• Clinical Research •

Smartphone use patterns and the impact on accommodation and convergence system of the eyes among Malaysian teenagers

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Abstract

● **AIM:** To determine the smartphone use patterns and effects of smartphone use on accommodation and convergence system of the eyes among Malaysian teenagers.

● **METHODS:** A total of 62 participants aged between 13 and 17y were involved. A self-administered questionnaires containing 12 items was used to evaluate the smartphone usage patterns. This was followed by an eye examination, involving a battery of accommodation and convergence assessments before and after the smartphone use. The data analysis comprised descriptive statistics, paired *t*-test, and correlation coefficients.

● **RESULTS:** The use of smartphones is at a high level and at an optimal distance daily, with more than 6h a day watching video films, games, and completing school projects. Majority of the participants not reported eye strain factors and eye prescription changes with the use of digital devices. The use of a smartphone continuously for 30min was found to significantly decrease amplitude of accommodation, accommodative facility, and positive relative accommodation ($P<0.001$). Meanwhile, the lag of accommodation parameters and negative relative accommodation increased with the use of smartphones significantly ($P<0.001$). The near point of convergence (NPC) and distance and near negative fusional vergence decreased significantly ($P<0.001$). The NPC parameter was found to have a weak negative association with the frequency of smartphone use ($R=-0.276$, $P<0.05$).

● **CONCLUSION:** Frequent and continuous use of smartphones have increased visual stress and resulted in weakness of accommodation and vergence functions. Therefore, frequent break is mandatory when using a smartphone and appropriate visual hygiene, the 20-20-20 rule (every 20min, view something 20 feet away for 20s) are required during smartphone use to maintain visual function.

● **KEYWORDS:** smartphone use patterns; accommodation and convergence; visual function; visual stress

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INTRODUCTION

Globally, 6.23 billion people use smartphones in their daily lives, which is expected to increase to 7.7 billion by 2027[1]. Smartphone use has increased significantly among Indian schoolchildren aged 14 to 16y, where 46.6% of them spend 840 to 1680min per week on digital devices[2]. In Malaysia, around 29 million people use smartphones, and this number is expected to increase by another 1.74 million in the year 2025[1]. Mobile phone users survey in 2021[3] by the Malaysian Communications and Multimedia Commission (MCMC) revealed that the use (95.6%) and ownership (89.4%) of smartphones is very high among teenagers. Based on the Smartphone User Persona Report 2015[4], Malaysians spend approximately 187min per day using electronic devices; this figure is higher among women (16%) who spend 3h and 39min per day on smartphones. Importantly, the use of electronic devices including smartphones has become more prevalent since the coronavirus (COVID-19) outbreak, with many individuals of all ages using smartphones for virtual learning and working.

Smartphones differ from regular mobile phones in the way they are used because they include more interactions involving the eyes[5]. Especially, the characteristics of smartphones, such as small screen size and text, require a close working distance and they place a higher demand on accommodation and convergence parameters compared to printed materials[6-7]. A closer working distance also increases near point stress in some individuals due to greater demand on accommodation and vergence parameters[8]. In addition, the viewing angle from the screen, room lighting, and spectral light distribution also affect the accommodation and convergence systems of the eyes[9].

The use of these devices degrades the values of amplitude of accommodation (AA), accommodative facility (AF), relative of accommodation, lag of accommodation, near point of convergence (NPC), and fusional vergence[10-14]. Binocular instability is reported to have affected reading speed, accuracy, and efficiency[15], as well as academic performance, fixation, attention, concentration, and overall quality of life[16-18]. Research on the effect of smartphone use on the eye accommodation and convergence system among teenagers is still in its infancy, and most previous studies have only focused on the effects of Visual Display Terminal and Computer Visual Syndrome. Therefore, there is a need to identify the smartphone usage patterns and the effect of smartphone use on accommodation and convergence system among Malaysian teenagers.

SUBJECTS AND METHODS

Ethical Approval The study adhered to the Declaration of Helsinki values and was approved by the Ethics Committee of University (UKM PPI/111/8/JEP-2020-665). All subjects and their parents were informed for the consent of the purpose, significance, and eye assessment processes of this study *via* a signed informed consent.

