Article ▸ Studies Comparing Tests for Presbyopic Add Power: A Literature Review

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ABSTRACT

The conventional treatment for presbyopia is the prescription of additional plus for nearpoint viewing. This paper reviews studies which have provided data on the mean differences between the add powers recommended by various tests and guidelines, and it reviews studies which have reported data on the mean differences between the adds from such tests and a preferred or prescribed add. Most of the studies also reported coefficients of agreement (COA), which represent a measure of the variability of the differences, or provided the data to make the calculation of them possible. Tests and guidelines studied include binocular cross cylinder, keep half the amplitude in reserve, balance negative relative accommodation and positive relative accommodation, nearpoint red/green test, plus build-up test, and age-expected add. The low mean differences between these tests and the preferred or prescribed add suggest that they are all reasonable starting points with which to establish a tentative add. However, the magnitudes of the COAs suggest that these tentative adds be modified or confirmed based on factors such as patient history, previous prescription, symptoms, visual needs, and other test results.

Keywords: amplitude of accommodation, lens prescriptions, optometric testing, presbyopia

Introduction

For hundreds of years, the treatment for the near vision condition that has come to be known as presbyopia has been plus lens additions for the restoration of clear vision at near.[1] Early determination of lens power was based on age, but with the advent of subjective optometric techniques, various test procedures have been devised to suggest appropriate reading addition powers.[2,3] Practitioners typically use those test results in the context of the history and the rest of the examination to determine the add to be prescribed.[4-7]

There appear to have been five published studies and two unpublished studies completed with presbyopic subjects that compare tests for the determination of presbyopic reading add power. There also have been two other studies that have evaluated tests and guidelines for presbyopic add power in other ways. The purpose of this paper is to review all of those studies.

Woo and Sivak

Woo and Sivak[8] compared three presbyopic reading add tests in 10 subjects who ranged in age from 41 to 59 years (mean age 49 years). Inclusion criteria for the subjects were not stated. The three testing procedures studied were: (1) cross cylinder going into plus with the conventional black line grid target, (2) cross cylinder going into plus with green vertical lines and red horizontal lines, and (3) keep half the amplitude in reserve.

Cross cylinder tests were done under monocular conditions. On the cross cylinder with conventional black lines, luminance was reduced, as is usually done with this test. The grid pattern was placed at 40 cm, and a cross cylinder lens was in place. Plus lenses were added until the subjects reported the horizontal and vertical lines to be equally clear. For the cross cylinder test using the red and green grid, luminance was not reduced. With the grid pattern at 40 cm and a cross cylinder in place, plus lenses were added until the vertical green lines and horizontal red lines were equally clear.

Table 1. Mean Differences between Tests and Coefficients of Agreement (COA) for the Ten Subjects in the Woo and Sivak[8] study. (COA represents the range either side of the mean difference which would include about 95% of the differences. Units are diopters.)

	Mean Difference	COA
Red/green grid – black grid	-0.16	0.40
Red/green grid – keep half amp. in reserve	+0.01	0.29
Black grid – keep half amp. in reserve	+0.17	0.51

For the keep half the amplitude in reserve formulation, they used a conventional near acuity chart to determine monocular amplitudes of accommodation with the conventional subjective technique of 'plus to clear' or 'minus to blur.' The reading addition was determined using the formula: Add power = dioptric working distance – (1/2 x amplitude of accommodation).

The authors reported that there was no statistically significant difference between the three tests. They concluded that "all three methods indicate similar monocular reading additions." They published individual data for their ten subjects, allowing the calculation of the mean adds for each test, the mean differences between the tests, and coefficients of agreement (COA) between tests. Coefficients of agreement were calculated by multiplying the standard deviations of the differences by 1.96, thus representing the range on either side of the mean difference over which 95% of the differences would be likely to occur.

The mean add with the red/green grid monocular cross cylinder test was +1.36 D. The black line grid pattern on the monocular cross cylinder test yielded a mean add of +1.52 D.

