

# A comparison of the conventional and modified push-up methods of measuring the near point of accommodation

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## Abstract

**Aim:** To compare the subjective near point of accommodation measurement with the RAF rule using the conventional (clear to blur) and modified (blur to clear) push-up methods.

**Methods:** Both methods of testing the near point of accommodation were carried out unocularly and binocularly in 32 visually normal participants (mean age: 20.08) with a range of visual experience.

**Results:** The modified push-up method (blur to clear) gave a near point of accommodation further away from the subject. A difference of 0.51 cm in the right eye, 0.61 cm in the left eye and 1.05 cm binocularly was found between the two methods which was statistically significant ( $p < 0.05$ ). No difference was found between naïve and expert groups ( $p < 0.05$ ). However, most participants reported that the end point was easier to judge with the modified method.

**Conclusion:** Despite being significantly different statistically, the difference between the two methods measuring the near point of accommodation with the RAF rule was small. The findings support the use of the modified method of measuring the near point of accommodation with the RAF rule, rather than the conventional method.

**Key words:** Accommodation, Blur to clear, Clear to blur, Conventional push-up method, Modified push-up method, Near point of accommodation, RAF rule

## Introduction

Accommodation is the ability of the lens to change its refractive power in order to focus on objects placed at different distances.<sup>1</sup> Measurements of accommodation aim to identify accommodation deficits that may be symptom producing. The most common method in orthoptic clinical practice is a subjective measurement of the near point of accommodation using the Royal Air Force (RAF) rule. Other subjective methods use a phoropter or a focometer<sup>2</sup> and objective methods include dynamic retinoscopy,<sup>3</sup> or using a Hartinger coincidence

refractometer<sup>2</sup> or a remote Haploscopic Videorefractor incorporating a PlusoptiX SO4.<sup>4</sup>

The near point of accommodation is the point nearest the subject that can be seen clearly<sup>5</sup> and it can be measured in two different ways using the RAF rule, both of which rely on accurate and reliable subjective responses. The conventional push-up method has been used for over a century,<sup>6</sup> during which a clear target is gradually moved closer to the subject until they report the point at which the target starts to blur. Measurements of accommodation (objective and subjective), in a small group of early presbyopes, have been shown to not differ as the target is moved closer to the subject from the point of first blur.<sup>7</sup> However, it should be recognised that the point of first blur will be slightly closer to the subject than the actual near point of accommodation.

The modified push-up method was first described by Scheiman and Wick.<sup>8</sup> The target is held at the end of the RAF rule closest to the subject, where it will be blurred, and is gradually moved away from the subject until they report it becomes clear. Subjective perception and reporting of blur is known to differ amongst individuals<sup>9</sup> and it has been suggested that the point at which a blurred target becomes clear is easier for a subject to judge, compared with a clear target beginning to blur. Previous studies comparing the conventional and modified push-up methods have provided conflicting results. Some studies have shown the two push-up methods give clinically and statistically similar results.<sup>10,11</sup> Yet others have found a statistically significant difference.<sup>12–14</sup> Most report that the conventional push-up method, with the end point being the point of first blur, gives a result closer to the subject than the modified push-up method<sup>10,12–16</sup> (i.e. a lower near point of accommodation (cm)). However, others report the modified push-up method gives an end point closer to the patient.<sup>11</sup> The interpretation of the results also differs between studies: for example Chen and O'Leary<sup>15</sup> concluded the two methods can be used interchangeably, despite finding statistically different results between them.

It is increasingly recognised that individuals with knowledge or experience of certain tasks can perform better and give more accurate responses than individuals who are naïve to the task.<sup>17</sup> Horwood and Riddell<sup>18</sup> found objective accommodation and vergence measures could be improved with practice, highlighting the need for caution when interpreting evidence from experienced observers and directly applying or comparing it with less experienced clinical populations.

