Original Article

Revisiting the impact of phenylephrine hydrochloride on static and dynamic accommodation

Samrat Sarkar[1], Ali Mohammed Hasnat[2], Shrikant R Bharadwaj[1,2]

Purpose: Phenylephrine hydrochloride (PHCl), a commonly used mydriatic agent, causes a small but significant deterioration of accommodation. The relative roles of pharmacology and optics in this deterioration, however, remain unascertained. The study determined the combined impact of PHCl concentration (pharmacology) and pupil size (optics) on the static and dynamic characteristics of accommodation. **Materials and Methods:** A total of 16 emmetropic Indian adults viewed a high-contrast visual target that switched between 67 and 33 cm viewing distance (1.5D stimulus) with their right eye (left eye occluded using infrared transmitting filter) through natural pupils and through 8, 6, 4, and 1 mm diameter artificial pupils. This protocol was repeated once without PHCl and once each with 2.5%, 5%, and 10% PHCl. Consensual accommodation of the left eye was recorded using infrared photorefraction (60 Hz). **Results:** Relative to no PHCl, the horizontal pupil diameter of left eye was significantly larger ($P < 0.001$) and the response magnitude and peak velocity of accommodation and disaccommodation were modestly but significantly smaller ($P < 0.02$ for all) for all concentrations of PHCl tested. There was no significant difference in these parameters across the three drug concentrations ($P > 0.4$ for all). The response magnitude and peak velocity also decreased significantly with pupil diameter, at similar rates for the no PHCl and the three PHCl conditions ($P < 0.001$ for all). **Conclusion:** The reduction in accommodative performance with all drug concentrations and with pupil diameter suggests independent roles of pharmacology and optics in determining accommodative performance with PHCl. The reduction in accommodative performance is, however, modest and may be clinically irrelevant in Indian eyes.

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Achieving pupil dilation (mydriasis) without affecting the accommodative ability of the eye (cycloplegia) is useful in many clinical and research contexts. Phenylephrine hydrochloride (PHCl), a synthetic sympathomimetic amine that acts directly on the α-receptor of the iris dilator muscle, is routinely used in the clinic for this purpose.[1] Typically, PHCl causes maximum mydriasis between 60 and 90 min after instillation, with the effect being greater in lighter than darker irides[2] and greater for higher (10%) than lower (2.5%) concentration of the drug.[3]

While PHCl is not expected to hamper accommodative performance, previous studies have observed a small negative impact of the drug on the static and dynamic characteristics of accommodation.[4-6] The near point of accommodation measured subjectively using the push-up technique reduces by 20–30%, the magnitude of accommodative step responses decreases by about 40% and the time taken to complete the response increases by about 300 ms, all after 1-hour of drug instillation.[4-6] The change in resting focus (i.e., accommodative state in the absence of any form vision) after drug instillation is somewhat variable, with one study showing a hyperopic shift of about 0.3D[5] and another study showing no change in resting focus after drug instillation.[7] All these results have been observed in Europeans or North-American Caucasians with light-colored irides. Whether PHCl will have a similar impact on the accommodative performance of Indians with significantly darker irides remains unknown.

Any reduction in accommodative performance with PHCl could be due to the pharmacological effect of the drug on ciliary muscle or due to optical changes in the eye following mydriasis or due to a combination of the two. While accommodative step responses are driven predominantly by parasympathetic innervation, there is a modest level of sympathetic input to the ciliary muscle that opposes the activity of parasympathetic innervation.[8] The hyperopic shift in resting focus of accommodation with 10% PHCl may arise from an increase in sympathetic innervation to the ciliary muscle caused by the sympathomimetic nature of PHCl.[1,5] Alternatively, the decrease in optical depth-of-focus (DOF) and increase in higher-order aberrations (HOAs) could also influence the accommodative response of the eye.[9-12] For instance, the presence of positive spherical aberration has been shown to increasing the accommodative lag for high targets demands while negative spherical aberration does the reverse.[11] Relative impacts of these factors on accommodative performance have not been addressed thus far.

Overall, this study determined the relative impact of PHCl concentration and pupil diameter on the static and dynamic accommodative performance of Indian eyes.

