ORIGINAL ARTICLE

The Effect of Smartphone Usage on Accommodation Status

Wiki Safarina Narawi, Shaz' Ain Razak, Nahdiyah Azman

Department of Optometry and Vision Science, Faculty of Health and Life Sciences, Management and Science University, University Drive, Off Persiaran Olahraga, 40100 Shah Alam Selangor

ABSTRACT

Introduction: Usage of smartphones have increased rapidly because of its importance in our daily life. This led to an increase in incidence of ocular problems among smartphone users. This research was conducted to determine the effect of smartphone usage on accommodation status. **Methods:** A cross-sectional study was conducted among young adults aged 19 to 30 years old in Management and Science University, Shah Alam. All subjects were asked to use smartphone for 20 minutes. The symptoms and accommodation status were evaluated before and after the smartphone usage. **Results:** Total subjects showed the mean age of 23.60 ± 2.77 years, 50% (n = 20) were males and 50% (n = 20) were females. The mean smartphone usage per day was 8.60 ± 2.80) hours. After 20 minutes of smartphone usage, subjects complained of tired eyes (92.50%), dry eyes (90.00%), blurred vision (87.50%), and headache (82.50%). Paired t-test showed significant reduction in amplitude of accommodation, monocularly from 9.9 ± 1.9 D to 8.76 ± 2.50 D (p = 0.00), and binocularly from 12.01 ± 1.95 D to 10.96 ± 2.16 D (p = 0.00); monocular accommodative facility from 13.93 ± 3.13 cpm to 11.10 ± 4.32 cpm (p = 0.00) and binocular accommodative facility from 12.70 ± 3.57 cpm to 9.70 ± 4.21 cpm (p = 0.00); positive relative accommodation from -2.72 ± 0.87 D to -2.13 ± 1.28 D (p = 0.00) and increase in lag of accommodation from 0.4 ± 0.26 D to 0.93 ± 0.48 D (p = 0.00). **Conclusion:** This study shows that there were significance changes on accommodation status after 20 minutes of smartphone usage which can lead to weakness of accommodation.

Keywords: Smartphone, Accommodation, Ocular problems

Corresponding Author:
Nahdiyah Azman, MHSc
Email: nahdiyah_azman@msu.edu.my
Tel: +603-5521 6460

INTRODUCTION

Nowadays, it is estimated to have approximately 4.77 billion mobile phone users worldwide in 2017 (1). Malaysia is at the 27th place among top 50 countries by smartphone penetration and smartphone users where about 19,967,000 users are owning a smartphone (2).

As the usage of smartphones are rapidly rising, there are also increase of incidence of ocular or visual problems among the smartphone users. Accommodation has been known as contributor to symptoms associated with computer use which is expected to be reported after the prolonged usage of smartphone. Accommodation is the mechanism by which the eye changes focus from distant to near images, is produced by a change in lens shape resulting from the action of the ciliary muscle on the zonular fibres (3). This study was conducted to identify the symptoms and clinical findings specifically on accommodation status among smartphone users. It was important to ensure that prolonged smartphone usage affects the ocular health especially the accommodation status. Thus, this study will help to setup a guideline to the eye care professional especially optometrists to rule out how the smartphone can lead to ocular problems as well as to give an awareness and public education on the symptoms and ocular problems due to exposure to prolong smartphone usage.

MATERIALS AND METHODS

Samples

This study was conducted on September 2018 to November 2018 in Management and Science University, Shah Alam. The subjects were voluntarily enrolled in this study with minimum of two hours per day smartphone usage (4). All subjects must be aged between 19 to 30 years old. Inclusion criteria were subjects with distance and near corrected visual acuity 6/6 and N6 or better in each eye, refractive error differences less than 1.00D between two eyes, and at least 5.00D accommodative amplitude to rule out in pre-presbyopia. Subject with best corrected vision less than 6/9 (20/30), strabismus, amblyopia and other ocular diseases or previous ocular surgery are excluded from the study. Further exclusion, subjects who under medication that used to treat systemic disease which can caused visual problems (4-7).