Table 2. Mean Add Findings (standard deviations in parentheses) from Tlachac and Patella.[9]

	With Phoropter	With Vision Analyzer
First data set (n=25)		
Minimum subjective add	+1.72D (0.59)	+1.79D (0.51)
Balance NRA and PRA	+1.78D (0.58)	+1.83D (0.51)
Second data set (n=11)		
Minimum subjective add	+1.77D (0.44)	+1.71D (0.45)
Balance NRA and PRA	+1.74D (0.57)	+1.79D (0.59)

Using the keep half the amplitude in reserve guideline resulted in a mean add power of +1.35 D. Coefficients of agreement are given in Table 1.

Tlachac and Patella

Tlachac and Patella[9] did two presbyopic add tests in both a conventional phoropter and in the Humphrey Vision Analyzer. Two sets of data were reported, one involving 25 subjects ranging from 42 to 75 years of age, and the other including 11 subjects ranging from 41 to 69 years of age. The two sets of data differed in two ways. In the first data set, Humphrey Vision Analyzer testing was done before phoropter testing, while in the second data set, there was alternation of which test was performed first. Also, in the first data set, a non-stereoscopic target was used with the Humphrey Vision Analyzer, while for the second data set, testing with the Vision Analyzer incorporated a stereoscopic target. The two tests done in both data sets were minimum plus subjective add and balancing the negative relative accommodation (NRA) and positive relative accommodation (PRA).

For the minimum plus subjective add test, a testing distance of 40 cm was used. Plus spheres were added until the best near visual acuity was reached with the minimum amount of plus. The add for balancing the NRA and PRA was the midpoint of the NRA and PRA blur points with testing at 40 cm.

The results are summarized in Table 2. The purpose of their study was to compare add powers derived using a conventional phoropter and a Humphrey Vision Analyzer, and they noted the close agreement in means. We can also see that the means for minimum subjective add and balancing the NRA and PRA did not differ using either set of equipment and with either set of data by more than 0.08 D. Individual data were not presented, so COA could not be calculated.

Ray

In an unpublished student research paper, Ray[10] compared the results of seven tests for the determination of presbyopic adds. Thirty-five subjects ranging in age from 45 to 55 years (mean age, 49 years) participated in the study conducted at Northeastern State University College of Optometry in Oklahoma. Inclusion criteria were normal age-related reduction in amplitude of accommodation and best-corrected distance visual acuity of at least 20/20. The seven tests performed were: (1) age-expected add, (2) keep half the amplitude in reserve, (3) balance the NRA and PRA, (4) plus build-up test, (5) binocular cross cylinder coming out of plus, (6) near red/green test, and (7) preferred add.

For the age-expected add, Ray stated that tables from Borish[11] were used. For subjects whose working distances were closer to thirteen inches, the adds were: age 45, +1.00 D; age 48, +1.50 D; age 50, +2.00 D; age 55, +2.50 D. For subjects with working distances closer to sixteen inches, the adds were: age 45, +0.75 D; age 48, +1.25 D; age 50, +1.75 D; age 55, +2.00 D.

For keep half the amplitude in reserve, the push-up amplitude of accommodation was determined by finding the point of first blur while viewing through +2.50 D lenses. The add was found by subtracting half the amplitude from the stimulus to accommodation at the working distance.

To balance NRA and PRA, the midpoint between the NRA and PRA points was determined. NRA and PRA testing was done to blur-out with 20/20 letters at 40 cm.

On the plus build-up test, testing started with distance subjective refraction lenses in place. Plus spheres were added binocularly until participants were first able to read 20/20 letters at 40 cm. The recommended add was found by adding +0.50 D to the amount of plus sphere added.

The binocular cross cylinder test (BCC) was performed with the cross grid at 40 cm viewed under dim illumination through cross cylinders with minus cylinder axes in the 90th meridian. The test was started with sufficient plus to make the vertical lines darker. Plus power was then reduced binocularly, with the endpoint being either the lens power which first made the vertical and horizontal lines equally dark or the lens power which first made the horizontal lines darker if equality was not reported.

Ray used a homemade device for the near red/green test. Red and green filters with transmission primarily at 642 and 520 nm, respectively, were placed over near point card letters. With the device at 40 cm, the test was started with enough plus to make the letters on the red side appear darker. Plus was then reduced binocularly until the letters first appeared darker on the green side. The add power at the first green response was used as the add recommended by this test.

