Original Article

Changes in vergence and accommodation parameters after smartphone use in healthy adults

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Purpose: To assess pre and post vergence and accommodation parameters after monitored reading on a smartphone device. **Methods:** This prospective comparative study was performed in a tertiary eye care center for a duration of 6 months (December 2017 – May 2018). A total of 47 healthy emmetropic subjects of age group ranging from 18-30 years were recruited for the study. Participants underwent an initial visual screening protocol, followed by accommodation and vergence parameters assessment. The subjects were given reading text of optotype N6 at 40cm working distance for 30 minutes in a smart phone device. Pre and post measurements were documented. **Results:** Among 47 subjects there were 17 male and 30 females with mean age group of 21.2+2.06 years. There was a statistically significant worsening of accommodative components (negative & positive relative accommodation, lag of accommodation). In vergence parameters, a statistically significant deterioration of negative (12.8 + 1.65 to 12.38 + 1.93 PD) and positive fusional vergence (15.48 + 1.53 to 16.08 +1.61 PD) was observed. The mean vergence facility also showed a statistically significant change in pre and post task measurements (13.51 + 1.64 to 10.71 + 1.91 cpm (cycles per minute)). **Conclusion:** The current study investigated that perusing text with a smart phone for 30 minutes shows significant effect on accommodative and vergence components for near task, with greater impact on vergence parameters. Drawn out exposure to digital screens at near, may bring about visual quality dysfunction.

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According to statistics, the number of mobile phone customers in India would be 442 million by the year 2022. India, China, and the United States are the nations with the highest number of smartphone users, with each country easily surpassing the 100 million user mark.[1]

Prolonged utilization of mobile devices might be related with changes in accommodation and vergence including accommodative amplitude (AA), facility (AF), vergence facility (VF) and accommodative convergence and accommodation ratio (AC/A). There are studies that examine the accommodation and vergence changes after monitored reading with a smartphone device[2,3] and at shorter working distance.[4,5] However, only selected parameters have been evaluated and thus, are not comprehensive. This led us to conduct a prospective study to analyze the changes in both accommodation and vergence parameters after monitored smartphone usage.

Methods

This prospective comparative study was performed in a tertiary eye care center for a duration of 6 months from December 2017 to May 2018. The study was acknowledged by Institutional review board and Ethics committee and it adhered to the tenets of Declaration of Helsinki. Informed consent was obtained from all the participants.

A total of 47 visually healthy normal subjects of age group ranging from 18-30 years were recruited for the study. Prior to the task, all the subjects had a comprehensive eye evaluation with visual acuity for distance and near at 40 cm using Snellen acuity chart, slit lamp bio-microscopy and dilated fundus evaluation. The subjects who had a best-corrected visual acuity (BCVA) of 6/6 (Log MAR Conversion 0.0) and N6, with a spherical equivalent less than or equal to 0.5D, with no history of asthenopia were included in the study. Subjects with squint, amblyopia, ocular or systemic diseases and previous ocular surgery were excluded. Accommodation and Vergence assessments were performed which included Near Point of Accommodation (NPA), Near Point of Convergence (NPC), Negative and Positive Fusional vergence amplitudes (NFV, PFV), AF, VF, Negative relative accommodation (NRA), Positive relative accommodation (PRA) and Accommodative response (MEM). The standards and procedure of accommodation and vergence data by Scheimenn and Wick[6] were used as guideline for the measured values obtained in our study.

The participants were seated on a chair in a room with ambient lighting of 480 – 500 lux from LED lamps with no glare from windows. The participants were given a reading material on a smartphone consisting of text with black letters displayed on a white background. The reading text of font size N6 was displayed on a smartphone (COOL PAD NOTE 3 LITE with

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a 5-inch LCD screen, 720 x 1280 pixels resolution and 294 ppi pixel density) and the luminance of the screen was adjusted to be constant and equal to 12.8 cd/m^2. As the subjects were optometry students, the content consisted of chapters from the student's books, corresponding to a Flesch reading score of 26 and Coleman liau file of 17.7 and the level of difficulty was analyzed using online tool (http//www.readabilityformulas.com/free-readbility-formula-tests.php). The smartphone was placed at a distance of 40 cm from the subject's eyes and monitored regularly. The participants read the text aloud for a period of 30 min. Visual acuity, accommodation and vergence parameters were re-assessed within 5 min of completion of reading task.

