Original Article

Comparing measurement techniques of accommodative amplitudes

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Aim and Background: This study was designed to compare four standard procedures, for determining the monocular accommodative amplitudes. **Materials and Methods:** Fifty-two students participated in this analytical–descriptive study. Accommodative amplitudes were measured using four common clinical techniques, namely: Push-up, push-down, minus lens, and modified push-up. **Results:** The highest amplitude was obtained using the push-up method (11.21 ± 1.85 D), while the minus lens technique gave the lowest finding (9.31 ± 1.61 D). A repeated-measures Analysis of Variance (ANOVA) showed a significant difference between these methods ($P < 0.05$), further analysis showed that this difference was only between the minus lens and other the three methods (the push-up ($P < 0.001$), the push-down ($P < 0.001$) and the modified push-up ($P < 0.001$)). The highest and the lowest mean difference was related to the push-up with the minus lens, and the push-down with the modified push-up, while the highest and the lowest 95% limits of agreement were related to the push-up with the modified push-up and the push-up with the push-down methods. There was almost a perfect agreement between the push-up and the push-down method, whereas, a poor agreement was present between the modified push-up and the minus lens technique, and a fair agreement existed between the other pairs. **Conclusions:** The quick and easy assessment of the amplitude using the push-up and the push-down methods compared to other methods, and the obtained perfect agreement between these two methods can further emphasize their use as a routine procedure in the clinic, especially if a combination of the two techniques is used to offset their slight over- and underestimation.

Access this article online

Website: www.ijo.in

DOI: 10.4103/0301-4738.126990

Quick Response Code:

Key words: Accommodation, agreement, amplitude of accommodation, push-up method

Accommodation can be defined as an increase in the refractive power of the eye for focusing near objects of regard on the retina.[1] For many optometrists, measurement of the maximum accommodation, (i.e., amplitude of accommodation) is a standard part of the routine clinical examination. It is also a key measurement when assessing the onset and development of presbyopia. Previous studies have demonstrated that the amplitude of accommodation decreases throughout life in a curvilinear manner from three to forty years of age, with the biggest change occurring between 20 and 50 years.[2]

A number of methods have been described for measuring the accommodative amplitude. Objective procedures include dynamic retinoscopy (DR) and the use of an open-field autorefractor, to assess the maximum accommodative response. In clinical practice, subjective techniques are used most commonly to measure the amplitude of accommodation.[3] The subjective techniques include the push-up (PU), push-down (PD) (also termed push-away), and minus lens (ML) methods.[4] The results of previous studies comparing these different methods[5-17] are shown in Table 1.

An alternative subjective technique is the modified push-up (MPU), where the amplitude of accommodation is measured through an additional minus lens added over the distance refractive correction. The push-up technique is then performed through this lens combination. The advantage of the modified push-up over the conventional push-up procedure is that the target appears smaller when viewed through the minus lens, and therefore, subjects will detect the presence of a blur earlier.[18] Furthermore, the near point of accommodation will be farther away from the subject compared with the push-up or push-down techniques. Hence, the linear space between the diopters will increase, thus making the procedure more precise. For example, with no supplementary lens, if the near point of accommodation is 10 D (10 cm), a 1 cm displacement of the target will produce a change of approximately 1.00 D. However, if a supplementary - 4.00 D lens is introduced for the same subject, then the near point of accommodation will now lie at 17 cm, and a 1 cm displacement of the target will generate an error of less than 0.5 D.

The modified push-up procedure also has a significant advantage over the minus lens technique, in that the closer target position will provide a greater stimulus to proximal accommodation. For achieving the maximum accommodative output, it is desirable to optimize all cues to accommodation. However, it is likely that the output of the proximal accommodation will be reduced in the modified push-up technique, when compared to the conventional push-up procedure. Accordingly, it does seem that there are advantages and disadvantages for each technique. To date, we are not aware of any published investigation that has compared the accommodative amplitude using four subjective procedures, that is to say, push-up, push-down, minus lens, and modified push-up together in one study. Therefore, the present study has examined the amplitude using each technique in a range of subjects between 18 and 25 years of age.

