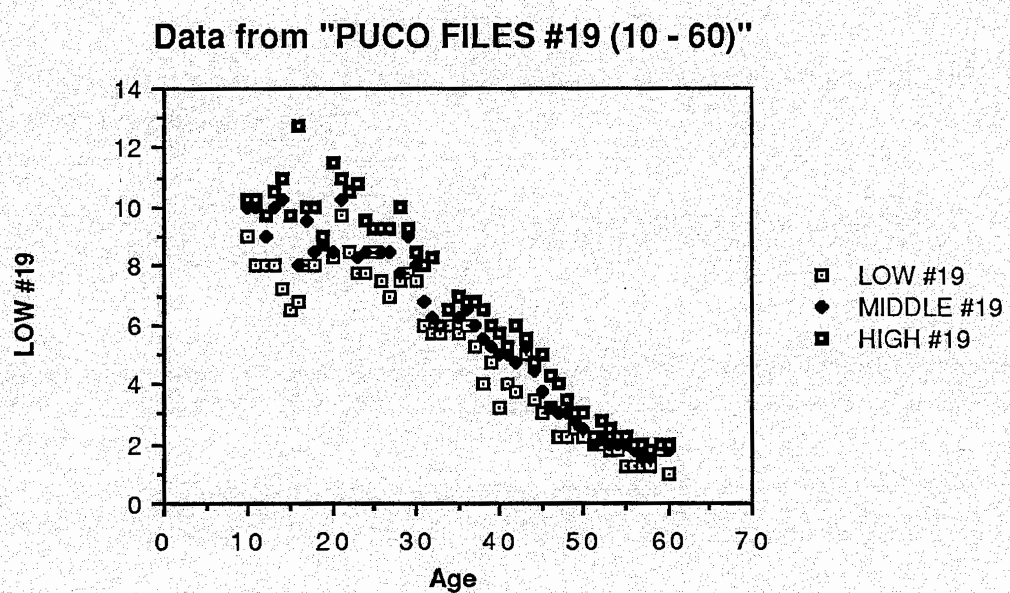
The O.E.P. Test #19, as performed in the PUCO clinic, uses a .62 M paragraph placed on the midline in front of the patient. Illumination is set at 10 to 15 foot-candles and a near point light is used to further illuminate the card. Pupillary distance for the phoropter is set for the patients near PD. The patient is instructed to read the paragraph aloud until it becomes too blurry to read, beginning with some arbitrary selected level such as the #7a,14b, or least plus to 20/20. The clinician continues to add minus spheres binocularly until a point of sustained blur has been reached. The value in the lens battery is recorded as the #19 Gross.

Calculation of the #19 Net is based on the total amount of minus added to the O.E.P Test's #7 finding which is then combined algebraically with 2.50 diopters to compensate for the decreased target distance. This is the O.E.P. #19 Net. If plus spheres are added to the O.E.P. #7 before the patient can begin to read the target, then that amount of plus must be deducted from 2.50 diopters for the O.E.P. #19 Net.