Tests for accommodation

Near point of accommodation

NPA is the point closest to the eye at which a target is sharply focused on the retina[7,8] measured with the help of RAF Ruler. Three consecutive measurements were taken and averaged. The measurement was taken in centimeter and converted into diopter. According to Hofstetter's formula, average amplitude for each subject was calculated.

Positive and Negative relative accommodation

NRA is a measure of the maximum ability to relax accommodation while maintaining clear, single binocular vision.[9] PRA is a measure of the maximum ability to stimulate accommodation while maintaining clear, single binocular vision.[10] The relative accommodation was measured with minus (negative) and plus (positive) lenses. The findings noted in Diopter (D). The normal range for NRA and PRA is + 2.00 to + 2.50 D and –2.37 to –3.37 D, respectively.

Accommodative response (MEM)

The accommodative response was measured objectively by dynamic retinoscopy using the MEM (Monocular Estimation Method). It is an objective method of measuring accommodative response at near when the patient is actively accommodating. It is performed with the patient seated comfortably wearing the appropriate refractive correction at habitual reading distance and sufficient room illumination. A small MEM card containing words or images was attached to the retinoscope head. Participants were asked to read aloud with both eyes open and dynamic retinoscopy was performed for each eye. The amount of "with "or "against "motion was estimated. Plus lens was used for neutralizing the "with motion", and minus lens is interposed for "against "motion. The amount of neutralizing lens is noted. The difference between the accommodative stimulus and accommodative response is called the lead or lag of accommodation.[11] The normal range is +0.50 D to +0.75 D. A value beyond than +0.75 D would indicate a lag of accommodation and a value less than +0.50 D would indicate a lead of accommodation.

Accommodative facility

AF is the ability of the eye to focus on stimuli at various distance and in different sequences in a given period[12] measured using flippers of +/- 1.50 D. The normal value is 12 cpm.

AC/A ratio

It is the ratio of accommodative convergence (AC (in prism diopters)) to the stimulus to accommodation (A (in diopters))[12] measured by using Heterophoria method. The normal range is 3-5:1.

Vergence parameters

Near point of convergence

NPC is the point closest to the eye at which a circular target is sharply focused on the retina[7,8] measured with the help of RAF Ruler. Three consecutive measurements were taken and averaged. The measurement was taken in centimetre.

Fusional vergence

The fusional vergence was assessed using a horizontal prism bar for both distance (6 m) and near fixation (33 cm). Both convergence and divergence break points and recovery points were measured with base-out (BO) prism called as PFV and base-in (BI) prism as NFV.[13] The normal values are Blur/Break/Recovery: BI 13/21/13 PD and BO 17/21/11 PD.

Vergence facility

VF is defined as the number of cycles per minute that a stimulus can be fused through alternating base-in and base-out prisms, attempts to capture the ability of the fusional vergence system to respond rapidly and accurately, to changing vergence demands over time.[14] VF was measured by using the prism flippers (12 PD BO and 3 PD BI) while reading N6 text at 40 cm. The normal value is 15 cpm.

Statistical analysis

The subject's details and relevant information were entered in a pre- designed Proforma in MS-excel sheet (2007). The analysis of results done by using SPSS (Statistical Package for Social Sciences, Version 16.0 Inc., Chicago, IL, USA). Descriptive statistics were calculated for the overall sample. Parametric tests was used for comparison of pre and post task measurements. Paired -T test used for comparison of the variables NPA, NRA, PRA, NFV, PFV, NPC, AC/a ratio, AF, VF and the alpha error was set at 5%.

Results

Among 47 subjects there were 17 male and 30 females with mean age of 21.2 ± 2.06 years (range 19–28 years). The mean, standard deviation and *P* values of all the accommodation and vergence parameters are listed in Tables 1 and 2.

After 30 min of monitored smartphone usage the following observations were noted.

Accommodative parameters

Accommodative response (MEM)

The mean accommodative response was 0.79 ± 0.2 DS pre-task and 1.47 ± 0.28 DS post task (p = 0.000)). This indicates that a lag of accommodation was induced after smartphone reading in 86% of participants.

Accommodative facility (AF)

The mean AF mean was 11.7 ± 1.98 cpm pre-task and 9.41 ± 1.98 cpm post-task (*P* = 0.000). This indicates increased accommodative fatigue induced by prolonged smartphone reading.