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Manuscript received: 18.04.13; Revision accepted: 15.09.13

Table 1: The mean amplitude of accommodation from previous studies

Author	Method (s)	Range age (Year)	Mean Amplitude (SD) (D)	Mean difference (D)
Ovenseri-Ogbomo *et al.*[5]	PU	8-14	16.86 (3.07)	-
Sterner *et al.*[6]	PU	6-10	RE: 12.40 (3.7) LE: 12.50 (3.8)	-
León *et al.*[7]	ML	18-30	9.47 (1.66) 9.53 (1.79)	-
Edwards *et al.*[8]	PU	11-65	-	-
Win-Hall *et al.*[9]	PU	21-31	4.76 (1.32)	-
Kim[10]	ML	16-20 21-25 26-30	10.75 (1.14) 8.66 (1.17) 7.25 (0.87)	-
Ostrin *et al.*[11]	PU ML at far	31-35	7.64 (1.88) 4.40 (1.61)	PU-ML: 3.24
Rosenfield *et al.*[12]	PU PD ML	23-29	10.11 (0.73) 9.50 (0.71) 9.10 (0.73)	PU-ML: 1.01 PU-PA: 0.61 PA-ML: 0.40
Wold *et al.*[1]	ML at far	23-28	7.02 (2.00)	-
Kragha[13]	PU ML	18-22 23-27 28-32	10.38 (1.89) 9.36 (1.81) 7.44 (1.78) 9.18 (1.77) 8.13 (1.70) 6.52 (1.81)	PU-ML: 1.20 D for 18-22 1.23 D for 23-27 0.93 D for 28-32
Antona *et al.*[14]	PU PD ML	18-32	13.08 (2.79) 11.25 (1.77) 8.56 (1.52)	PU-PA: 1.83 PU-ML: 4.52 PA-ML: 2.69
Rambo *et al.*[15]	PU, ML	Mean: 27.7	-	PU-ML: 1.49
Hokoda *et al.*[16]	PU, ML	21-28	-	PU-ML: 0.54
Chen *et al.*[17]	PU MPU	7-28	RE: 12.29 (2.41) LE: 12.85 (2.61) RE: 12.06 (1.99) LE: 12.28 (2.16)	RE, PU-MPU: 0.23 LE, PU-MPU: 0.37

PU: Push-up, PD: Push-down, ML: Minus lens, MPU: Modified push-up, RE: Right eye, LE: Left eye

Materials and Methods

In this analytical–descriptive study, subjects were randomly selected from the list of students. Fifty-two students, who met the inclusion criteria (listed below), were entered into the study. The project was introduced to the subjects and their informed consent was obtained before starting the study. In addition, we assured the subjects that their information would be kept confidential in accordance with the tenets of the Declaration of Helsinki. Inclusion criteria comprised of: Visual acuity of 20/20 or better in each eye at both 6 m and 40 cm either with or without correction, no strabismus at 6 m or 40 cm, refractive error less than ± 2.00 D (sphere or cylinder), a lag of accommodation with Monocular Estimate Method (MEM) retinoscopy within 0.25-0.75 D, and no history of ocular trauma, ocular disease, amblyopia, aphakia or pseudophakia.

The refractive errors were determined initially by static retinoscopy, using a Heine ß-200 retinoscope, and subsequently refined by subjective refraction and dissociated red–green balance (duochrome) test.[3] Subsequently, the amplitude of accommodation was measured with the push-up, push-down, minus lens, and modified push-up methods. For all four techniques, this correction was mounted in a trial frame and normal room illumination was used. The subject's attention was directed to a 20/20 row of letters on a handheld reduced Snellen chart. Each test was performed monocularly on the dominant eye (determined by using the Miles test),[19] with the fellow eye being occluded. The order of carrying out the four techniques in each trial was randomized.