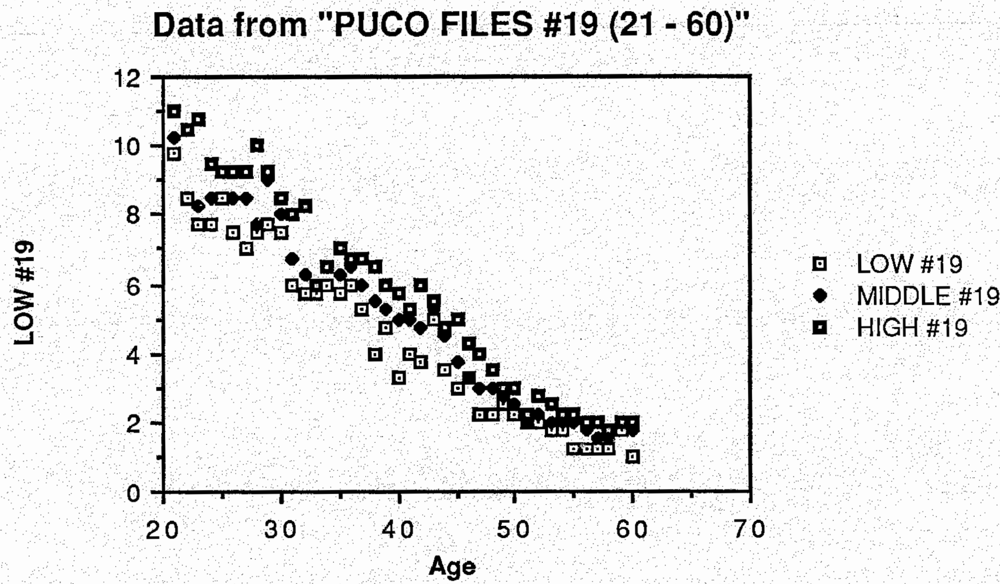
RESULTS

The results of the data gathered from the P.U.C.O. clinic files O.E.P. #19 is presented in Table #1 (see pages 16 a, b). A low, medium, high, and an average value are given for each age group. These results are also shown on scatter plots (Figure #2 and Figure #3) for easy visualization. The ordinate represents the age in years and the abscissa represents the amplitude of accommodation in diopters.

FIGURE #2



FIGURE#3



Through general inspection of the scatter plot for all points collected (Figure #1), it can be noticed that the data remains close through the years 21 to 60 but not for the ages 10 to 20. The increased scattering between points of the age group 10 to 20 may be due to error factors which will be discussed later. For this reason, two scatter plots are drawn to closer inspect the age group 21 to 60. The data from each scatter plot is also represented in three corresponding regression lines and slope formulas to show the low, medium, high, and average values for accommodative amplitude (see figures 4a, 4b, 4c for ages 10 to 60 and figures 5a, 5b, 5c, for ages 21 to 60 at end of this section). The slope formulas derived from the P.U.C.O. clinic files data are as follows:

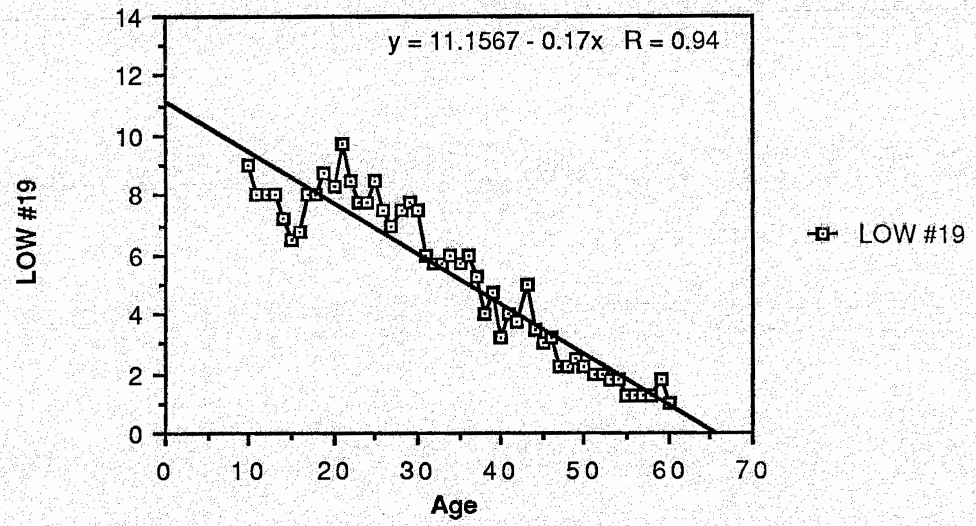
	Ages 10 - 60	**Ages 21 - 60**
Low	Y=11.1567-0.1700XAge	Y=13.0765-0.2124XAge
Medium	Y=12.8440-0.1948XAge	Y=14.3819-0.2286XAge
High	Y=14.1847-0.2117XAge	Y=15.7712-0.2470XAge
	(avg. slope 0.19) R=0.97	(avg. slope 0.23) R=0.99

TABLE #1
PUCO FILES #19 (10-60)