The current study aimed to compare the conventional

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**Table 1.** Comparison of near point of accommodation measurements with the conventional and modified push-up methods

	Right eye		Left eye		Both eyes open	
	Conventional (cm)	Modified (cm)	Conventional (cm)	Modified (cm)	Conventional (cm)	Modified (cm)
Mean	8.59	9.10	8.72	9.33	7.76	8.81
Standard deviation	1.52	1.45	1.51	1.59	1.11	1.47
Standard error	0.27	0.26	0.27	0.28	0.20	0.26

and modified push-up methods of measuring the near point of accommodation in young visually normal participants. Of particular interest were differences between more and less experienced observers and whether participants found the end point easier to perceive with either method.

## Methods

### Participants

Approval for the study was granted by a local institutional ethics committee. Thirty-two orthoptic and non-orthoptic students were recruited to take part in the study. The inclusion criteria were: no history of ocular pathology, age range 18–25 years (to exclude presbyopic individuals), monocular visual acuity of 0.200 logMAR or better, no manifest deviation, stereo-acuity of 85 seconds of arc and a near point of convergence of 8 cm or better. Participants with refractive errors were included and were required to be wearing glasses or contact lenses during the assessment.

### Procedure

Once informed consent was gained, the testing procedure was explained and participants were assigned to either the naïve or expert group. All participants aware of the concept of clear and blur were placed in the ‘expert group’; these were typically second- or third-year orthoptic students, or first-year orthoptic students with previous experience of optometry. Those with no specific experience of blur were placed in the ‘naïve group’; these were typically first-year orthoptic students or non-orthoptic students.

The subjective near point of accommodation was measured in centimetres using both the conventional push-up method (target moved from clear to blur) and the modified push-up method (target moved from blur to clear). Each measurement was repeated three times. N5 print on the RAF rule was used as the target and the RAF rule was held in a slightly depressed position, with the cheek rests held in position by the participant. The conventional push-up method was tested with the target at the examiner’s end of the RAF rule each time. The participants were asked to report when the target started to blur;<sup>9</sup> they were encouraged to make a blurred target clear if they could before accepting the point they reported as first blur. The modified push-up method was tested with the target at the participant’s end of the RAF rule each time. Participants were encouraged to make the blurred target clear and were asked to report the point at which the target became clear.

The near point of accommodation was measured monocularly first, then binocularly. The method tested

first and the eye tested first for monocular testing was counterbalanced to reduce order effects. All testing was carried out by the same examiner (H.E.). Whilst the speed of movement of the target and the reaction time of each participant were not recorded, all efforts were made to keep the target speed constant and standardised between participants. The same encouragement was given for each method and each participant, the same clinical room with the same luminance was used and testing conditions were kept constant. After the testing was complete, participants were asked which end point, if any, they found easier to judge: the clear target starting to blur (conventional push-up method) or the blurred target becoming clear (modified push-up method).

## Results

The conventional push-up method resulted in near point of accommodation measurements that were slightly closer to the participants than those from the modified method. The near point of accommodation measurements from both methods are shown in Table 1 and Fig. 1. The variance across the groups was similar for both the conventional and modified push-up methods for the right eye, left eye and both eyes open.

Binocular and monocular measurements of the near point of accommodation were consistently closer to the participant with the conventional push-up method (i.e. lower measurements were recorded (cm)): 0.51 cm closer for right monocular testing, 0.61 cm closer for left monocular testing and 1.05 cm closer for binocular testing (Table 1). Using paired *t*-tests this difference was found to be statistically significant for the results for the right eye ( $p < 0.05$ ), left eye ( $p < 0.05$ ) and both eyes open ( $p < 0.001$ ).

Combining the binocular and monocular results for the right and left eyes, the mean near point of accommodation using the conventional push-up method was 8.35 cm and using the modified push-up method was 9.08 cm. A blurred target was therefore seen to become clear a mean of 0.73 cm further away from the participant, compared with the point when they saw a clear target start to blur. A two-way ANOVA was carried out on the data with the participant and push-up methods (conventional and modified) used as factors. The test showed a statistically significant difference between the two push-up methods when data from right eye, left eye and both eyes open were combined ( $F = 17.135$ ,  $df = 1.31$ ;  $p = 0.002$ ,  $p < 0.05$ ).