[1]Visual Optics and Psychophysics Laboratory, Champalimaud Translational Centre for Eye Research, Prof. Brien Holden Eye Research Centre, L V Prasad eye Institute, Hyderabad, [2]Department of Clinical Epidemiology and Bio-Statistics, Prof. Brien Holden Eye Research Centre, L V Prasad eye Institute, Hyderabad, India

Correspondence to: Dr. Shrikant Bharadwaj, Brien Holden Eye Research Centre, L V Prasad Eye Institute, L V Prasad Marg, Road 2 Banjara Hills, Hyderabad - 500 034, Andhra Pradesh, India. E-mail: bharadwaj@lvpei.org

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Materials and Methods

Sixteen visually normal adults (9 females and 7 males; age range: 21–30 years; mean ± 1 SD = 24 ± 2.16 years) participated in the study after providing written informed consent that was duly approved by the local Institutional Review Board, L V Prasad Eye Institute, Hyderabad. The study was conducted according to the tenets of declaration of Helsinki. All subjects were emmetropic, except one who had 1.0 D of astigmatism. This error was discovered after the experiment concluded and therefore data was collected from this subject without any correction for the refractive error.

Subjects participated in four experimental sessions (once without PHCl or once each with 2.5%, 5%, and 10% PHCl), with each session consisting of five viewing conditions (viewing with natural pupils and with 8, 6, 4, and 1 mm diameter artificial pupils before the right eye). In all PHCl sessions, both eyes were dilated with three drops of a given concentration of the drug, instilled one drop every 15 min, and the experiment commenced 1 hour after instillation of first drop. At least 1 week was allowed between each experimental session to completely nullify the effect of previous PHCl instillation. The experimental sessions and viewing conditions were randomized across subjects.

Subjects watched a high contrast, high spatial frequency visual target (subtending 6.3° × 6.3° at 67 cm) displayed on one of the two liquid-crystal display (LCD) screens that were placed at 67 and 33, cm, respectively, before the subject [Fig. 1]. The front LCD screen was mounted such that its image was reflected off a beam-splitter to reach the subject without occluding the LCD screen behind it [Fig. 1]. In each trial, the visual target was electronically switched between the two LCD screens, once every 4 s, thereby creating an accommodative demand of 1.5 D. Subjects fixated on the target with their right eye while the left eye was occluded using the infrared (IR) transmitting filter [Fig. 1]. The viewing was therefore monocular while accommodative responses were recorded bilaterally. The subject's head was supported using a forehead rest and the pupil was placed 12–14 mm before the right eye and aligned such that the subject could comfortably view the target through the pupil. Each trial lasted for 15 s (15 s × 60 fps=900 frames) and the entire experimental session lasted for about 45 min. Breaks were given to the subject as and when required.

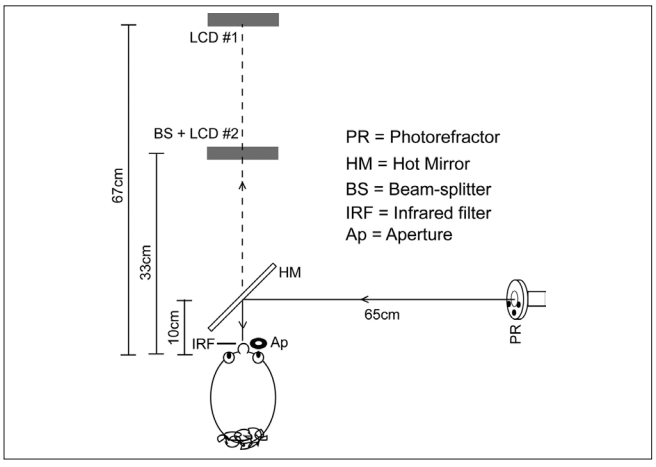

Figure 1: Experimental set-up with its key components highlighted

Accommodative responses and pupil diameter from both eyes were measured simultaneously at 60 fps using a custom-designed dynamic IR photorefractor [Fig. 1]. The photorefractor was aligned to the mid-line between the two eyes of the subject and images were obtained using light that was reflected from a beam-splitter [Fig. 1]. The beam-splitter reflected IR light and transmitted visible light, allowing simultaneous stimulation and recording of accommodative and pupil responses. Details of the device and its calibration characteristics can be found elsewhere.[13]