For the push-up method, the subjects initially viewed the target at a distance of approximately 40 cm and then the target was moved slowly toward him/her along the ruler. The subjects were instructed to keep the target as clear as possible and to report when it first became blurred. The endpoint was the first slight sustained blur, which was considered to be the point when the target could not be cleared after two or three seconds of viewing. The distance from the target to the spectacle plane was measured with a millimeter ruler and converted to diopters.[20]

In the push-down method, the accommodative target was advanced toward the subject until a significant blur was produced, and then the target was pushed away until the subject could just read the 20/20 row of letters. Again, the distance from the target to the spectacle plane was measured and converted to diopters.[3]

In the minus lens procedure, a reduced Snellen chart was positioned at 40 cm. The subjects were asked to fixate on the 20/20 row of letters on the chart, while a minus power was added (in 0.25 D steps) to the previously-determined subjective refraction until the letters became, and remained, blurred. The ML amplitude was taken as 2.50 D (the dioptric equivalent of the working distance) plus the amount of minus lens power added.[20]

The modified push-up method was similar to the push-up technique, except an additional - 4.00 lens was added to the distance refractive correction worn in the trial frame.[21]

After data collection, the data were analyzed with the SPSS.17 software, using the paired independent-sample *t*-test, repeated measurement analysis of variance (ANOVA), the Pearson correlation, and the intraclass correlation coefficient (ICC).

Results

From the 52 students under study, 30 (57.7%) were female and 22 (42.3%) male. The mean ages in all subjects and separately in females and males were 21.2 ± 1.4, 21.2 ± 1.3, and 21.2 ± 1.6 years, respectively. The age range was 18-25 years. The independent-sample *t* test did not show a significant difference between the mean ages of males and females ($P = 0.8$).

The mean (±1 SD) values for the push-up, push-down, modified push-up, and minus lens techniques are shown in Table 2. The mean difference, correlation, and Intraclass Correlation Coefficient (ICC) between the four procedures are shown in Table 3. Additionally, the Bland-Altman technique has also been used to compare the findings.[22] Here, the difference between each pair of values is plotted against the mean. These results are shown in Figs. 1a-c, 2a, b, and 3.

Discussion

Many clinicians have observed that patients show the highest accommodative amplitudes with the push-up method and the lowest with the minus lens technique. Even as the latter may be more accurate, the former is faster to perform, and therefore, more widely used. This study validates and quantifies the difference between the techniques, but also suggests small modifications the clinicians can make, to make the push-up technique more accurate.

Table 2: Mean, SD and 95% confidence interval of the amplitude of accommodation with different measuring methods

Techniques	PU	PD	MPU	ML
Mean±SD	11.21±1.85	10.92±1.69	10.99±1.02	9.31±1.61
95% CI	10.69-11.73	10.45-11.39	10.70-11.27	8.86-9.76

PU: Push-up, PD: Push-down, ML: Minus lens, MPU: Modified push-up, CI: Confidence interval, SD: Standard deviation

The results of this study showed that the push-up method results had an apparently higher accommodative amplitude [Table 2], compared to the other three methods. The minus lens technique had the lowest measured amplitude among the different methods, which was in agreement with the results of Ostrin *et al*.,[11] Rosenfield *et al*.,[12] Kragha[13] Antona *et al*.,[14] Rambo *et al*.,[15] and Hokoda *et al*.[16]

This difference between the methods is predictable according to the type of accommodative system stimulation. In the push-up method, corresponding to the decrease in the target distance, the angular size of the retinal image increases and also the proximal stimulation to the accommodation increases, inversely proportional to the target distance. Hence, the push-up method gives a higher value compared to other methods.[23]

In the minus lens method, there is minification of the retinal image due to the optical property of the concave lenses. Unlike the push-up method, the relative distance magnification is absent and proximal stimulation remains constant.[20] Generally, the above-mentioned reasons indicate why the push-up