Study Population This study was an experimental cross-sectional study. A total of 62 students aged between 13y and 17y participated in this study. The sample size was calculated according to Cochran's (1977) formula using the prevalence of smartphone use among Malaysian teenagers, which is 4.2%[19]. The inclusion criteria are teenagers aged 13 to 17 years old who were willing to participate, smartphone users, had good visual acuity (VA) at distance (6/6) and near (N5) and normal accommodation and vergence functions[20]. Meanwhile, the exclusion criteria include a history of ocular disease and surgery, amblyopia, manifest squint, a refractive error of ≥3.00 DS of myopia or hyperopia, and ≥1.50 DC of astigmatism[21].

Study Procedures All eye examinations were performed by an experienced optometrist, and the purpose and methods for each technique were carefully explained to each subject before starting the study. Valid optometric tools and procedures were used as described in an optometry textbook for all visual function and binocular vision assessments[22]. A trial check was performed to ensure that participants understood all instructions. In addition, all the measurement was conducted with standard protocol and repeated three times to ensure consistency. A structured questionnaire adopted from a previous study was used[2]. This questionnaire consists of three parts, namely, the study information, respondent information and questions related to digital devices usage. This questionnaire was self-administered. Then, accommodation and convergence tests were performed before and after the use of a smartphone. Each subject was instructed to play the same game, namely, *Candy Crush* in a Huawei Nova 3i smartphone for 30min[12] at a distance of 40 cm with the refractive correction determined on the day of the measurement on trial frame. The viewing distance was determined using a measuring tape. The screen brightness was set to automatic mode and the room brightness was measured with luxmeter which ranged between 470 to 480 lx. The same room and illumination level were used for every participant. The sequence of measurement of accommodation and vergence parameters was performed randomly for each subject to prevent the effects of eye fatigue.

Ocular Examinations All participants underwent a screening phase, which included measurement of distance and near VA with Snellen Chart and N-notation near chart using sentences, refractive error (Auto Refractometer FA-6500K, Keeler Retinoscope 2.8V Bulb and Subjective Refraction), and ocular alignment at distance and near (Cover-Uncover Test). Techniques used in subjective refraction were Duochrome, Plus/Minus, Cross Cylinder and Alternate Occlusion. The accommodation parameters that were assessed were AA (Push Up Test with Royal Air Force rule), AF (Flipper Lens Test ±2.00 DS), accuracy of accommodation (Monocular Estimation Method) and relative accommodation. The positive relative accommodation (PRA) was measured by adding negative lenses and the negative relative accommodation (NRA) was measured by adding positive lenses. Meanwhile, vergence parameters that was assessed were NPC with RAF rule, negative fusional vergence (NFV) with base-in Risley prism and positive fusional vergence (PFV) with base-out Risley prism.

Statistical Analysis Study data was analysed using the Statistical Package for the Social Sciences version 26.0. Patterns of digital device use among teenagers was evaluated with descriptive analysis. A paired *t*-test was used to analyse the differences in accommodation and convergence system of the eyes before and after using a smartphone. A value of $P<0.05$ is considered significant. Spearman's correlation test was used to assess the relationship between patterns of digital devices use and accommodation and convergence parameters.

RESULTS

Socio-Demographic of Subjects The study involved 62 participants, 56.5% (n=35) were male and 43.5% (n=27) were female. The study participants were aged 13y (n=14), 14y (n=19), 15y (n=11), 16y (n=15), and 17y (n=3). The mean and median age of the participants was 14.58 and 14, respectively. The participants consisted of Malays (*n*=59), Indians (*n*=2), and others (*n*=1).

Patterns of Digital Device Use Among Teenagers The study found that the majority of the participants chose the format of reading from smartphones. The use of smartphones and laptops are at a high level. Digital devices were used every day at an ideal distance for more than six hours a day watching video films, playing games, completing school projects, and for social networking. Majority of the participant not reported eye strain factors and eye prescription changes with the use of digital devices. Each respondent could choose more than one option for questions regarding “types of digital devices use” and “purpose of digital device use”. Therefore, the number of responses for these questions were more than 62. Table 1 summarised the patterns of digital devices use among Malaysian teenagers.