Data analysis was performed using Matlab® (Manufacturer: Mathworks Inc® Supplier: Nantucket, MA, USA), Excel® (Microsoft Corporation, USA), SPSS® (IBM® New York, USA) and R®. Raw photorefraction videos were analyzed using custom-designed Matlab algorithms that detected the pupil edge, first Purkinje image position and the slope of the luminance profile across the pupil in each video frame.[13] A frame was determined to contain a blink if the eyelid covered part or entire pupil of either eye and such frames were removed from the analysis.[13] Typically, a 15 s video with 900 frames contained approximately 2–3 blinks that spanned 6–10 frames each. Reflections from the IR filter or the artificial pupil before the right eye were rare and these frames were also discarded. Overall, about 30–50 frames were discarded from each video.

Horizontal pupil diameter was determined as the pixel separation between the left and right edges of the pupil image and it was converted into millimeter units by placing apertures of known diameter (10–3 mm in 1 mm steps) at the same plane where the subject was positioned in the main experiment. A total of 5 s long photorefraction videos were collected for each aperture and pupil diameter in pixel units was measured for each frame of a given video and averaged. A linear regression equation was fit to the data of mean pupil diameter (in pixels) against the corresponding values of aperture diameter (in millimeters) to obtain a conversion factor of 6.4 pixels per millimeter.

The raw stimulus, pupil diameter, and accommodation traces were smoothed using a 200 ms-averaging window. Accommodation position traces were subsequently differentiated using a 2-point central difference algorithm to obtain the velocity profile. Responses to accommodative (far-to-near focusing) and disaccommodative (near-to-far focusing) demands were analyzed separately as their static and dynamic characteristics have been shown to be different from each other.[14] A total of 2 s (60 fps × 2 s = 120 data points) of the most stable period of the response (identified visually from the raw data) was averaged for each viewing distance and the difference between them was calculated to determine the response amplitude. The corresponding peak velocity of the response was calculated from the highest point in the velocity profile. Multiple responses magnitudes and peak velocities in each condition from a subject were averaged to obtain the overall mean response magnitude and peak velocity. Only consensual responses from the occluded left eye, with no aperture placed before it, were considered for analyses in all sessions.

Separate multiple regression analyses with pupil size as a continuous variable and PHCl concentration as a

categorical variable was performed to determine the change in accommodative response magnitude, accommodative peak velocity, disaccommodative response magnitude, and disaccommodative peak velocity. Separate one-factor analysis of variance (ANOVA) analyses with *post hoc* Bonferroni correction were also performed to determine the impact of PHCl concentration on accommodative and disaccommodative response magnitude and peak velocity.

Control experiments

As will be shown in the results, accommodative performance to near-vision demands reduced only modestly after instillation of PHCl. The control experiments were designed to address three possible reasons for this outcome.

Control Experiment I determined if accommodation of subjects who participated in the main study could be completely paralyzed using a routinely used cycloplegic drug, 1% cyclopentolate hydrochloride.[15] The main experiment was repeated in four subjects, 1 hour after bilateral instillation of three drops of 1% cyclopentolate hydrochloride. The results would act as a positive control for the modest loss of accommodative performance achieved with PHCl in the main study.

Control Experiment II determined if the difference in accommodation with and without PHCl may be seen for larger near-visual demands.[5] The main experiment was repeated in eight subjects to 0.25D, 1.5D, 3.5D, and 5D near demand with and without 10% PHCl. A calibrated open-field auto-refractor (Grand Seiko WR-5100K®) was used to record accommodation despite significant near-pupillary miosis.[16] The custom-photorefractor requires a minimum pupil diameter of 3 mm for data collection.[13]

Control Experiment III determined the accommodative performance with 10% PHCl, when proximity was held constant and blur was the primary cue to the motor response. This was in contrast to the main experiment wherein accommodative responses were driven by a combination of blur and proximity cues. The main experiment was repeated in eight subjects by placing a -1.50D trial lens (same magnitude as the main experiment) before their right eye at 12–14 mm vertex distance (left eye occluded using the IR transmitting filter), once every 4 s for a total period of 30 s, while they watched the visual target at a constant viewing distance of 67 cm. Accommodative responses were recorded using the custom-photorefractor in this experiment.