AGE	LOW #19	MEDIUM #19	HIGH #19	AVERAGE #19
10	9.00	10.00	10.25	9.75
11	8.00	10.00	10.25	9.42
12	8.00	9.00	9.75	8.92
13	8.00	10.00	10.50	9.50
14	7.25	10.25	11.00	9.50
15	6.50	9.75	9.75	8.67
16	6.75	8.00	12.75	9.17
17	8.00	9.50	10.00	9.17
18	8.00	8.50	10.00	8.83
19	8.75	8.75	9.00	8.83
20	8.25	8.50	11.50	9.42
21	9.75	10.25	11.00	10.33
22	8.50	10.50	10.50	9.83
23	7.75	8.25	10.75	8.92
24	7.75	8.50	9.50	8.58
25	8.50	9.25	9.25	9.00
26	7.50	8.50	9.25	8.42
27	7.00	8.50	9.25	8.25
28	7.50	7.75	10.00	8.42
29	7.75	9.00	9.25	8.67
30	7.50	8.00	8.50	8.00
31	6.00	6.75	8.00	6.92
32	5.75	6.25	8.25	6.75
33	5.75	6.00	6.00	5.92
34	6.00	6.50	6.50	6.33
35	5.75	6.25	7.00	6.33
36	6.00	6.50	6.75	6.42
37	5.25	6.00	6.75	6.00
38	4.00	5.50	6.50	5.33
39	4.75	5.25	6.00	5.33
40	3.25	5.00	5.75	4.67
41	4.00	5.00	5.25	4.75
42	3.75	4.75	6.00	4.83
43	5.00	5.25	5.50	5.25
44	3.50	4.50	4.75	4.25
45	3.00	3.75	5.00	3.92
46	3.25	3.25	4.25	3.58
47	2.25	3.00	4.00	3.08
48	2.25	3.00	3.50	2.92
49	2.50	2.75	3.00	2.75

AGE	LOW #19	MEDIUM #19	HIGH #19	AVERAGE #19
50	2.25	2.50	3.00	2.58
51	2.00	2.00	2.25	2.08
52	2.00	2.25	2.75	2.33
53	1.75	2.00	2.50	2.08
54	1.75	2.00	2.25	2.00
55	1.25	2.00	2.25	1.83
56	1.25	1.75	2.00	1.67
57	1.25	1.50	2.00	1.58
58	1.25	1.50	1.75	1.50
59	1.75	2.00	2.00	1.92
60	1.00	1.75	2.00	1.58

Data from "PUCO FILES #19 (10 - 60)"



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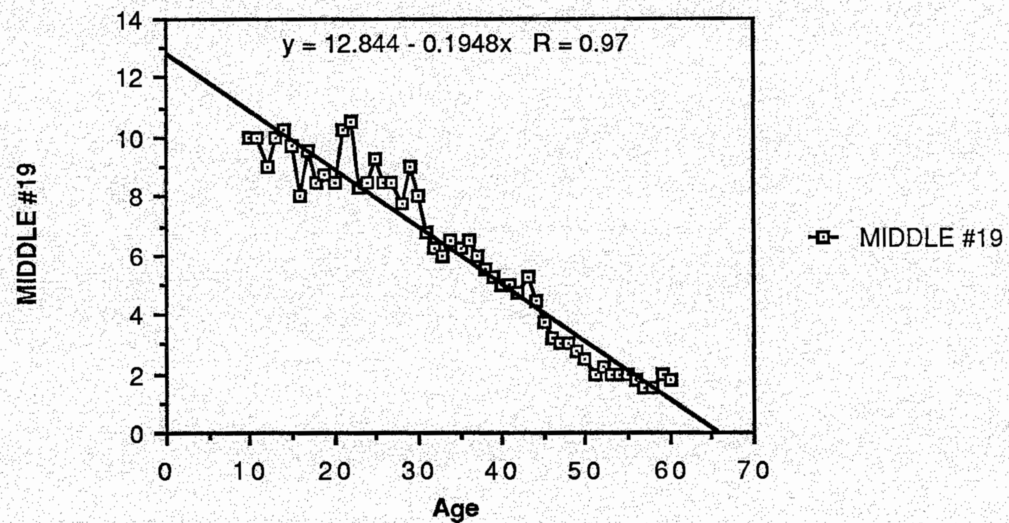