For determination of the preferred add, subjects judged the distance at which given adds yielded the most clear and comfortable vision. The preferred add was the add for which that distance most closely matched the subject's working distance.

Ray compared the preferred add to the results of each of the other six tests by the mean differences between them and by correlation coefficients. The coefficients of correlation of preferred add with the other tests were: plus build-up test, r=0.90; near red/green test, r=0.89; balance NRA and PRA, r=0.84; BCC, r=0.81; age-expected add, r=0.67; keep half the amplitude in reserve, r=0.63. Coefficients of agreement with

Table 3. Comparison of Each Test to the Preferred Add in the 35 Subjects from Ray.[10] (Mean difference was positive when the preferred add was more plus than the add from the given test and negative when the preferred add was less plus than the add from the given test.)

	Mean Difference	COA
Age-expected add	+0.16 D	0.65
Keep half the amplitude in reserve	+0.04 D	0.75
Balance NRA and PRA	-0.06 D	0.45
Plus build-up test	+0.11 D	0.36
Binocular cross cylinder	-0.11 D	0.48
Near red/green test	-0.01 D	0.38

Table 4. Comparison of Each Test to the Prescribed Add from Antona et al.[12] (Mean difference was positive when the prescribed add was more plus than the tentative add from the individual test and negative when the prescribed add was less plus.)

	Mean Difference	COA	Stat. sig. of Difference
Low neutral dynamic retinoscopy	-0.19	0.86	0.0007
Keep one third amplitude in reserve	-0.34	1.02	0.0001
Age expected add	+0.01	0.52	0.8
BCC coming out of plus	-0.02	0.57	0.6
BCC going into plus	+0.13	0.66	0.003
Near red/green	-0.13	0.55	0.0004
Balance NRA and PRA	-0.07	0.53	0.04

the preferred add were calculated from the data for individual subjects in Ray's paper by multiplying the standard deviations of the difference by 1.96. Mean differences and coefficients of agreement are given in Table 3. The largest mean difference was between age-expected add and preferred add (0.16 D).

Antona et al.

Antona et al.[12] compared the tentative presbyopic adds derived from seven different testing procedures to the add prescribed in 69 healthy subjects. The study participants ranged in age from 40 to 60 years of age (mean age 51 years). They had spherical refractive errors ranging from -6.50 to +8.00 D, with less than 2.50 D of astigmatism. Inclusion criteria were: corrected monocular visual acuity of at least 20/25 at distance and near, anisometropia less than 2.00 D, no binocular vision problems, no history of strabismus or amblyopia, no manifest or latent nystagmus, no ocular pathology, no systemic disease that could affect accommodation or oculomotor function, and no medications likely to affect accommodation or fusional vergence ranges.

The seven testing procedures used to derive tentative adds were: (1) low neutral dynamic retinoscopy, (2) keep one-third of the amplitude in reserve, (3) age-expected add, (4) BCC coming out of plus, (5) BCC going into plus, (6) near red/green test, and (7) balance NRA and PRA.

For low neutral dynamic retinoscopy, testing began with distance subjective refraction lenses in the phoropter. Subjects viewed 20/25 visual acuity optotypes at 40 cm and tried to keep them clear. Plus lenses were added until the examiner observed neutrality. The mean of the lens power added to the right and left eyes was the tentative add for analysis of this testing procedure.

The add for the keep one third of the amplitude in reserve method was calculated by subtracting two-thirds of the amplitude of accommodation from 2.50 D. The amplitude in that formula was the mean of the right eye and left eye amplitudes using a minus lens method. Subjects reported when 20/25 visual acuity optotypes at six meters blurred out with the addition of minus lenses.

The age-expected addition was determined as follows: 40-42 years, +0.75 D; 43-45 years, +1.00 D; 46-47 years, +1.25 D; 48-50 years, +1.50 D; 51-52 years, +1.75 D; 53-55 years, +2.00 D; 56-57 years, +2.25 D; and 58-60 years, +2.50 D.