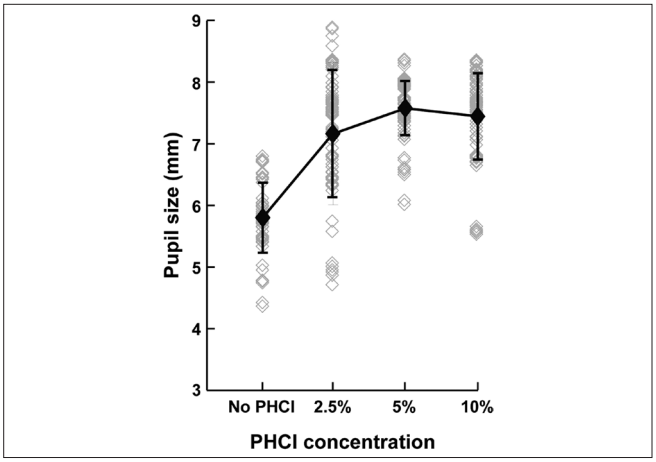

Figure 2: Mean (±1 SD) horizontal pupil diameter of the occluded left eye for the no PHCl condition and for 2.5%, 5%, and 10% PHCl concentrations. The open gray symbols show the individual data points while the closed black symbols show the mean data for each experimental condition

Results

Post dilation accommodation and pupil data were successfully collected from all participants. Predilation data could not be obtained in five subjects as their pupil diameters were below the minimum value required by the photorefractor to collect data. Data with 10% PHCl could not be collected from one subject due to his nonavailability for that session.

Fig. 2 plots the mean (±1 SD) horizontal pupil diameter of the occluded left eye for the three PHCl concentrations used in this study. One-factor ANOVA showed that the main effect of PHCl on the pupil diameter was statistically significant ($F(3, 202)=66.5$; $P < 0.001$). *Post hoc* test showed that the pupil diameters with the three PHCl concentrations were not statistically significantly different from each other ($P = 0.66$) but they were all statistically significantly larger than the pupil diameter obtained before dilation ($P < 0.001$). The data from the right eye (not shown here) were similar to those of the left eye.

Fig. 3 plots the accommodative response magnitude (top panels) and the corresponding peak velocity (bottom panels) as a function of pupil size in the no PHCl (panels a and e), 2.5% PHCl (panels b and f), 5% PHCl (panels c and g), and 10% PHCl (panels d and h) conditions. The data showed a larger inter-subject variability, with both parameters decreasing with pupil size for all concentrations of PHCl. The response magnitude changed significantly with pupil size at the rate of 0.06D/mm ($P < 0.001$) [Table 1]. The *y*-intercept of the multiple regression fit was 0.54D for the no PHCl condition and this

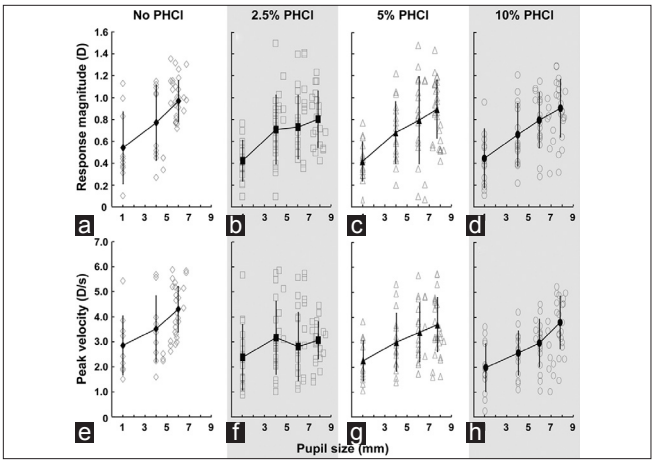

Figure 3: Response magnitude (panels a–d) and peak velocity (panels e–h) of accommodation plotted as a function of pupil size for the no PHCl, 2.5%, 5%, and 10% PHCl conditions. The open gray symbols show individual data from all subjects who participated in the study. The filled black symbols represent the mean (±1 SD) data for 1.0 ± 0.5, 4.0 ± 0.5, 6.0 ± 0.5, and 8.0 ± 0.5 mm pupil size bins. Data was grouped into different pupil size bins only to show the overall trend in the data. Pupil size was considered as a continuous variable for statistical analyses