To analyse whether either method gave more variable results than the other, the difference between the standard deviations of each of the measures taken was analysed using a paired *t*-test. The standard deviations were not significantly different statistically when

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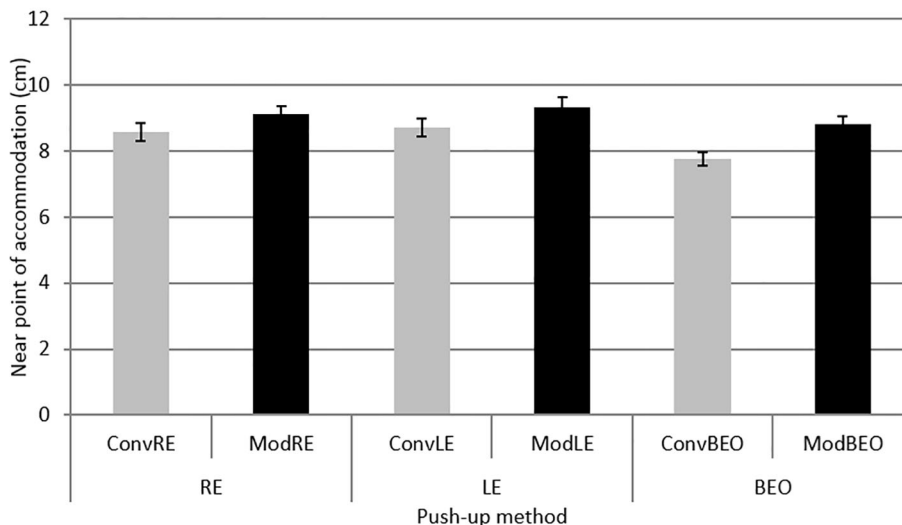


Fig. 1. A bar chart to show the mean near point of accommodation and standard error for the right eye (RE) and left eye (LE) separately and both eyes together (BEO) for the conventional (Conv) and modified (Mod) push-up methods.

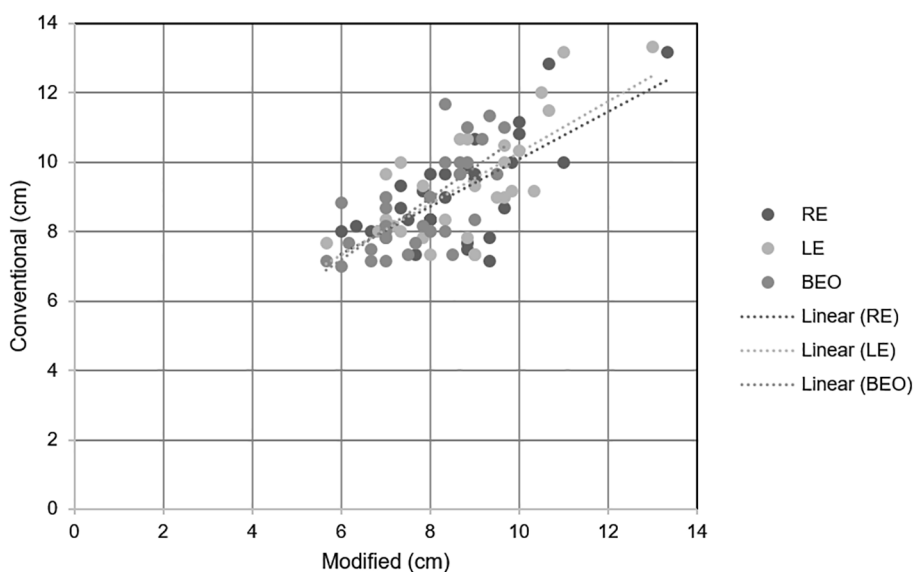


Fig. 2. A graph to show the near point of accommodation measured with the conventional push-up method plotted against near point of accommodation measured with the modified push-up method. Abbreviations as in Fig. 1.