The add using the BCC coming out of plus was derived by first adding +3.00 D lenses over the distance refraction. Plus power was reduced binocularly in 0.25 D steps until the vertical and horizontal lines were reported to be equally clear. For the BCC going into plus, testing was started with the distance refraction lenses in the phoropter. Plus lenses were added binocularly in 0.25 D steps until equal clarity of the horizontal and vertical lines was observed.

On the near red/green test, subjects viewed a card with 20/25 visual acuity Landolt Cs on a red/green background at 40 cm. Testing was started with the distance refraction lenses in place, and plus lenses were added binocularly until the test objects appeared approximately equally sharp on the red and green backgrounds. Balancing the NRA and PRA was done by performing NRA and PRA tests and finding the midpoint of the range between them.

Mean differences between each of the seven test procedures and the prescribed add were calculated. Coefficients of agreement (COA) were calculated by multiplying the standard deviations of the differences by 1.96. Statistical significance of the difference between the adds from the seven test procedures and the prescribed add was determined by t-test. Results are summarized in Table 4.

The lowest mean differences from the prescribed add were found for the age-expected add, the BCC coming out of plus, and balancing the NRA and PRA. The test with the highest mean difference from the prescribed add was keep one-third the amplitude in reserve. The authors concluded that because the mean differences from the prescribed add were fairly similar for each of the tests, "other aspects, such as ease of application and time taken, will affect choice of method." However, they also noted high values for COA, suggesting that "every tentative addition should be adjusted according to the particular needs of the patient."[12]

Wee et al.

Wee et al.[13] compared tentative adds from five different procedures to a final add based on the adequacy of a subjective range of clear vision for a 40 cm working distance. The 41 participants in the study ranged in age from 42 to 60 years. They had spherical refractive errors between -5.50 D and +2.00 D, less than 2.00 D of astigmatism, and less than 2.00 D of anisometropia. Selection criteria included corrected visual acuity of at least 20/20 in each eye, no strabismus, near point of convergence break less than 7.5 cm, distance heterophoria less than 3^{Δ} exo or eso, and no history of ocular disease or refractive surgery. The five procedures used to determine tentative adds were: (1) near red/green test, (2) BCC with white background, (3) BCC with red background, (4) BCC with green background, (5) BCC with red and green background, and (6) age-expected add.

For the red/green test, subjects viewed letters on red and green backgrounds. Testing began without near lens addition, with greater clarity of the letters on the green background. Plus lenses were added until the clarity of the letters was the same for the red and green backgrounds.

On each of the variations of the BCC test, testing was started with a +3.00 D addition to the distance refraction lenses. Testing was done at 40 cm under low illumination, with reduction in plus power binocularly until vertical and horizontal lines were equally distinct. The variations of the BCC involved four different backgrounds: the standard white background, a red background, a green background, and a combination background with both red and green. On the combination red and green background, the border between red and green extended diagonally across the test card so that the upper part of the vertical lines was on red, the lower part of the vertical lines was on green, the left side of the horizontal lines was on red, and the right side of the horizontal lines was on green. For the BCC on the combination red and green background, the endpoint was reached when the four sets of lines (vertical on red, vertical on green, horizontal on red, and horizontal on green) all appeared equally distinct.

The add powers for age-expected add were the same as those used by Antona et al.[12] Mean differences of the tentative adds from the final add and the coefficients of agreement are summarized in Table 5. This table also gives the statistical significance of the differences between the final add and each of the tentative adds by t-test. Low mean differences were found for all but the near red/green test and the red background BCC. The mean difference was low for the age-expected add, but its coefficient of agreement was the highest of the six tests, indicating more variability in the differences between it and the final add. The authors suggested that because of the low mean difference from the final add and the low COA, the combination red and green background BCC may be a useful test.

Table 5. Comparison of Each Test for Tentative Add to the Final Add from Wee et al.[13] (Negative mean differences indicate that the final add was less plus than the tentative adds.)