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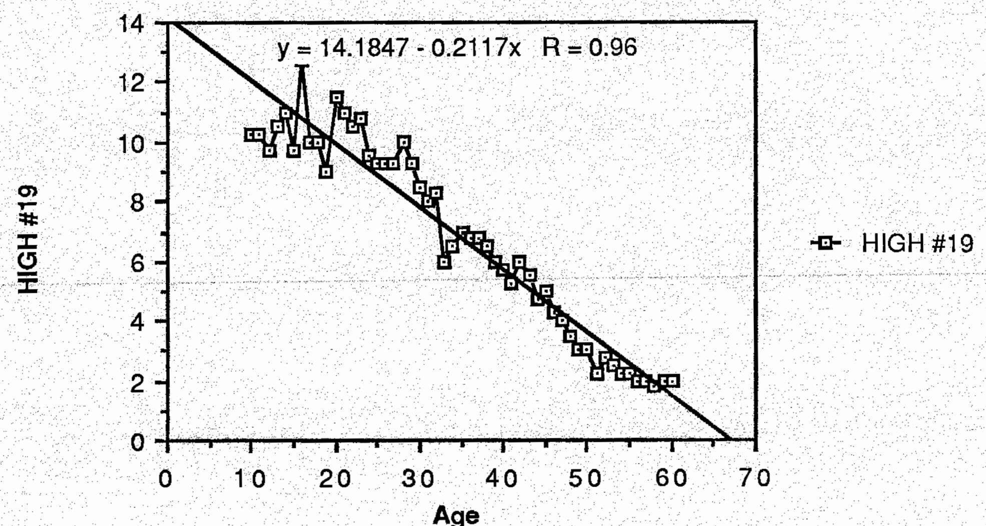

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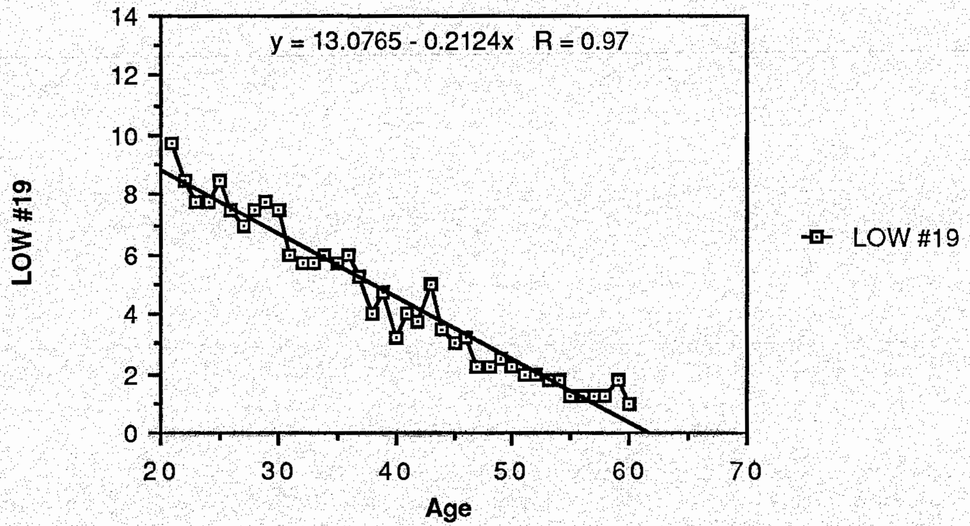