comparing the two methods (right eye:  $p = 0.074$ , left eye:  $p = 0.402$ , both eyes open:  $p = 0.943$ ;  $p > 0.05$ ). The results of the two methods were also compared to see if they showed a correlation. The Pearson correlation coefficients were found to be high when comparing the results for the right eye ( $r = 0.71$ ), left eye ( $r = 0.70$ ) and both eyes open ( $r = 0.71$ ) (Fig. 2).

The data were further analysed to compare naïve and expert participants. The results show there was no statistically significant difference between the two groups ( $F = 0.345$ ,  $df = 1.30$ ;  $p = 0.5614$ ,  $p > 0.05$ ). Of the 32 participants that took part, 27 considered the modified push-up method the easier end point to judge

and 5 participants thought the conventional push-up method was the easier end point to judge. No participants reported diplopia during binocular testing for either method.

#### Discussion

This study found a difference between the conventional (clear to blur) and modified (blur to clear) push-up methods of measuring near point of accommodation, which was statistically significant. Conventional push-up measurements were found to be closer to the participant (lower measurement (cm)) compared with the modified

push-up method, which is comparable to the findings of several other studies.<sup>10,12-16</sup> Although the results from the two methods were significantly different statistically, clinically the difference was small as the conventional push-up method produced results that were, on average, 0.73 cm closer to the participant than the modified method. When comparing right eye, left eye and binocular measurements, the difference was still low (right eye: 0.51 cm, left eye: 0.61 cm, both eyes open: 1.05 cm). Both the conventional and modified push-up methods had a small and comparable standard deviation, meaning most participants achieved a near point of accommodation close to the mean for both the push-up methods. A strong correlation was also found between the two push-up methods monocularly and binocularly. This indicates that all individuals who had a closer (lower) near point of accommodation measurement with the conventional push-up method also achieved a closer (lower) near point of accommodation measurement with the modified push-up method. Other studies have also found a strong correlation between the two push-up methods.<sup>10,15,16</sup>

Differences in methodology make direct comparisons with other studies difficult, yet the methodology of this study most closely resembles that of Chen and O'Leary.<sup>15</sup> This study found results that were further away from the participant (higher mean near point of accommodation measurements) for the conventional push-up method (8.59 cm in right eye, 8.72 cm in left eye and 7.76 cm with both eyes open) compared with their study (8.13 cm in right eye, 7.79 cm in left eye and 7.06 cm with both eyes open). However, these differences may be due to the different end points used, as this study used the first blur point but Chen and O'Leary<sup>15</sup> used the point at which the blurred target could not be made clear. The mean values for the modified push-up method found in this study were 9.10 cm in right eye, 9.33 cm in left eye and 8.81 cm with both eyes open; whereas Chen and O'Leary<sup>15</sup> found 8.28 cm in right eye, 8.14 cm in left eye and 7.79 cm with both eyes open. The difference could be due to the different type and size<sup>19</sup> of targets used by Chen and O'Leary<sup>15</sup> for the different push-up methods. They used LEA symbol targets equivalent to N8 on the RAF rule for the modified push-up method and the N5 line for the conventional push-up method, while this study used the N5 line as the target for both methods. Another difference between the two studies was mean age of the participants, which was 20.08 years for the current study and 13.03 years for the Chen and O'Leary<sup>15</sup> study, which may contribute to their lower measurements. Taub and Shallo-Hoffman<sup>11</sup> reported measurements closer to the participant with the modified push-up method (8.54 cm) compared with the conventional push-up method (9.10 cm) in an adult population similar to ours (age range 21-36 years, mean age 25.5 years). The difference between their results and those found in our study could be due to the use of a different instrument, the Accommodative Convergence Rule (ACR); however, the instrument appears similar to the RAF rule from images and the description.<sup>11</sup> Koslowe *et al.*<sup>16</sup> also used the ACR, but in contrast to Taub and Shallo-Hoffman<sup>11</sup> found measurements closer to the participant for the conventional push-up method.