	Mean difference	COA	Stat. sig. of difference
Near red/green test	-0.24	0.40	<0.0001
White background BCC	-0.07	0.43	0.038
Red background BCC	-0.31	0.42	<0.0001
Green background BCC	-0.01	0.35	0.66
Red & green background BCC	-0.05	0.26	0.011
Age-expected add	-0.04	0.56	0.343

Baars and Roginski

Baars and Roginski,[14] in an unpublished student research paper, collected data retrospectively for 99 presbyopic patients from the files of the clinics at the Indiana University School of Optometry in Bloomington, Indiana. Included were patients who were 50 to 80 years of age and who had a comprehensive vision examination that included BCC, NRA, and PRA tests. Excluded were pseudophakic patients and patients for whom a near add was not prescribed.

They derived an age-expected add based on interpolation and extrapolation of the results of a survey of optometrists reported by Kragha and Hofstetter.[15] The values they used were: 50-51 years, +1.75 D; 52-55 years, +2.00 D; 56-60 years, +2.25 D; >60 years, +2.50 D. The adds prescribed for the patients were compared to the adds found based on (1) BCC coming out of plus, (2) balance the NRA and PRA, and (3) age-expected add. Results are summarized in Table 6. The mean differences were close to zero for the age-expected add and balancing the NRA and PRA, but coefficients of agreement were fairly high. The add from the BCC averaged 0.15 D less plus than the prescribed add.

Bittencourt et al.

Bittencourt et al.[16] compared the adds derived from four tests to the final add used in 80 patients with presbyopia. The patients ranged in age from 40 to 60 years (mean age 50 years). The patients had monocular corrected visual acuities of at least 20/25, anisometropia less than 1.50 D, no history of refractive surgery, no history of strabismus or amblyopia, no ocular disease, and no systemic disease or medications that could affect accommodation or vergence.

The four testing methods used were: (1) keep half the amplitude in reserve, (2) one-third of the demand over the minimum plus to clear near vision, (3) balance the NRA and PRA, and (4) BCC going into plus.

For keep half the amplitude in reserve, the amplitude of accommodation was determined by the minus lens method. The add was calculated as 2.50 D minus half the amplitude.

Table 6. Data for 99 Patients from Baars and Roginski.[14] (Mean difference was positive when the prescribed add was more plus than the add from the given test and negative when the prescribed add was less plus.)

	Mean Difference	COA
BCC coming out of plus	+0.15	0.82
Balance NRA and PRA	+0.02	1.10
Age-expected add	-0.02	0.65

Table 7. Comparison of Each Test to the Final Add from Bittencourt et al.[16] (Mean difference was positive when the final add was greater than the add from the given test and negative when the final add was less plus.)

	Mean Difference	COA
Keep half the amplitude in reserve	-0.003	0.73
One-third the demand over min. plus	+0.10	0.70
Balance NRA and PRA	+0.10	0.55
BCC going into plus	-0.02	0.58

The one-third of the demand over the minimum plus to clear near vision method involved adding plus in 0.25 D steps until "fine print" on a test card at 40 cm was clear. That lens power was subtracted from 2.50 D to yield an accommodative demand value. One-third of that accommodative demand was then added to the minimum plus lens power to clear near vision to yield a recommended add.

The add power recommended by balancing the NRA and PRA was the dioptric midpoint between the NRA and PRA endpoints. The NRA and PRA were done using a 40 cm test distance. The BCC was performed with the grid pattern target at 40 cm. Starting with the distance correction, plus was added until the two sets of lines were equally clear and dark.

The procedure by which the final addition was determined was not stated. A mean difference between the final add and the add from each of the four methods was determined. A coefficient of agreement was found by multiplying the standard deviation of the differences by 1.96.

The results are summarized in Table 7. The differences between the final add and the four methods all averaged 0.10 D or less. The COA values were between 0.55 and 0.73 D, indicating variability in the individual differences. The authors suggested that the procedures they studied on average "provided a tentative addition close to the final addition," but like Antona et al.,[12] they noted that the "addition should be adjusted according to the particular needs of the patient."[16]

Hanlon et al.

In a different type of study from those discussed above, Hanlon et al.[17] attempted to assess errors made in prescribing presbyopic adds. They studied records of patients seen at the Southern California College of Optometry in a review service where patients who had difficulties with their lens prescriptions or treatment plans were re-examined. The study included 37 patients who were 40 to 60 years of age and who had difficulty with their add prescription. Exclusion criteria were the taking of medications known to affect accommodation, distance visual acuity less than 20/20 in either eye, and known ocular pathology.