Changes in Accommodation Systems Before and After Use of Smartphone The mean AA of both right and left eye decreased significantly by more than 25% with smartphone use. Meanwhile, the mean of binocular AA also decreased significantly by 1.73% after using a smartphone. Next, the mean AF of the right eye decreased significantly by 28.24% and the left eye decreased significantly by 27.81%. A significant difference was reported with the mean of binocular AF, where the reading decreased by 23.96% with the use of a smartphone. Furthermore, the mean lag of accommodation on right and left eyes increased significantly by 208% and 186.79%, respectively, with smartphone use. NRA readings increased significantly by 53.50% while PRA readings increased significantly by 40.50% after the use of smartphones. Table 2 showed the mean, standard deviation, *t* and *P* values before and after using a smartphone for 30min.

Changes in Convergence Systems Before and After Use of Smartphone The mean of NPC decreased significantly by 61.92% with smartphone use. NFV break and recovery at far showed a statistically significant difference, where both readings decreased by more than 25% with smartphone use. Mean NFV of blur, break, recovery at near also showed a significant decreased by 30.31%, 22.92%, and 37.69%, respectively. Meanwhile, the mean PFV at near showed significant changes, where the break point increased by 2.26% and the recovery point decreased by 2.88%. Table 3 showed the distribution of the mean, standard deviation, and *P* value before and after the use of a smartphone for 30min.

Association between the Frequency, Duration, and Distance of Smartphone Use and Accommodation and Convergence System The convergence function has a weak significant negative correlation towards the frequency of smartphones use (r_s=-0.28, P<0.05, two-tailed, *n*=62). No significant association was observed between the duration and distance of smartphone use with accommodation and vergence parameters. Table 4 presented the readings of correlation

Table 1 Patterns of smartphone use among teenagers

Characteristics of smartphone use	*n* (%)
Time spent in a day reading a paper book or writing	
Less than 2h	38 (61.3)
2 to 4h	17 (27.4)
4 to 6h	3 (4.8)
More than 6h	4 (6.5)
Other reading format besides reading from paper books	
Desktop computer	10 (16.1)
Smartphone	42 (67.7)
Tablet	7 (11.3)
Not using a digital device	3 (4.8)
Frequency of digital device used	
3 to 4 times/wk	7 (11.3)
5 to 6 times/wk	1 (1.6)
Everyday	54 (87.1)
Time spent in a day on digital device	
Less than 2h	7 (11.3)
2 to 4h	18 (29.0)
4 to 6h	17 (27.4)
More than 6h/d	20 (32.3)
Distance from digital device while reading	
Less than 25 cm	18 (29.0)
Within 25 to 40 cm	29 (46.8)
At arm’s distance	15 (24.2)
Posture while reading	
Sitting on the chair	31 (50.0)
Lying on the bed	31 (50.0)
Types of digital device used	
Laptop	17 (18.7)
Desktop computer	6 (6.6)
Smartphone	58 (63.7)
Tablet	6 (6.6)
E-book reader	4 (4.4)
Purpose of digital device used	
Social networking	33 (21.6)
School projects	34 (22.2)
Reading E-books	13 (8.5)
Watching movies/videos	37 (24.2)
Gaming	35 (22.9)
Others	1 (0.7)
Use of eye glasses	
Yes	41 (66)
No	21 (34)
Eyestrain after using digital devices	
Yes	28 (45.2)
No	34 (54.8)
Prescription changes after using a digital device	
Yes	15 (24.2)
No	47 (75.8)
Smartphone use at bedtime with light switched off	
Yes	40 (64.5)
No	22 (35.5)