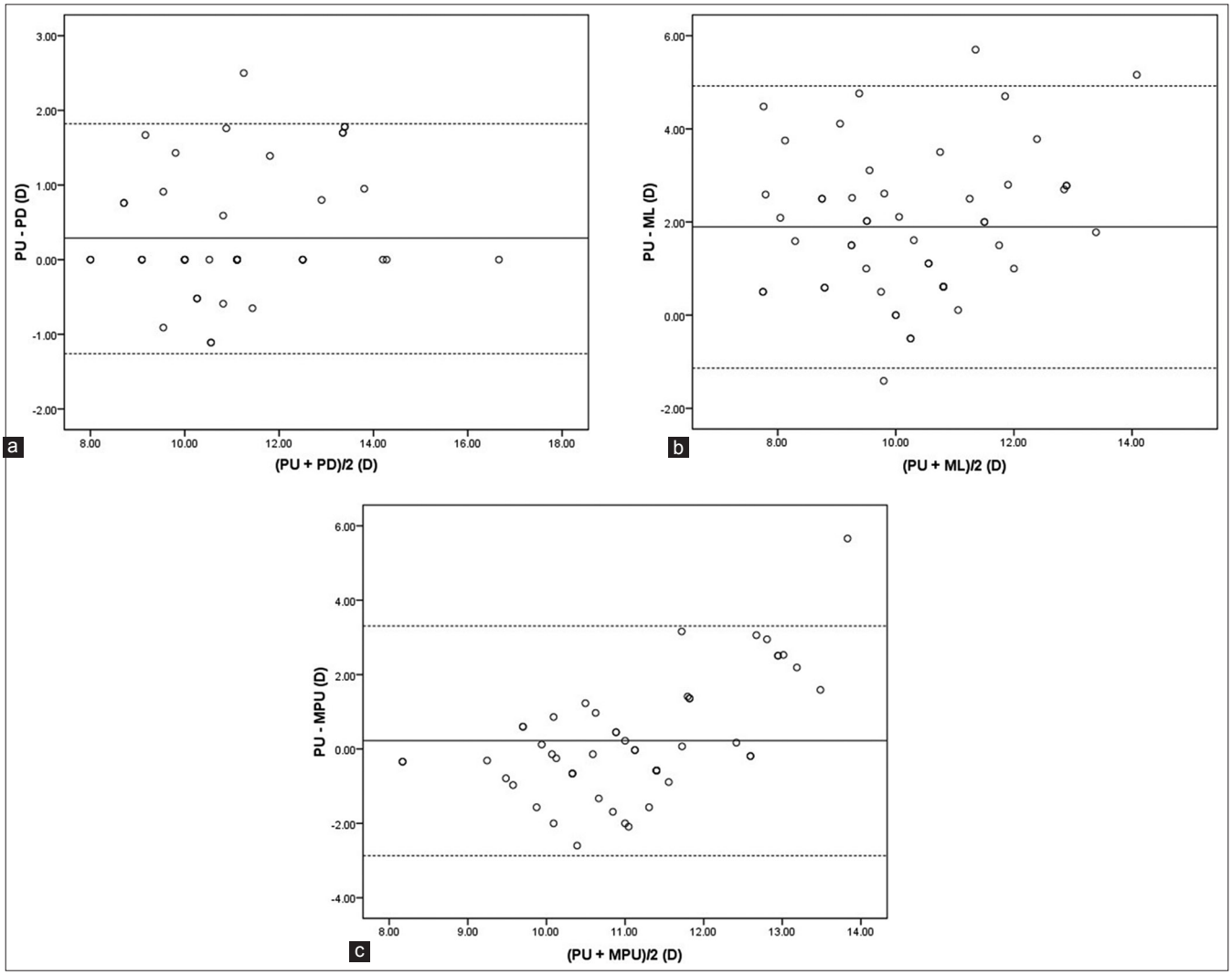

Figure 1: Agreement rate of the push-up method with the push-down (a), the minus lens (b), the modified push-up (c) techniques in determination of the accommodative amplitude associated with 95% CI for difference

Table 3: Mean difference, 95% limit of agreement, Correlation coefficient (r), ICC and Pairwise comparisons between different measuring methods