Table 1: Output of the multiple regression analysis performed to assess the combined impact of phenylephrine hydrochloride concentration and pupil size on the magnitude and peak velocity of accommodative and disaccommodative step responses

	Coefficients	Estimate	95% CI		*P*-value
			Lower limit	Upper limit	
Accommodative response magnitude	Slope	0.06	0.05	0.08	<0.001
	Intercept no PHCl	0.54	0.44	0.64	
	Intercept 2.5% PHCl	0.39	0.19	0.59	<0.001
	Intercept 5% PHCl	0.39	0.18	0.59	<0.001
	Intercept 10% PHCl	0.38	0.18	0.38	<0.001
Accommodative peak velocity	Slope	0.19	0.13	0.24	<0.001
	Intercept no PHCl	2.90	2.49	3.31	
	Intercept 2.5% PHCl	2.09	1.27	2.91	<0.001
	Intercept 5% PHCl	2.18	1.36	3.00	<0.001
	Intercept 10% PHCl	1.87	1.46	2.7	<0.001
Disaccommodative response magnitude	Slope	0.05	0.04	0.07	<0.001
	Intercept no PHCl	0.51	0.41	0.62	
	Intercept 2.5% PHCl	0.39	0.18	0.60	0.02
	Intercept 5% PHCl	0.39	0.19	0.61	0.03
	Intercept 10% PHCl	0.38	0.17	0.59	0.01
Disaccommodative peak velocity	Slope	0.11	0.06	0.16	<0.001
	Intercept no PHCl	2.44	2.07	2.79	
	Intercept 2.5% PHCl	2.37	1.64	3.1	0.72
	Intercept 5% PHCl	2.15	1.42	2.88	0.13
	Intercept 10% PHCl	2.18	1.44	2.91	0.17

The *P* values for slopes in the last column of the Table indicate statistical significance of the rate of change of the dependent variable with pupil size. The *P* values for the intercepts indicate statistically significance of that concentration of phenylephrine hydrochloride when compared with the intercept of the no phenylephrine hydrochloride condition

was significantly different from zero ($P < 0.001$) [Table 1]. The *y*-intercepts reduced to 0.39D, 0.39D, and 0.38D for the 2.5%, 5%, and 10% PHCl conditions, respectively [Table 1]. One factor ANOVA with *post hoc* Bonferroni correction showed that the response magnitudes across all pupil sizes for the three PHCl concentrations were not statistically significantly different from each other ($P > 0.8$ for all) but they were all significantly different from the no PHCl condition ($P < 0.03$ for all).

Peak velocity of accommodation changed at the rate of 0.19D/s per unit change in pupil size ($P < 0.001$), with a *y*-intercept of 2.90D/s ($P < 0.001$). The *y*-intercepts for the 2.5%, 5%, and 10% PHCl conditions were 2.09, 2.18, and 1.87D/s, respectively [Table 1]. One factor ANOVA with *post hoc* Bonferroni correction showed that peak velocity of accommodation with no PHCl was significantly larger that those with all three concentrations of PHCl ($P < 0.01$ for all) while the data for the three drug concentrations were not significantly different from each other ($P > 0.6$ for all).

Fig. 4 plots the disaccommodative response magnitude (top panels) and the corresponding peak velocity (bottom panels) as a function of pupil size in the no PHCl (panels a and e), 2.5% PHCl (panels b and f), 5% PHCl (panels c and g), and 10% PHCl (panels d and h) conditions. Disaccommodative response magnitude changed with pupil size at the rate of 0.05D/mm, with a *y*-intercept of 0.51D ($P < 0.001$ for both) [Table 1]. The peak velocity of disaccommodation also changed at the rate of 0.11D/smm with pupil size, with a *y*-intercept of 2.29D/s ($P < 0.001$ for both) [Table 1]. The change in disaccommodative