Table 2 Accommodation parameters before and after using a smartphone mean±SD

Accommodation parameters	Before using a smartphone for 30min	After using a smartphone for 30min	Mean difference (%)	*t*	[c]*P*
AA (right), D	13.64±0.57	10.19±1.04	25.29	23.65	0.000[a]
AA (left), D	13.60±0.60	10.05±1.09	26.10	22.59	0.000[a]
AA binocular, D	13.88±0.56	13.64±0.44	1.73	2.66	0.010[b]
AF (right), cpm	11.26±1.94	8.08±1.60	28.24	10.26	0.000[a]
AF (left), cpm	11.11±1.95	8.02±2.01	27.81	8.77	0.000[a]
AF binocular, cpm	10.56±1.70	8.03±1.58	23.96	8.85	0.000[a]
Accuracy of accommodation (right), D	0.50±1.53	1.54±0.40	208	18.21	0.000[a]
Accuracy of accommodation (left), D	0.53±1.51	1.52±0.42	186.79	18.01	0.000[a]
PRA, D	-2.42±0.42	-3.40±0.40	40.50	14.11	0.000[a]
NRA, D	2.00±0.26	3.07±0.51	53.50	14.51	0.000[a]

[a]*P*<0.001; [b]*P*<0.05; [c]Paired *t*-test. SD: Standard deviation; AA: Amplitude of accommodation; AF: Accommodative facility; PRA: Positive relative accommodation; NRA: Negative relative accommodation; D: Dioptre; cpm: Cycle per minute.

Table 3 Vergence parameters before and after using a smartphone mean±SD

Vergence parameters	Before using a smartphone for 30min	After using a smartphone for 30min	Mean difference (%)	*t*	[c]*P*
NPC, cm	6.04±0.82	9.78±1.09	61.92	22.97	0.000[a]
NFV blur (far), p.d.	0.84±0.53	1.05±0.68	25.00	1.84	0.071
NFV break (far), p.d.	6.96±1.47	5.21±1.57	25.14	9.31	0.000[a]
NFV recovery (far), p.d.	4.02±0.98	3.01±1.03	25.12	8.24	0.000[a]
PFV blur (far), p.d.	9.21±2.01	9.66±1.65	4.89	1.51	0.137
PFV break (far), p.d.	19.27 ±1.87	19.23±2.24	0.21	0.14	0.889
PFV recovery (far), p.d.	10.18±1.90	9.06±1.67	11.00	5.62	0.000[a]
NFV blur (near), p.d.	13.10±1.92	9.13±1.99	30.31	14.65	0.000[a]
NFV break (near), p.d.	21.60±1.63	16.65±2.32	22.92	15.90	0.000[a]
NFV recovery (near), p.d.	13.48±2.08	8.40±1.84	37.69	16.47	0.000[a]
PFV blur (near), p.d.	17.66±1.92	17.47±2.11	1.08	1.62	0.160
PFV break (near), p.d.	20.84±1.87	21.31±2.01	2.26	2.12	0.038[b]
PFV recovery (near), p.d.	10.76 ±1.86	10.45±2.01	2.88	2.09	0.041[b]

[a]*P*<0.001; [b]*P*<0.05; [c]Paired *t*-test. SD: Standard deviation; NPC: Near point of convergence; NFV: Negative fusional vergence; PFV: Positive fusional vergence; p.d: Prism dioptre.

coefficient and *P* value for frequency, duration and distance of smartphone uses with accommodation and convergence parameters.

DISCUSSION

The present study found that smartphones were the most widely used digital devices among school teenagers for the purpose to watching movies/videos, and games. Similar finding was reported in a study by Ichhpujani *et al*[2], where school teenagers in India choose smartphone as their favoured digital device for the purpose to complete school projects and video gaming. In contrast, numerous studies reported that the major use of smartphones were to make calls, text, social network services, and surf the internet[23-24,19]. Teenagers choose smartphones as their favourite device, which may be due to their growing environment that is dense with the internet, computers and video games that really attract their attention[25], apart from the attractive features on smartphones, such as high-resolution LCD screens, ease of operation, and mobile application technology[26].

In this study, smartphones usage was reported to be daily for more than 6h/d. Similarly, Lee *et al*[27] reported that the frequency of smartphone use was higher during weekend among Malaysian school students. It was found that smartphones were used at an optimal distance which was within 25 cm to 40 cm. A study done by Padavettan *et al*[12] described 50% of school students used smartphones at an ideal reading distance and only a few of them holds the device at the closest distance. Screen viewing time for a longer period may increase the visual demand thus leads to poor visual status[28]. Moreover, the use of smartphones at close range causes deterioration in accommodation and vergence functions due to spasms of ciliary and iris muscles[25,29], as well as eye fatigue, meiosis, itchiness, and headache[30-31].