Method	Mean difference±SD (95% CI)	95% limits of agreement	*r* *P*	ICC	Bonferroni *P* value
PU-PD	0.28±0.79 (0.06 to 0.51)	−1.26-1.82 (± 1.54)	0.90<0.001	0.890	0.06
PU-ML	1.89±1.55 (1.46 to 2.33)	−1.14 to 4.92 (± 3.03)	0.60<0.001	0.377	<0.001
PU-MPU	0.22±1.58 (−0.21 to 0.66)	−2.87 to 3.31 (±3.09)	0.51<0.001	0.439	1.00
PD-MPU	−0.06±1.49 (−0.48-0.35)	−2.98 to 2.86 (± 2.92)	0.48<0.001	0.437	1.00
PD-ML	1.60±1.48 (1.19 to 2.02)	−1.30 to 4.50 (± 2.90)	0.59<0.001	0.407	<0.001
MPU-ML	1.67±1.51 (1.25 to 2.09)	−1.28 to 4.62 (± 2.95)	0.41 0.002	0.213	<0.001

r: Correlation coefficient, PU: Push-up, PD: Push-down, ML: Minus lens, MPU: Modified push-up, CI: Confidence interval, SD: Standard deviation, ICC: Intraclass correlation coefficient

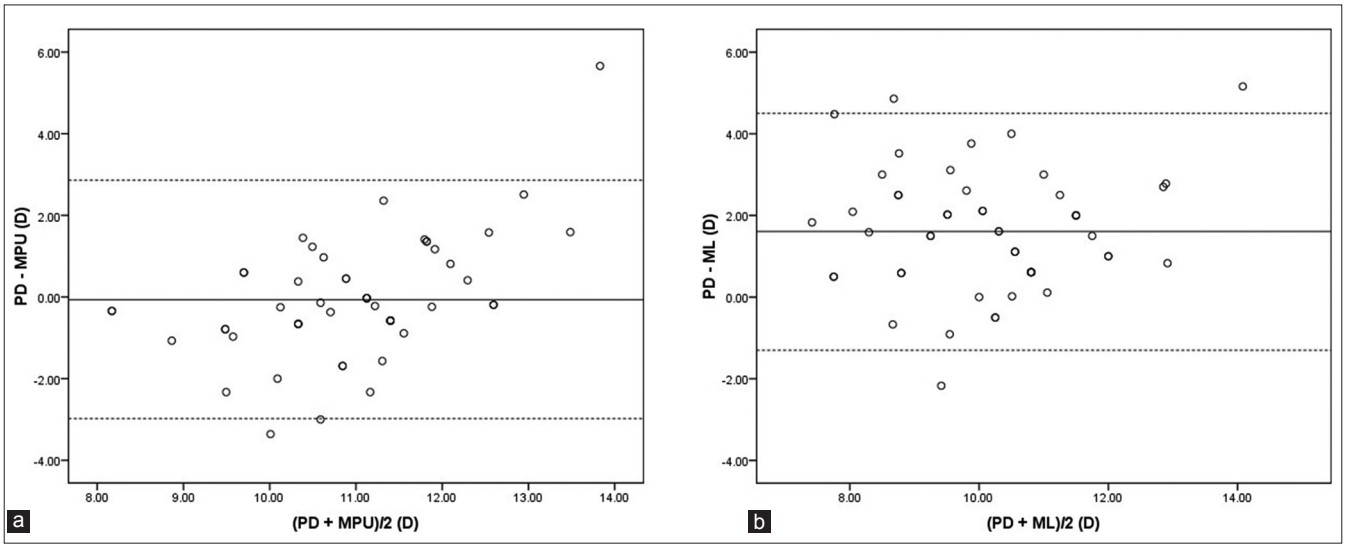

Figure 2: Agreement rate of the push-down method with the the modified push-up (a), the minus lens (b) techniques in determination of the accommodative amplitude associated with 95% CI for difference