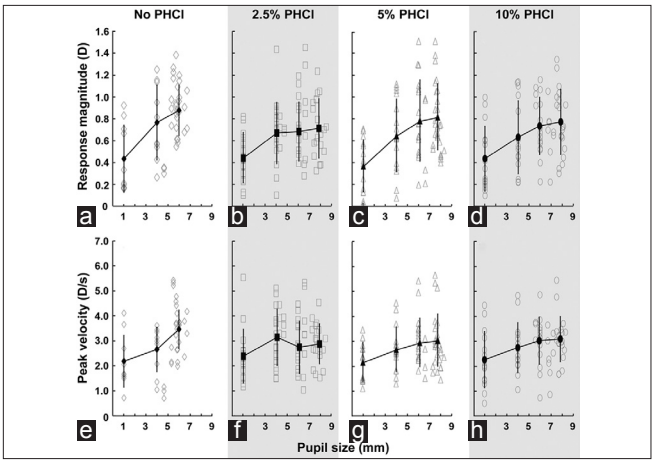

Figure 4: Response magnitude (panels a–d) and peak velocity (panels e–h) of disaccommodation plotted as a function of pupil size for the no PHCl, 2.5%, 5%, and 10% PHCl conditions. All other details are same as Figure 3

response magnitude with PHCl concentration approached statistically significance, with response magnitudes for all three PHCl concentrations similar to each other but smaller than the no PHCl condition [Table 1]. The change in disaccommodative peak velocity with PHCl was not statistically significant [Table 1].

Overall, these results indicate that PHCl had a small but statistically significant negative impact on the response

magnitude and peak velocity of accommodation but not that of disaccommodation.

One-factor ANOVA with *post hoc* Bonferroni test showed that the accommodative responses in *Control Experiment I* with 1% cyclopentolate HCl were significantly smaller than those obtained before and after instillation of 10% PHCl ($P < 0.001$) (Fig. 5, panel a). The responses before and after instillation of PHCl were not different from each other ($P < 0.001$) (Fig. 5, panel a). As expected,[15] 1% cyclopentolate HCl had the desired cycloplegic effect on all four subjects while 10% PHCl had only a modest impact on the accommodative performance of these subjects.

In *Control Experiment II*, the monocular accommodative responses in Control Experiment II increased with near-vision demand with and without PHCl, with both groups showing similar 'lag' of accommodation (Fig. 5, panel b). Two-factor ANOVA showed significant main effect of viewing distance on the accommodative response magnitude ($F(3, 55) = 143.49$; $P < 0.001$) and no significant main effect of PHCl instillation ($F(1, 55) = 0.021$; $P = 0.89$) or interaction between the two factors ($F(3, 55) = 0.119$; $P = 0.95$) was not statistically significant. Accommodative responses corresponding to 0.25D and 1.5D viewing distances were not significantly different from each other ($P = 0.49$) while the responses at all other viewing distances were significantly different from each other ($P < 0.001$).

In *Control Experiment III*, the mean (±1 SD) accommodative response obtained with and without 10% PHCl was slightly larger when accommodation was stimulated by switching the visual target from one viewing distance to another (i.e., in the presence of proximity cues) than when the demand was stimulated using negative lenses (i.e., when the proximity cue was held constant) (Fig. 5, panel c). Two-factor ANOVA showed a marginally significant main effect of proximity on the accommodative response magnitude ($F(1, 27) = 4.22$; $P = 0.05$) and no significant main effect of PHCl instillation ($F(1, 27) = 1.42$; $P = 0.24$) or interaction between the two factors ($F(1, 27) = 0.18$; $P = 0.68$).

Discussion

Previous studies that had demonstrated a small but significant reduction in accommodative performance with PHCl did not differentiate the pharmacological effect of the drug from the optical changes that happen after mydriasis.[4-6] For instance, the near-point of accommodation measured before PHCl instillation using the clinical push-up technique could be exaggerated because of an increase in optical DOF due to pupil miosis.[10] A more realistic estimate of the NPA would be obtained after mydriasis due to the reduction in optical DOF.[10] Any change in NPA following PHCl instillation may therefore reflect underlying changes in the optical DOF. Further, the accommodative system may interact with the HOAs of the eye to optimize retinal image quality.[9,11,12] The magnitude of HOAs are expected to increase following pupil dilation[17] and, therefore, any change in the accommodative response with PHCl might also reflect the interaction between blur and higher-order aberrations to optimize retinal image quality.