A reason for the conventional push-up method consistently producing a near point of accommodation measurement closer to the participant could be the influence of different stimuli. The subject is unaccommodated for the modified push-up method and is required to bring the target into focus with blur being the major stimulus, whereas for the conventional push-up method the subject is required to gradually maintain fusion and clarity. Convergence, binocular disparity, blur and proximity cues have all been described as being responsible for driving accommodation.<sup>5,20,21</sup> The differing strength or influence of these cues may be another reason for the difference between the results of two methods.

Koslowe *et al.*<sup>16</sup> and Antona *et al.*<sup>13</sup> moved the target at a standardised rate of 5 cm/s during their studies. Both studies tested the right eye only, the conventional push-up method giving an average near point of accommodation of 7.38 cm<sup>16</sup> and 7.64 cm<sup>13</sup> and the modified push-up method giving an average near point of accommodation of 9.04 cm<sup>16</sup> and 8.89 cm.<sup>13</sup> Whilst target speed was not specifically standardised in the current study, the same observer tested all participants following a standardised testing protocol which aimed to reduce variability in the results gained. The results from these studies<sup>13,16</sup> are more comparable to our modified push-up method results (9.10 cm) than our conventional push-up method results (8.59 cm) for the right eye. The lack of standardisation of target speed is therefore acknowledged as a potential source of error in this study. It is also acknowledged that the reaction times of participants were not recorded or accounted for in the analysis of the results in this study and this could have introduced a difference in the results of the two methods.

Results from this study showed no statistically or clinically significant difference between measurements from the naïve group compared with the expert group. This is in contrast to the findings of Horwood and Riddell<sup>18</sup> who found a significant difference between naïve and expert observers when measuring vergence and accommodation. The difference between these results may be due to the different tests used: Horwood and Riddell<sup>18</sup> used a laboratory setup to measure different aspects of accommodation and vergence and we used the RAF rule to measure the near point of accommodation, as would be measured clinically. The alternative explanation could be that our participants were not truly 'naïve' or 'expert' and therefore were not different enough, and may be different to the observer groups used by Horwood and Riddell.<sup>18</sup>

Chen and O'Leary<sup>15</sup> concluded that the modified and conventional push-up methods of measuring the near point of accommodation with the RAF rule could be used interchangeably, yet the findings of this study do not support that conclusion. Instead it is suggested that the method used to measure the near point of accommodation should be recorded, as well as the result gained, to improve test accuracy, particularly when comparing results measured on different visits. The end point of the test used should also be considered, as patients are commonly asked to report the point at which the target starts to blur when the conventional push-up method is used. This point of first blur, as used in this

study, is not strictly the near point of accommodation; instead the point at which the target was last seen to be clear is. It is therefore recommended that the end point of the test used should also be recorded to further improve test accuracy. The majority of participants (27 of 32) reported it was easier to judge the end point of the test using the modified method, when the target was moved from blurred to clear. Whilst this evidence cannot be considered conclusive, it is an area that warrants further study to improve the subjective testing of the near point of accommodation.

## Conclusion

The conventional and modified push-up methods can both be used to measure the near point of accommodation subjectively; the two methods are comparable and the results are strongly correlated. The modified push-up method will give a measurement slightly further away from the participant (higher measurement (cm)) compared with the conventional method, therefore it is not recommended that the two methods be used interchangeably. Instead it is recommended that the method used, the end point reported and the result measured should all be documented to help improve testing accuracy and standardisation. Most participants found the end point of the modified push-up method easier to judge compared with the conventional method, but further study is required to investigate whether one method is superior to the other or whether both methods are important clinically.

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