Experimental Protocol

All subjects were assessed on their ocular status before and

after reading on the smartphone. Subjects were required to complete a short questionnaire describing their symptoms before and after exposure to the smartphone. The accommodation status is measured before and after exposure to the smartphone which includes amplitude of accommodation (monocular and binocular), lag of accommodation, accommodation facility (monocular and binocular), negative relative accommodation (NRA) and positive relative accommodation (PRA). Each subject was required to play a word search game from the smartphone at a viewing distances of 40 cm for a continuous 20 minutes period under normal room illumination.

Instrumentation

Structured questionnaire is divided into four sections concerning duration of smartphone usage, intensity of ocular symptom (watery, feeling of dryness, itching, pain behind eye, aching, soreness, and tiredness), visual symptom (blurred vision and diplopia), and systemic symptom (shoulder pain, neck pain, back pain, and headache). The symptom scores are ranked on intensity rating as 0 = none or asymptomatic, 1 = very mild, 2 = mild, 3 = moderate, 4 = intense, and 5 = very intense. Symptoms score entered to statistical analysis using this intensity rating scale.

The amount of amplitude of accommodation was measured on Royal Air Force (RAF) rule with N6 target letter. The print then moved towards the subject until the letters became blurred. The test must be repeated at least 3 times to get average value.

Lag of accommodation was determined by using dynamic retinoscopy. It was carried out by monocular estimation method (MEM). Fixation target (MEM card) is a white card containing one-half-inch-hole. The card used is Adult card. The card is attached to the retinoscope and researcher must be at subject customize working distance. Subject is wearing distance correction and read the target throughout the test. The lag of accommodation is neutralized simultaneously for right eye and left eye.

Accommodative facility was measured with ± 2.00 D binocular flipper lens at 40 cm distance viewing target letter size equivalent to N8. The flipper lens will interchangeably between +2.00 D and -2.00 D when the subject saw the target become clear in one-minute time. The result was recorded in cycle per minute (cpm).

PRA and NRA were assessed while the patient was fixating the horizontal line of 6/6 letters at 40 cm. NRA is performed by adding plus lenses binocularly, +0.25 D at a time, until the patient reports the first sustained blur. 'First sustained blur' means that the patient notices that the letters were not as sharp and clear as they were initially, even if the patient can still read them. The total amount of plus added is the NRA. PRA is performed by adding minus lenses binocularly, –0.25 D at a time, until the patient reports the first sustained blur. The total amount of minus added is the PRA.

The word search game used in this study is Word Search Version 5.1 which is developed by Wixot Limited on August 10, 2014. The game has white background and the standard grid size is 12 x 12 will be used throughout the study. The font size is same as standard font size in the smartphone.

Statistical Analysis

All data is evaluate using statistical tools in statistical package for social science (IBM SPSS statistics version 22). The symptoms associated with smartphone usage is analysed with Wilcoxon signed rank test while the assessment of the accommodation status before and after 20 minutes exposure of smartphone usage is analysed with paired t-test. Mann-Whitney test is used comparing symptom scores between genders. The accommodation anomalies among smartphone users is assessed using descriptive test. The level of significant or p-value is set at $p \leq 0.05$ (4).

RESULTS

There were 40 participants with mean age of 23.60 ± 2.77 years. 50% (n = 20) were males and 50% (n = 20) were females. The average hours of smartphone usage among the subjects were 8.60 ± 2.80 hours/day. 95 percent of the respondents used smartphone in dark room conditions (Table I). After 20 minutes of continuous smartphone usage, three most common symptoms reported were tired eyes (n = 37, 92.50%), dry eyes (n = 36, 90.00%), blurred vision (n = 35, 92.50 %), and headache (n = 33, 82.50%). The least reported symptoms were pain behind eyes (n = 10, 25.00%) and double vision (n = 10, 25.00%) (Table II). The analysis using Wilcoxon signed rank test showed there were significant difference in all symptoms associated with smartphone usage except for shoulder pain between before and after 20 minutes of smartphone usage (Table III). However, there was no significant differences when comparing symptom scores between genders (Table IV). Paired t-test analysis showed significant changes in accommodation status before and after 20 minutes of continuous smartphone usage ($p < 0.00$), except for NRA which have no statistically significant change ($p > 0.05$) (Table V). Most of the subjects developed accommodation insufficiency after smartphone usage (62.50%), while others formed accommodative fatigue, accommodative infacility and accommodative excess where contributed percentage were 7%, 4% and 4% respectively (Table IV).