This study determined the combined impact of PHCl concentration and pupil diameter on the response magnitude and peak velocity of accommodation to determine the relative contribution of pharmacology and optics on accommodative performance. If accommodative performance were determined entirely by the optical effect of mydriasis, then the response magnitude and peak velocity would be similar with and without PHCl—the data would however span a larger range of pupil diameters after mydriasis than before mydriasis. Alternatively, if accommodative performance were determined entirely by the pharmacology of PHCl or by a combination of pharmacology and optics, then the response magnitude and peak velocity of accommodation would reduce by a constant value for all pupil diameters with PHCl, than without PHCl. Five key results were observed:

1. Pupil diameters obtained with the three concentrations of PHCl were not significantly different from each other but they were all significantly larger than the no PHCl condition [Fig. 2].
2. Response magnitude and peak velocity of accommodation obtained with the three PHCl concentrations were not significantly different from each other but they were modestly, albeit statistically significantly, smaller than those in the no PHCl condition [Fig. 3, Table 1].

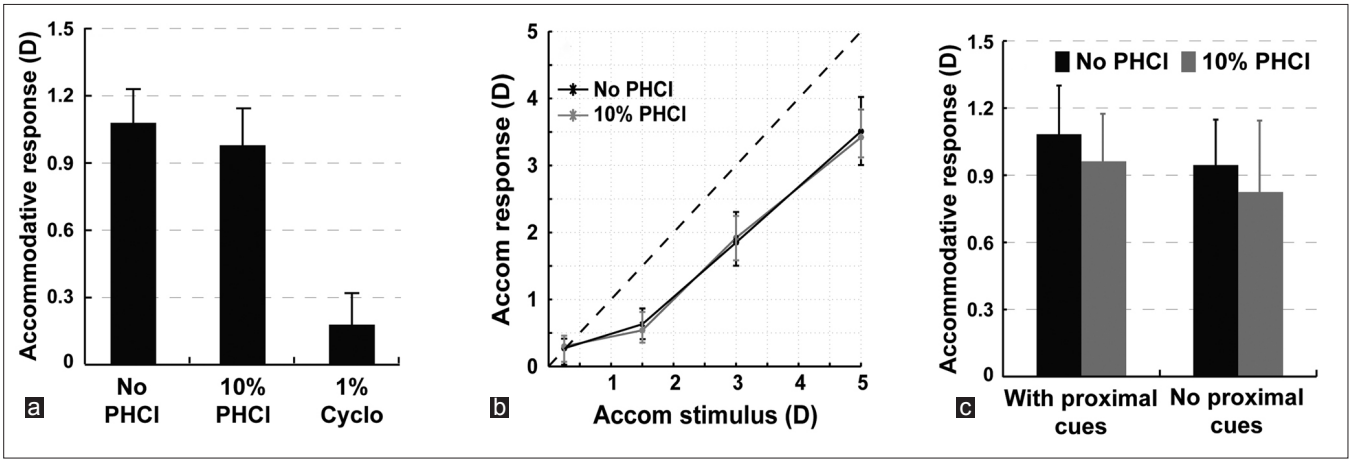

Figure 5: (Panel a) Mean (±1 SD) accommodative response obtained from control experiment I. (Panel b) Mean (±1 SD) accommodative response plotted as a function of the accommodative stimulus from control experiment II. (Panel c) Mean (±1 SD) accommodative response obtained from control experiment III

3. The reduction in accommodative response with 10% PHCl remained modest for accommodative demands of up to 5D [Fig. 5, panel b] and with or without proximity cues [Fig. 5, panel c].
4. Deterioration in response magnitude and peak velocity of disaccommodation following PHCl instillation was smaller than those observed for accommodation [Fig. 4, Table 1].
5. The rate of change of accommodative and disaccommodative response magnitude and peak velocity with pupil size was similar before and after PHCl instillation [Fig. 3 and 4, Table 1].

When compared with no PHCl condition, the response magnitude and peak velocity of accommodation decreased at the rate of 0.06D/mm and 0.19D/smm, respectively, for all three concentrations of PHCl [Fig. 3 and Table 1]. The *y*-intercept of the multiple regression analysis (i.e., the response magnitude and peak velocity when the pupil size was zero) was lesser by 0.11D and 0.95D/s, respectively, for all three concentrations of PHCl when compared with the no PHCl condition [Fig. 3 and Table 1]. There appeared to be no obvious interaction between drug concentration and pupil size on accommodative performance, suggesting that the pharmacological effect of PHCl and the optical effect of increased pupil diameter following PHCl instillation both contribute toward the reduction in accommodative performance. The reduction in accommodative performance is, however, modest and does not carry a large clinical significance. This drug could therefore be used to achieve pupil mydriasis without dramatically hampering accommodation.