Furthermore, the existing study revealed that half of the

Table 4 Correlation for frequency, duration, and distance of smartphone use with accommodation and convergence systems

Parameters accommodation and convergence	Corelation coefficient (r_s)	[b]P
Frequency		
AA	-0.115	0.374
AF	-0.032	0.806
Lag (right)	-0.171	0.183
Lag (left)	+0.077	0.554
NRA	-0.160	0.215
PRA	+0.070	0.588
NPC	-0.276	0.030[a]
Duration		
AA	-0.092	0.479
AF	-0.113	0.381
Lag (right)	-0.236	0.064
Lag (left)	-0.083	0.520
NRA	-0.104	0.420
PRA	-0.058	0.652
NPC	-0.219	0.088
Distance		
AA	-0.036	0.782
AF	+0.161	0.212
Lag (right)	-0.076	0.556
Lag (left)	+0.203	0.113
NRA	-0.048	0.713
PRA	-0.200	0.119
NPC	+0.062	0.634

[a]P<0.001. [b]Spearman's correlation. AA: Amplitude of accommodation; AF: Accommodative facility; NRA: Negative relative accommodation; PRA: Positive relative accommodation; NPC: Near point convergence.

students used their digital devices while lying down. In contrast, Padavettan *et al*[12] indicated that most of the students using the devices while sitting on a chair. Smartphone use while lying down may increase the possibility of experiencing ocular pathologies and reduce sleep quality[2]. The reason for that viewing distance of the electronic screen in lying position is shorter than in sitting position. Furthermore, holding the screens in wrong position will create unstable lighting and display position thus leads to visual symptoms, such as dry and sore eyes, blurred and double vision, and neck pain[32]. However, one study found that there was no significant association between sitting position and visual function[33]. Hence, further research would be necessary for a better understanding between smartphone use and posture.

In this study, only 45.2% of participants reported eye strain with use of digital devices. This could be because the subjects are younger cohorts, which might have active accommodation and vergence functions. Additionally, only fewer number of subjects reported a change in their spectacle prescription after the use of digital devices; the finding coincides with the study done by Ichhpujani *et al*[2]. This may because of the optimal distance of smartphone use among teenagers that does not lead to any changes in vision. Additionally, this study reported high usage of smartphone at bedtime with lights switched off. Digital screens are back lighted and emits blue light waves which reduces melatonin secretion[2] and disrupt sleep quality[25] when used in dark.

Continuous use of smartphones had significantly decreased AA functions; the finding concurrent with previous studies done in Korea[34-35]. Reduction in AA may be due to an impaired in tonic accommodation as a result of continuous close work[12,14,36]. A study done in Malaysia among university students revealed that 20min of smartphone use caused a significant decreased in AA parameters that may be due to the high lag of accommodation found among subjects[13]. Smartphone use at closer distance may cause constant strain to crystalline lens and eye muscles thus increased the accommodative adaptation. Also, less blinking during continuous near work may lead to extended near point of accommodation[35]. Digital devices demand the individual to quickly shift their accommodation to fixate on the visual display unit and then relax accommodation for distant objects in order to maintain a clear image[37]. The present study showed that AF functions declined after the smartphone use; similar finding was found in recent studies[7,38]. Golebiowski *et al*[39] said a declined in AF parameters may strongly influenced by the weakness of vergence facility. Furthermore, AF function decreased significantly among convergence insufficiency (CI) subjects after the smartphone use. This is because less convergence creates a slow relaxation, and more convergence and accommodation demands are needed simultaneously to see images clearer[40].