Negative relative accommodation (NRA)

Mean NRA values for pre and post task measurements was observed to be 2.71 ± 0.27 DS and 3.07 ± 0.45 DS respectively (*P* = 0.000). The ability to relax accommodation showed 13% deterioration post smartphone reading.

Positive relative accommodation (PRA)

Mean PRA values pre and post-task was 3.0 ± 0.67 DS and 3.89 ± 0.94 DS respectively (*P* = 0.000). There was a 29% increase in accommodative demand after 30 min of smartphone reading.

Accommodative facility (AF)

The mean AF pre and post-task was 11.7 ± 1.98 and 9.41 ± 1.98 cpm (*P* = 0.000). This indicates that there is a deterioration of the ability to stimulate and relax accommodation in rapid succession after smartphone reading.

Table 1: Mean and Standard deviation of accommodation parameters

Accommodation Parameters					
Parameter	Pre Task		Post Task		*P*
	Mean	SD	Mean	SD	
NPA	8.85	1.08	8.87	1.60	0.929
NRA	2.71	0.27	3.07	0.45	0.000
PRA	3.00	0.67	3.89	0.94	0.000
MEM	0.79	0.20	1.47	0.28	0.000
AF	11.70	1.98	9.41	1.98	0.000

NPA: Near point of accommodation, NRA: Negative relative accommodation, PRA: Positive relative accommodation, MEM: Monocular Estimate method, AF: Accommodative facility

Table 2: Mean and Standard deviation of vergence parameters

Vergence Parameters					
Parameter	Pre Task		Post Task		*P*
	Mean	SD	Mean	SD	
NPC	7.70	0.83	9.14	1.50	0.000
NFV (Blur)-D	1.10	3.14	0.42	2.00	0.077
NFV (Break)-D	11.87	1.52	11.19	1.65	0.014
NFV (Rec)-D	7.74	1.64	5.44	2.15	0.000
PFV (Blur)-D	6.25	0.15	6.21	0.35	0.973
PFV (Break)-D	14.38	1.93	14.81	2.23	0.096
PFV (Rec)-D	9.91	2.53	9.61	2.34	0.376
NFV (Blur)-N	1.95	4.40	2.21	4.38	0.744
NFV (Break)-N	12.80	1.65	12.38	1.93	0.168
NFV (Rec)-N	8.63	1.82	5.70	2.04	0.000
PFV (Blur)-N	8.04	6.49	7.87	6.35	0.897
PFV (Break)-N	15.48	1.53	16.08	1.61	0.042
PFV (Rec)	10.93	1.55	10.21	1.73	0.376
Vergence Facility	13.51	1.64	10.71	1.91	0.000

NPC: Near Point of Convergence, NFV: Negative fusional vergence, D: Distance; N: Near; Rec: Recovery, PFV: Positive fusional vergence

The NPA and AC/A ration did not show any significant changes post task.

Vergence parameters

Near point of convergence (NPC)

Mean NPC showed pre and post task values to be 7.7 ± 0.83 and 9.14 ± 1.5 cm respectively ($P = 0.000$). After smartphone reading, the subjects' convergence was found to recede by 15.8% in the post task group.

Negative fusional vergence (NFV) and Positive fusional vergence (PFV)

Mean PFV at near pre and post-task was 15.48 ± 1.53 and 16.08 ± 1.61 respectively, which was noted to be statistically significant in the break response. A 3.7% decrease in the vergence values was noted post task.

Vergence facility (VF)

The mean VF in pre and post-task was 13.51 ± 1.64 and 10.71 cpm ± 1.91 cpm. ($P = 0.0000$). This indicates that there is a deterioration of the ability to stimulate and relax convergence in rapid succession after smartphone reading.

No changes in visual acuity was found in our study after smartphone reading.

Discussion

The current study analyzed in detail the accommodative and vergence components after 30 min of continuous monitored reading on a smartphone device.