Data from the initial examination were used to determine the add suggested from the BCC, from balancing the NRA and PRA, from keeping half the amplitude in reserve, and from age-expected values. The latter values were: age 40, +1.00 D; age 44, +1.25 D; age 45, +1.37 D; age 48, +1.50 D; age 49, +1.62 D; age 51, +1.75 D; age 52, +1.87 D; age 54, +2.00 D; age 57, +2.25 D; and age 59, +2.37 D. The mean prescribed add was +1.80 D (SD=0.60). The mean adds recommended from the four tests were: BCC, +1.82 D (SD=0.57); balancing NRA and PRA, +1.91 D (SD=0.51); keep half the amplitude in reserve, +1.54 D (SD=0.46); and age-expected add, +1.82 D (SD=0.34).

Testing in the review service determined whether the original add was too high or too low, although the methods by which that determination was made were not stated. If the original add power was judged to be too high, any test recommending that add power or higher was held to be high. If the original add power was judged to be too low, any test recommending that add power or lower was considered to be low.

The BCC suggested adds which were too high in 48% of cases and too low in 13% of cases. Balancing the NRA and PRA suggested adds that were too high in 40% of cases and too low in 6% of cases. The adds from keeping half the amplitude in reserve were too high in 17% of cases and too low in 13% of cases. The age expected add was too high in 14% of cases. The authors suggested that "using age expected values … may be at least as informative as other methods used." One possible explanation for the higher percentages of high or low adds from some tests as compared to others may simply be that more reliance was placed on those tests for the original prescription. The authors suggested in conclusion that "none of the methods investigated should be considered the final determinant of the add," and that "add power should be evaluated against the patient's specific visual needs and, in many cases, the final power will be determined with the aid of a trial frame."[17]

Millodot and Millodot

Millodot and Millodot[18] reported a study investigating whether the rule of keeping half of the amplitude in reserve or some other percentage, such as keeping one-third of the amplitude in reserve, gave add values close to those that were prescribed. After a careful distance refraction, plus was increased binocularly starting at +0.50 D while the patient viewed the smallest line on a near reading card. While the lowest power add that was most comfortable to the patient was in a trial frame, the range of clear vision was evaluated, making sure that the range behind the card was greater than

Table 8. Mean Percentage of Accommodation Left in Reserve with the Preferred Add from Millodot and Millodot.[18]

	N	Mean percent
Overall	305	49
Males	122	58
Females	183	44
Age 40-52	81	35
Males	33	43
Females	48	29
Age 53-62	134	51
Males	53	60
Females	81	45
Age 63-83	90	60
Males	36	68
Females	54	54

the range in front of the card. This add was prescribed for the patient.

With that add in place, the near point of accommodation was determined with the scale on a near point rule. A test card was viewed binocularly and moved toward the patient until blur was reported. The card was then moved a little closer before being pulled away from the patient until it was clear. That recovery point was found three times, and the mean was used to calculate the amplitude of accommodation.

Three hundred five patients (122 males and 183 females) who were satisfied with their distance and near prescriptions were included in the study. They were 40 to 83 years of age, had normal visual acuity, had no ocular pathology, did not take medications known to have effects on accommodation, and had no history of binocular vision problems.

Amplitude of accommodation data showed a decrease from 40 to about 52 years of age, after which it leveled off. The correlation coefficient of age and amplitude between 40 and 52 was 0.49 ($p<0.01$), and after 52 it was 0.03. Reading distance tended to decrease with age, showing a correlation coefficient of 0.14 ($p<0.05$).

The mean percentages of the amplitude of accommodation that were left in reserve are shown in Table 8. Overall, the mean was 49.3%, agreeing with the guideline of keeping half of the amplitude in reserve. Exceptions were for 40- to 52-year-old women, for whom the mean percentage was closer to keeping one-third of the amplitude in reserve, and for 63- to 83-year-old men, for whom the percentage was close to keeping two-thirds of the amplitude in reserve. Another exception to keeping half of the amplitude in reserve was short working distances. There was a significant correlation between working distance and percent amplitude used ($r=-0.52$, $p<0.001$). Of course, one would expect such a correlation because working distance is used in the calculation of the recommended add. A regression equation of those two parameters found that at a working distance of 33 cm, the percent amplitude in reserve was 33%.