This study reported a steep increase in accommodative lag with the smartphone use; these findings concur with previous studies[12-13,35]. In addition, accommodative lag was increased significantly in convergence excess subjects, which may be due to eye fatigue from continuous smartphones use[40]. Furthermore, luminous material and light refection from the screen display also causes tension to the accommodation system[29,41]. In addition, RA functions dropped significantly after the smartphone use. For instance, Padavettan *et al*[12] revealed that both RA had decreased significantly with the decline in fusional vergence, which is attributable to the reliance of both RA parameters on fusional vergence to maintain binocular single vision. Meanwhile, the PRA function dropped among Malaysian adults with 20min of smartphone use due to high accommodative demand found in a short duration[13]. Generally, eye focusing mechanism does not work well with electronically generated letters, as compared with printed letters. Printed characters have clear edges and good contrast, whereas the pixel characters generated electronically are bright in the centre and have fuzzy edges. Therefore, human eyes failed to maintain focus and rest to focus behind the screen[38].

The current study found a significant decrease in NPC after using the smartphone. Likewise, a study done in India[12] reported that NPC decreased significantly by 15.8% after the smartphone use due to visual stress from continuous close work. Smartphone usage for a longer period degraded the eye convergence system due to the small display size[14] and close working distance[42]. Additionally, NPC function declined in accommodation insufficiency and excess subjects compared to the normal group. This increase may be due to prolonged close work that requires constant eye adjustment[43]. Moreover, smartphone use during sleep causes poor convergence scores due to the light emitting feature[30]. The present study described both FV parameters significantly altered at near after the smartphone use. Equally, a study done by Padavettan *et al*[12] and Porcar *et al*[44] showed that NFV functions were significantly deteriorated after the smartphone use. Moreover, NFV is increased in CI subjects due to lack of convergence thus requires more convergence as compensation to maintain a binocular single vision while PFV is increased in CI subjects due to the tension of the eye's rectus muscle[45]. A recent report revealed that PFV parameters significantly declined after 30min of visual display terminal (VDT) use[5] and among high digital device users[38].

This study found significant correlation between the frequency of smartphone use and NPC. This is because smartphone use is reported to be daily in the present study, and this may lead to near point pressure among subjects. Similar finding was found in previous study, where high frequency of smartphone use deteriorated the NPC function[30]. Continuous smartphones use at close range increased the vergence demand, and poor NPC function may deteriorate the binocular vision[8]. The limitation of the study is gaming activities on smartphones, which do not control the external factors, such as head posture and viewing angle. Correspondingly, self-reported questionnaires may not effectively capture the relationship between smartphone use patterns and accommodation and convergence functions among teenagers. Therefore, future studies should carefully consider this limitation and test older age cohort (20–29) or following up with the same cohort after a duration of 5 to 10y. This approach could provide a more comprehensive understanding of how smartphone use affects visual functions across different age groups. In conclusion, the use of smartphone in close range causes an increase in the demand for accommodation and convergence system, and continuous use can cause constant pressure to the binocular visual system. Therefore, regular breaks in activity are mandatory when using a smartphone and appropriate visual hygiene, the 20-20-20 rule are required during smartphone use to maintain binocular visual functions. Accommodation and convergence assessments should be mandatory for patients with excessive digital device use and symptoms of computer vision syndrome to avoid binocular visual problems.

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REFERENCES

1 The Statistic Portal. Smartphone users worldwide 2022-2027 (Internet). 2022. https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/

2 Ichhpujani P, Singh RB, Foulsham W, Thakur S, Lamba AS. Visual implications of digital device usage in school children: a cross-sectional study. *BMC Ophthalmol* 2019;19(1):76.

3 Malaysian Communication and Multimedia Commission (MCMC). Hand phone users survey, 2021. https://www.mcmc.gov.my/skmmgovmy/media/General/pdf2/FULL-REPORT-HPUS-2021.pdf

4 Vserv. Smartphone Users Persona Report (SUPR). 2015. https://www.digitalnewsasia.com/sites/default/files/files_upload/SUPR_2015_Infographic_Malaysia.pdf

5 Kim J, Yang DJ, Choi DY, Kim SR, Park M. Changes in heterophoria and fusional vergence after near work with smartphone and paper book. *J Korean Ophthalmic Opt Soc* 2016;21(4):385-392.

6 Bababekova Y, Rosenfield M, Hue JE, Huang RR. Font size and viewing distance of handheld smart phones. *Optom Vis Sci* 2011;88(7):795-797.