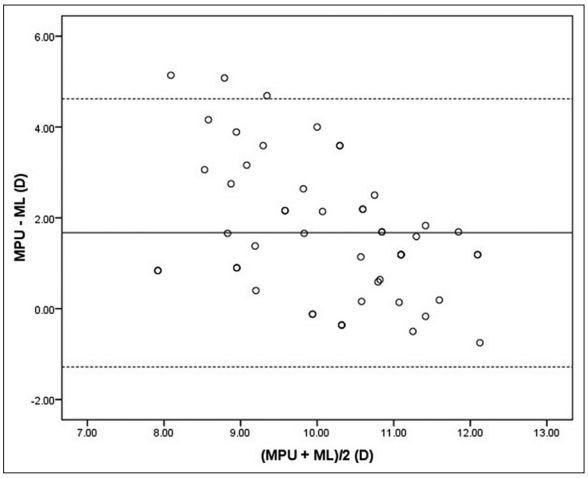

Figure 3: Agreement rate of the modified push-up method with the minus lens technique in determination of the accommodative amplitude associated with 95% CI for difference

amplitude is higher than the minus lens amplitude, although the minus lens method may be more accurate.

In addition, the descending order of values (i.e., push-up, modified push-up, push-down, and minus lens) were in concordance with the results of Antona *et al*.,[14] with an exception of the modified push-up method that was not performed in their study. However, it should be noted that the push-up and push-down findings in the present study were lower than those reported by Antona *et al*., while the minus lens mean (9.31 D) was higher than their reported value. This difference could be attributed to the difference in the mean age of their subjects (19.7 years vs. 21.2 years in the present study).[7]

When examining subjects of a similar age to those in the current investigation, León *et al*., reported a mean of 9.43 D (SD = 1.66) using the minus lens technique, which was very similar to the mean of 9.31 D (SD = 1.61) found here. In all methods, the standard deviation of amplitude was lower in our study. Although the mean difference between each method was

higher in their study compared to our results, another common point in the two studies was the highest mean difference, which was related to the push-up and the minus lens methods.

Comparing of different methods using the Bland-Altman technique showed a good agreement between the push-up and the push-down methods. This finding was in agreement with the results of Woehrle *et al*., who reported that the obtained amplitude with the pull-away method was comparable with the conventional push-up method.[24]

In addition, the Bland-Altman technique represented a good agreement between the push-up and the modified push-up methods, while the agreement was not so good between the push-up and the minus lens methods, the push-down and the modified push-up outputs, between the push-down and the minus lens results, and between the modified push-up and the minus lens methods.

Our findings, with the use of ICC, show an almost perfect agreement (0.890) between the push-up and the push-down methods, which is similar to the results of Atchison *et al*.[25] However, the finding is contrary to the results of Antona *et al*., who have found a poor agreement between the three methods, namely, push-up, push-down, and minus lens.[14] Furthermore, the current study has found a poor agreement between the modified push-up and minus lens techniques, unlike the results of Antona *et al*.[14]

With attention to the push-up and the modified push-up methods, the measured amplitude was lower in the modified push-up method. This was similar to the findings of Chen *et al*., but they found a higher mean difference between the two methods compared to the present study (0.4 vs. 0.2 D). Also, they determined a higher correlation between the two methods, and cited that these two methods could be used interchangeably. We did not find an agreement better than fair for those methods.[17]

Conclusions

The quick and easy assessment of the accommodative amplitude, using the push-up and the push-down methods compare favorably with the other methods. Especially, in the absence of a phoropter, the perfect agreement between these two methods can further emphasize their use as a routine procedure in the clinic, especially if a combination of the two techniques is used to offset their slight over- and underestimation. Finally, the results obtained from the modified push-up method are much more similar to the push-down results, rather than the results of the push-up method.

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Cite this article as: Momeni-Moghaddam H, Kundart J, Askarizadeh F. Comparing measurement techniques of accommodative amplitudes. Indian J Ophthalmol 2014;62:683-7.

Source of Support: Nil. **Conflict of Interest:** None declared.