The authors concluded that the keep half of the amplitude in reserve guideline "was found to be valid in most cases, except for women between the ages of 40 and 52 and men beyond 63 years of age, who behaved differently for reasons unknown. Also corroborated was Morgan's suggestion that for short working distances, 'one half rule in reserve' should become the 'one third rule' in selecting a reading add."

Discussion

In the studies comparing the various tests, the order in which tests were taken generally was not counter-balanced or stated. It appears that tests were typically done by one person in each study, potentially leading to some inadvertent bias. Given these limitations, it may be noted that the magnitude of differences between tests and between a preferred or prescribed add and each of the tests was always 0.25 D or less, with one exception. That exception was the difference between the prescribed add and keep one-third the amplitude in reserve in the Antona et al.[12] study. However, coefficients of agreement between tests or between preferred adds and the various tests usually were between about 0.4 and 0.8 D, indicating significant variability in the differences.

Millodot and Millodot[18] found that the keep half the amplitude in reserve method was overall closer to the prescribed add than the keep one-third in reserve method, although the latter was closer for shorter working distances and for women in the early years of presbyopia. A variable in basing an add on keeping some percentage of the amplitude in reserve is whether amplitude is determined from push-up, push-away, or minus lens procedure. The keep half the amplitude in reserve guideline averaged 0.04 D less plus (COA, 0.75 D) than the preferred add in the Ray[10] study, and 0.003 D more plus (COA, 0.73 D) than the final add in the Bittencourt et al.[16] study.

The study by Hanlon et al.[17] suggests that balancing the NRA and PRA has a tendency to yield too much plus. Other studies seem divided on this matter, and mean differences from the preferred or prescribed add were low. The NRA and PRA balance averaged more plus than a preferred or prescribed add in the studies by Ray[10] (by 0.06 D) and Antona et al.[12] (by 0.07 D) but less plus in the studies by Baars and Roginski[14] (by 0.02 D) and Bittencourt et al.[16] (by 0.10 D).

The different studies showed variations in cross cylinder procedure. Variations included monocular vs. binocular, different colored grids, different colored backgrounds, and going into plus vs. coming out of plus. Woo and Sivak[8] did not find a significant difference between monocular cross cylinder with black grid and monocular cross cylinder with a red and green grid. The Antona et al.[12] study did BCC coming out of plus and BCC going into plus. They found that the BCC coming out of plus averaged 0.02 D more plus (COA, 0.57 D) than the prescribed add, and the BCC going

into plus averaged 0.13 D less plus (COA, 0.66 D) than the prescribed add. The BCC coming out of plus averaged 0.11 D more plus (COA, 0.48) than the preferred add in the study by Ray[10] but 0.15 D less plus (COA, 0.82 D) in the study by Baars and Roginski.[14] Bittencourt et al.[16] reported the BCC going into plus to average 0.02 D more plus (COA, 0.58 D) than the final add.

The tabled values for add power expected for different ages varied from one study to another. Age-expected adds averaged 0.16 D less plus (COA, 0.65) than the preferred add in the Ray[10] study, 0.007 D less plus (COA, 0.52) than the prescribed add in the Antona et al.[12] study, and 0.02 D more plus (COA, 0.65 D) than the prescribed add in the Baars and Roginski[14] study.

Conclusion

The tests described in the studies reviewed here generally all have the potential of being useful tests for deriving tentative powers for presbyopic adds. The final adds prescribed can then be determined based on consideration of factors such as the patient's working distance, refractive error, current prescription, symptoms, visual acuity, and vocational and recreational visual needs. Determination of the best final add can also be facilitated by following Carter's recommendations that the practitioner should (1) consider total nearpoint power rather than just the add power by itself, (2) evaluate add power under conditions similar to the situations of use by the patient, and (3) make power changes great enough to relieve symptoms but not so large as to create difficulties in adaptation.[4]

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