7 Antona B, Barrio AR, Gascó A, Pinar A, González-Pérez M, Puell MC. Symptoms associated with reading from a smartphone in conditions of light and dark. *Appl Ergon* 2018;68:12-17.

8 Long J, Cheung R, Duong S, Paynter R, Asper L. Viewing distance and eyestrain symptoms with prolonged viewing of smartphones. *Clin Exp Optom* 2017;100(2):133-137.

9 Male SR, Bhardwaj R, Majumder C. Influence of spectral distribution on accommodation—vergence and reading performance. *Ann Eye Sci* 2018;2:29.

10 Jaiswal S, Asper L, Long J, Lee A, Harrison K, Golebiowski B. Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know. *Clin Exp Optom* 2019;102(5):463-477.

11 Zamani Shahri R, Jafarzadehpour E, Mirzajani A. Study of lag of accommodation after using a smartphone. *Func Disabil J* 2021;4(1):38.

12 Padavettan C, Nishanth S, Vidhyalakshmi S, Madhivanan N, Madhivanan N. Changes in vergence and accommodation parameters after smartphone use in healthy adults. *Indian J Ophthalmol* 2021;69(6):1487-1490.

13 Narawi WS, Razak SA, Azman N. The effect of smartphone usage on accommodation status. *Mal J Med Health Science* 2020;16(2):244-247.

14 Kang JW, Chun YS, Moon NJ. A comparison of accommodation and ocular discomfort change according to display size of smart devices. *BMC Ophthalmol* 2021;21(1):44.

15 Hussaindeen JR, Rakshit A, Singh NK, Swaminathan M, George R, Kapur S, Scheiman M, Ramani KK. Binocular vision anomalies and normative data (BAND) in Tamil Nadu: report 1. *Clin Exp Optom* 2017;100(3):278-284.

16 Alrasheed SH, Elmadina AEM. Effect of binocular vision problems on childhood academic performance and teachers' perspective. *Pak J Ophthalmol* 2020;36(2):163-168.

17 Nunes AF, Monteiro PML, Ferreira FBP, Nunes AS. Convergence insufficiency and accommodative insufficiency in children. *BMC Ophthalmol* 2019;19(1):58.

18 CITT-ART Investigator Group. Effect of vergence/accommodative therapy on reading in children with convergence insufficiency: a randomized clinical trial. *Optom Vis Sci* 2019;96(11):836-849.

19 Osman MT, Abdullah ZA, Sanusi T, Nic A, Abdullah. A study of the trend of smartphone and its usage behavior in Malaysia. *International Journal of New Computer Architectures and their Applications (IJNCAA)* 2011;1(1):275-286.

20 Scheiman M, Wick B. *Clinical management of binocular vision: heterophoric, accommodative and eye movement disorders*. Philadelphia: Lippincott Williams & Wilkins; 1994:3-125.

21 Abraham NG, Srinivasan K, Thomas J. Normative data for near point of convergence, accommodation, and phoria. *Oman J Ophthalmol* 2015;8(1):14-18.

22 Elliot DB. *Clinical procedures in primary eye care*. 5th ed. Elservier Science Limited; 2020:26-204.

23 Kumar K, Darshineeylingeswaran, Attalla S, Jeppu AK. The impact of smartphone addiction on the psychological well-being. *Psychology and Education* 2020;55:2465-2468.

24 Said AH, Mohd FN, Yusof MZ, Mohd Win NAN, Mazlan AN, Shaharudin AS. Prevalence of smartphone addiction and its associated factors among pre-clinical medical and dental students in a public university in Malaysia. *Malays Fam Physician* 2022;17(3):64-73.

25 Bozzola E, Spina G, Ruggiero M, Memo L, Agostiniani R, Bozzola M, Corsello G, Villani A. Media devices in pre-school children: the recommendations of the Italian pediatric society. *Ital J Pediatr* 2018;44(1):69.

26 Kwon K, Woo J, Park M, Kim S. The change of accommodative function by the direction of eye movements during computer game. *J Korean Ophthalmic Opt Soc* 2012;17(2):177-184.