While the main results of this study were qualitatively similar to the study by Mordi *et al.*,[5] the magnitude of change in pupil diameter and accommodative response seen here were smaller than those observed earlier. The overall mydriasis of about 1.8 mm achieved with 10% PHCl, relative to no PHCl, was much smaller than the mydriasis of about 3.2 mm observed by Mordi *et al.* for the same two viewing conditions [Fig. 2].[5] The accommodative response for the 1.5D stimulus reduced by about 0.11D for all pupil sizes in this study while it reduced by up to 0.3D for the same accommodative demand in the Mordi *et al.* study[5] [Fig. 3, Table 1]. The magnitude of reduction was also approximately constant for accommodative demands of up to 5D in this study while it increased with increasing accommodative demands in the study by Mordi *et al*.[5] [Fig. 5, panel b]. The small reduction in the peak velocity of accommodation with PHCl is qualitatively akin to the increase in response duration of accommodation observed by Mordi *et al.* [Fig. 3, panel b].[5] These results suggest that a given concentration of PHCl has a relatively weaker effect on the pupils and accommodation of the 16 Indian eyes with darker irides than those of European and North-American Caucasian eyes with lighter irides. This interpretation is in line with the general expectation that PHCl tends to be a more effective mydriatic in light irides than in dark irides.[2,18] The current study had a sample size of only 16 adults and therefore quantitative inferences may not be drawn for the entire population from this data. However, given that most Indians have dark irides, it is expected that the responses of the population may be qualitatively similar to those observed here.

From a pharmacology standpoint, the modest reduction in accommodative and disaccommodative performance with PHCl is somewhat expected given the sparse nature of adrenergic input to the ciliary muscle and its limited role in regulating the dynamic accommodative responses of the eye.[19,20] Even when present, the adrenergic input appears to act via the β_2 receptors of the ciliary muscle that are relatively immune to PHCL activity.[1,19] Alternatively, the bioavailability of PHCl at the level of iris dilator and ciliary muscle might be constant for all three concentrations, thereby resulting only in a modest loss of accommodation that is independent of drug concentration [Figs. 3 and 4, Table 1]. This possibility is also supported by the saturation of mydriasis achieved here for all three concentrations of PHCl [Fig. 2]. Indeed, higher concentration of PHCl (10%) is contraindicated for young children due to their systemic side effects.[1] The current results suggests that a lower concentration of the drug (2.5% or 5%) may be as effective as the 10% concentration to achieve the same magnitude of mydriasis [Fig. 2].

The reduction in accommodative performance with pupil size is also expected based on an increase in the optical DOF that is associated with a reduction in pupil size.[10] Accommodative response magnitude decreases progressively with decreasing pupil size, with the responses reaching a near-zero value for pupil diameters < 0.5 mm.[21,22] The current data show the same trend and extend the results for the dynamics of accommodation as well [Figs. 3 and 4]. The reduction in peak velocity of accommodation reflects a slower rate of change of ciliary muscle contraction in response to the accommodative demand and this may be concurrent to the reduction in response magnitude (main-sequence plot).[14] Our current understanding of the impact of HOAs on accommodation suggests that the response for a given stimulus might be smaller in the presence of some HOAs like spherical aberration and coma in order to optimize retinal image quality.[9,11,12] While the pattern of HOAs was not quantified in this study, their overall magnitudes are expected to increase with an increase in pupil diameter.[17] There was, however, no obvious trend toward a reduction in the accommodative response with increasing pupil sizes—if any, the response reduced with decreasing pupil diameters.

Conclusions

This study determined the combined impact of PHCl concentration and pupil size on the accommodative performance of Indian adults. The results showed that the three concentrations of PHCl used here (2.5%, 5%, and 10%) induce significant mydriasis with only a modest reduction in accommodative performance. Accommodative performance also decreased with pupil size and the rate of reduction with pupil size was similar before and after PHCl instillation. These results suggest that PHCl could be used in a clinical or research setting to achieve pupil mydriasis without dramatically hampering accommodation.

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