Vergence parameters

Decrease in NPC may lead to visual and ocular discomfort while performing near visual tasks.[15] In our study, significant changes were noted in the NPC (break), though constant working distance was maintained and monitored for a period of 30 min. Indirect measures of vergence parameters such as NRA, PRA significantly reduced after 30 min of reading. This shows that longer task duration can instigate changes in the vergence and possibility of ocular fatigue may increase in such conditions. This is in concurrence with past studies.[16,17] As near work increases, clinically subjects become symptomatic and further it leads to reduction in visual demand, comprehension and perception. Further, both NFV and PFV showed significant changes for near with respect to break point, which indicates a decline of fusional and accommodative vergence post smartphone reading. Therefore, adequate reserve of both these systems are required for the subject to reestablish binocularity after prolonged reading on smartphone. In a study done by Park *et al*.[18] a significant decrease in NFV in both presbyopic and non-presbyopic groups was noted. However, the visual task assigned was watching movies using smartphone for 30 min. Another study showed NPA and fusional vergence deterioration following continuous text reading at 50 centimeters for 20 min on an I-Pad.[2] With regards to desktop computers, past investigations have reported inconsequential vergence changes with more effect in NFV compared to PFV.[19,20] These findings did not have comparable outcomes with smartphone in similar age groups.[18]

The VF measurements showed significant decline post-task. These results suggest that subjects cannot tolerate rapid changes in vergence dynamics after prolonged reading with smartphone. Over a period, this might cause poor binocular vision and asthenopic symptoms in adults.

Accommodation parameters

Our study found to have no significant outcomes in the near point of accommodation of both the eyes. This may be most likely due to the robust accommodative reserve seen in young adults who are asymptomatic, as seen in our sample group. However, some studies do observe reduction in the amplitude of accommodation after smartphone use for 30 min.[2,18,21,22] This could probably be due to the tonic accommodation caused due to prolonged near work.[23,24]

We found significant changes in both NRA and PRA post smartphone reading. Both NRA and PRA depend on fusional vergence to maintain binocularity. Hence, the decline in fusional vergence could be the causative factor for the decrease in relative accommodation. Park *et al*.[22] reported diminished PRA after watching movie with Smartphone for 30 min. Seo *et al*.[25] reported decrease in both NRA and PRA following the use of computers as visual task in adult population. On the other hand, kwon *et al*.[18] studies in age group of 36-50 years found reduction in the ability to relax and stimulate accommodation as the age factor becomes a major component for such a decline.

In our investigation we found to have greater lag of accommodation in smartphone which corresponds to the other studies where similar results were obtained when comparing

with printed text reading at 25–40 cm for 30 min.[2,3,22] In our study, the working distance and luminance were monitored constantly and text size was N6. The small font size,[5] and the steady perusing without a break could have stressed the dynamics of the accommodative components resulting in lag of accommodation. In a study by Moulakkai *et al.*,[26] the accommodative response change was found to be associated with age and amplitude of accommodation and not just based on handheld electronic devices.

The binocular AF significantly reduced in our study following smartphone usage. It was in concurrence with past references in young adults, by Park *et al.*[22] and in middle-aged subjects by Kwon *et al.*[18] where watching movies was given as visual undertaking for the subjects using smartphone.

AC/A ratio showed no significant change after monitored reading. This explains that AC/A ratio is dependent on accommodation and convergence, which is active in young adults. A study conducted by Mark *et al.*[27] found myopic progression in adults and high AC/A ratio by performing near task at a close distance when using desktop computers.

To the best of our knowledge, this is the first study to explore VF and AC/A ratio among smartphone use. A significant reduction was observed not only in the vergence amplitudes but also in vergence efficiency.

The strengths of our study are that it is a prospective study conducted in a controlled, monitored environment with a comprehensive evaluation of binocular vision parameters, especially VF and AC/A ratio.

The limitation of our study is that there was no control group who read from printed text, which would have given comparative data on the better format of reading. However, we compared our results with similar studies conducted with printed text in similar age groups and found that text viewing by smartphones has a more profound effect on accommodation and vergence parameters than viewing from printed text. Also, the recovery of accommodation and vergence parameters after reading task was not analyzed as a part of the study.

Conclusion

From our study, we observed that the perusing text with a smartphone for thirty min shows a significant effect on accommodative and vergence components for near task, of which there is more impact on the vergence system. Exposure to these gadgets may bring about ocular fatigue and binocular vision dysfunction much earlier in young adults. Hence, it may be recommended to have frequent breaks while reading from smartphones. Further studies are warranted comparing binocular vision parameters between printed text and smartphone, by altering the text dimension, viewing distance, and the duration of viewing.

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Conflicts of interest

There are no conflicts of interest.

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