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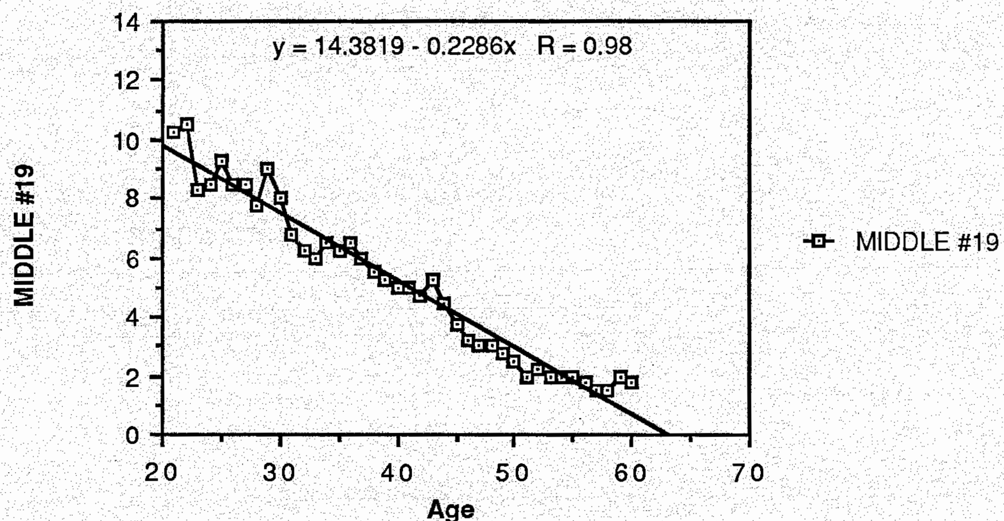

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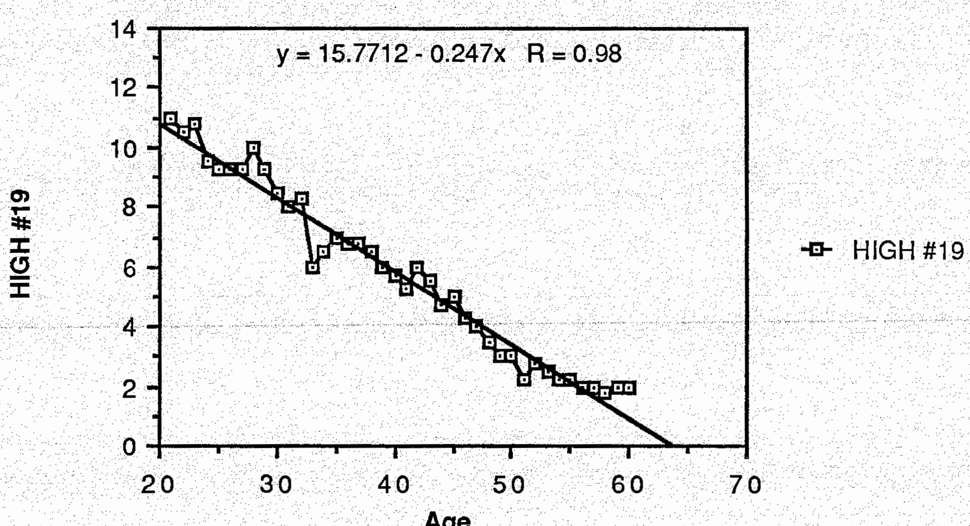

DISCUSSION

Once the values representing ages 10 to 20 were omitted, the remaining values followed the regression line with a higher correlation (Low R = 0.97; Medium R = 0.98; High R = 0.98). This omission is justified by the hypothesis of Turner[10] (1958) that accommodative amplitudes above 12.0 diopters may not exist and that the actual change in amplitude with age more closely resembles that of a sigmoid curve than a regression line. There may have existed a lack of communication between clinician and this younger age group even though the O.E.P. #19 test is well controlled in it's instructions. This may have affected the patients understanding of the end point of the test or their willingness to try to achieve maximum accommodation. An additional consideration for the inconsistency of the data found in the younger population is that, as Wold[11] mentions in his paper, the measuring of accommodative amplitude in a young population may be falsely low because of the presence of uncorrected hyperopia. Using the O.E.P. #7 instead of the #7a to calculate the #19 Gross helps to alliviate some of the hyperopia but cannot control for the latent hyperope. Since the O.E.P. method requires the patient to read aloud it makes measuring of the accommodative amplitude on a younger population more difficult. Reading of the paragraph may require more energy for the younger than it would for the older individual where reading skills are suppossed to be more efficient. Therefore the task at hand may be more difficult for a larger percentage of the young.