27 Lee SP, Zamimi HA, Syed Elias SM, Atan A, Makhdzir N. Smartphone use and addiction among secondary school students in kuantan, Malaysia. *Int J Care Scholars* 2021;4(1):36-41.

28 Pillay R, Munsamy AJ. A review exploring convergence insufficiency in younger populations and e-devices in the digital era. *Afr Vis Eye Health* 2021;80(1):a623.

29 Hue JE, Rosenfield M, Saá G. Reading from electronic devices versus hardcopy text. *Work* 2014;47(3):303-307.

30 Male SR. Effect of smartphone activity over convergence insufficiency score before sleep. *Journal of PeerScientist* 2018;1(1):e1000002.

31 Mohan A, Sen P, Shah C, Jain E, Jain S. Prevalence and risk factor assessment of digital eye strain among children using online e-learning during the COVID-19 pandemic: digital eye strain among kids (DESK study-1). *Indian J Ophthalmol* 2021;69(1):140-144.

32 Maddii S. Decompensated esophoria and asthenopia correlated with electronic screens overuse in childhood: a case report. *New Front Ophthalmol* 2018;4(1):1-3.

33 Leung TW, Chan CT, Lam CH, Tong YK, Kee CS. Changes in corneal astigmatism and near heterophoria after smartphone use while walking and sitting. *PLoS One* 2020;15(12):e0243072.

34 Kwon KI, Kim HJ, Park M, Kim SR. The functional change of accommodation and convergence in the mid-forties by using smartphone. *J Korean Ophthalmic Opt Soc* 2016;21(2):127-135.

35 Park M, Ahn YJ, Kim SJ, You J, Park KE, Kim SR. Changes in accommodative function of young adults in their twenties following smartphone use. *J Korean Ophthalmic Opt Soc* 2014;19(2):253-260.

36 Pachiyappan T, Ashokan Srambikkal S, Sushmitha. Changes in accommodation and vergence measurements after smartphone use in healthy young adults. *Rjahs* 2023;3(2):8-12.

37 Kaliugavaradhan A, Ramamurthy D. Accommodative facility and response time before and after computer task of varying durations in young adults. *Br Ir Orthopt J* 2023;19(1):85-95.

38 Maharjan U, Rijal S, Jnawali A, Sitaula S, Bhattarai S, Shrestha GB. Binocular vision findings in normally-sighted school aged children who used digital devices. *PLoS One* 2022;17(4):e0266068.

39 Golebiowski B, Long J, Harrison K, Lee A, Chidi-Egboka N, Asper L. Smartphone use and effects on tear film, blinking and binocular vision. *Curr Eye Res* 2020;45(4):428-434.

40 Kim SR, Kwak H, Kang MS, Kim SI, Park M. The changes in convergence function of accommodative anomalies in their twenties after watching video on a smartphone. *J Korean Ophthalmic Opt Soc* 2017;22(2):133-142.

41 Ha NR, Kim CJ, Jung SA, Choi EJ, Kim HJ. Comparison of accommodative system according to the material and font size of near visual media. *J Korean Ophthalmic Opt Soc* 2014;19(2):217-224.

42 Park KJ, Lee WJ, Lee NK, Lee JY, Son JS, Yu DS. Changes in near lateral phoria and near point of convergence after viewing smartphones. *J Korean Ophthalmic Opt Soc* 2012;17(2):171-176.

43 Kim SR, Park MO, Lee SY, Song JH, Lee JH, Choi HD, Park M. The change of accommodative function of vergence anomalies subjects in their twenties after near work with smartphone. *J Korean Ophthalmic Opt Soc* 2017;22(1):71-80.

44 Porcar E, Montalt JC, Pons ÁM, España-Gregori E. Symptomatic accommodative and binocular dysfunctions from the use of flat-panel displays. *Int J Ophthalmol* 2018;11(3):501-505.

45 Kim SR, Park SY, Yeo HJ, Kim DY, Jeong JH, Jang HS, Shin JC, Park M. The change of convergence function of convergence insufficiency in their twenties after doing near work using a smartphone. *J Korean Ophthalmic Opt Soc* 2018;23(1):47-56.