When using a push-up method to measure the amplitude of accommodation, the retinal image size becomes larger as the target is moved towards the eye. This would effectively increase the measurable amplitude. With a minus sphere method, as the dioptric value is increased, minification of the target is induced. For this reason the target used in the O.E.P. #19 is a .62 M paragraph.

Consideration of the minification factor suggest that as the amplitude of and individual increases the smaller the target will become. This would effectively reduce the maximum measurable amplitude of those with high amplitudes, namely the younger population. At the other end of the age spectrum, if the patient displays little ability to accommodate their amplitude may be generously measured since the target is larger than a 20/20 demand for the test distance.

Upon converting the data obtained in this study to slope formula, the first observation made is the low value for the slope. Hofstetter predicts that the average decrease for accommodative amplitude each year is .30 D with a maximum of .40 D. and minimum of .25 D. Calculation from the P.U.C.O. clinic based on the O.E.P. #19 method of measuring accommodative amplitude suggests that the high expected decrease is approximately .25 D, the middle expected is .23 D and the low is .21 D per year. The lower slope values are likely artifacts of the considerations of the O.E.P. #19 made previously in this section.

Since the slope value for the P.U.C.O. data is less than that of Hofstetter's, the regression lines must eventually share a common point. By comparing Hofstetter's probable amplitude formula (18.5-.30XAge = Probable AA) with the mean amplitude formula derived from the P.U.C.O. data for patients ages 21 to 60, these lines become coincident at approximately age 58. This comparison is made by setting the equations equal to each other and solving for the age (Hofstetter's Probable 18.5-.30XAge = P.U.C.O.'s Medium 14.3819-0.2286XAge). When ages are chosen arbitrarally and the Hofstetter's probable and P.U.C.O.'s medium predictions for age are solved, the P.U.C.O. predictions are less by 2.70 D at age 21, 2.00 D at age 30 and 1.25 D at age 40.

If a similar comparison is made using Hofstetter's minimum amplitude to P.U.C.O.'s medium amplitude, the P.U.C.O. data falls outside of, what Hofstetter tells us is two standard deviations, until the age 29. For ages above 29, the deviation is not as great due to the loss of accommodative facility being .23D per year instead of .30 D as Hofstetter suggests. It is only in the older population that the measurable amplitude via O.E.P. #19 falls within a more reasonable one standard deviation of Hofstetter's predictions.

For patient's ages 10 to 20, the highest value of accommodative amplitude found in the P.U.C.O. clinic files fell outside of two standard deviations from Hofstetter's lowest predictions. The medium value of accommodative amplitude was lower than Hofstetter's lowest predictions by more than 2.00 D.

SUMMARY

Hofstetter's formulas have long been used as a standard for assessing accommodative insufficiency and amplitudes both in the laboratory and the clinic. Because they were derived from data based on a laboratory setting, I have conducted this study in an attempt to determine how well Hofstetter's formulas actually predict the accommodative amplitude in a clinical setting when using the Optometric Extension's Test #19 as the method of measurement. From my research in the P.U.C.O. clinic, I have found that Hofstetter's predictions are quite different from clinical values. For patients ages 10 to 29, the data found in the P.U.C.O. clinic files falls outside of Hofstetter's two standard deviations. For ages 30 to 60, the deviation is not as great and actually meets at approximately age 58. This is due to the fact that the loss of accommodative facility in the P.U.C.O. data is about .23 D per years instead of .30 D as Hofstetter suggests.

The sample size of this study is 150 patients, which is 3 patients per year for ages 10 - 60. Hofstetter's formula are based on Duane's 400 patients, which range from 8 - 72 in age and is approximately 6.3 per age group. I feel that before the formulas derived in this study can be used for comparision a sample size of 500 patients is needed to increase the statistical certainty. 500 patients ages 10 - 60 would allow 10 values for each age group. More emphisis will also need to be placed on gathering data from the 10 - 20 age group.

The O.E.P. #19 is a common clinical method of establishing the accommodative amplitude for a patient, and its values do differ from Hofstetter's predictions, largely due to the difference in methods of measurement. The establishment of new standard formulas for comparison will enable the clinician to better interpret values as normal or abnormal for the patients age.

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