DISCUSSION

This research differentiated the symptoms before and after viewing smartphone for 20 minutes and the

Table I: Description of participants and smartphone usage

	Description		Particulars
i)	Gender	Male	20 (50%)
		Female	20 (50%)
ii)	Age ± SD		23.60 ± 2.77 years
		Male	23.70 ± 2.68 years
		Female	23.50 ± 2.93 years
iii)	Average smartphone usage daily		8.60 ± 2.80 h/day
		Male	9.20 ± 2.78 h/day
		Female	8.00 ± 2.75 h/day
iv)	Duration of smartphone usage	1-6 h/day	10 (25%)
		7-12 h/day	28 (70%)
		13-18 h/day	2 (5%)
v)	Time range of smartphone usage	Weekdays	
		6am – 12pm	5 (12.5%)
		12pm – 6pm	32 (80%)
		6pm – 12am	37 (92.5%)
		12am – 6pm	13 (32.5%)
		Weekend	
		6am – 12pm	4 (10%)
		12pm – 6pm	37 (92.5%)
		6pm – 12am	37 (92.5%)
		12am – 6pm	24 (60%)
vi)	Smartphone usage in dark room condition		38 (95%)

Table II: Distribution of symptoms reported before and after smartphone usage

Symptoms		Before, n (%)	After, n (%)
Ocular symptoms			
1.	Watery eyes	5 (12.50)	13 (32.50)
2.	Dry eyes	24 (60.00)	36 (90.00)
3.	Itchy eye	20 (50.00)	32 (80.00)
4.	Pain behind eye	4(10.00)	10 (25.00)
5.	Aching eye	8 (20.00)	15 (37.20)
6.	Sore eye	10 (25.00)	29 (72.50)
7.	Tired eye	22 (55.00)	37 (92.50))
Visual symptoms			
1.	Blurred vision	13 (32.50)	35 (87.50)
2.	Double vision	2 (5.00)	10 (25.00)
Systemic symptoms			
1.	Shoulder pain	5 (7.50)	13(32.50)
2.	Neck pain	10 (25.00)	30 (75.00)
3.	Back pain	10 (25.00)	24 (60.00)
4.	Headache	8 (20.00)	33 (82.50)

Table III: Mean symptom scores before and after smartphone usage.

		Before	After	p value
Ocular symptoms				
1.	Watery eyes	0.25 ± 0.74	0.63 ± 1.08	0.007
2.	Dry eyes	1.18 ± 1.08	2.75 ± 1.52	0.000
3.	Itchy eyes	0.83 ± 0.96	1.58 ± 1.17	0.000
4.	Pain behind eyes	0.18 ± 0.55	0.45 ± 0.93	0.021
5.	Aching eyes	0.28 ± 0.60	0.65 ± 1.00	0.004
6.	Sore eyes	0.38 ± 0.74	1.23 ± 1.10	0.000
7.	Tired eye	0.88 ± 0.99	2.95 ± 0.93	0.000
Visual symptoms				
1.	Blurred vision	0.50 ± 0.85	1.55 ± 0.88	0.000
2.	Double vision	0.05 ± 0.24	0.38 ± 0.74	0.008
Systemic symptoms				
1.	Shoulder pain	0.35 ± 0.98	0.50 ± 0.82	0.161
2.	Neck pain	0.37 ± 0.73	1.43 ± 1.06	0.000
3.	Back pain	0.38 ± 0.77	1.15 ± 1.17	0.000
4.	Headache	0.35 ± 0.80	1.58 ± 1.06	0.000

Confidential interval 95%; p: Value significant at level 0.05.
Wilcoxon Signed Ranks Test

Table IV: Mean symptom scores after smartphone usage between genders

		Male	Female	p value
Ocular symptoms				
1.	Watery eyes	0.45 ± 0.83	0.80 ± 1.23	0.351
2.	Dry eyes	2.90 ± 1.12	2.60 ± 1.50	0.575
3.	Itchy eyes	1.60 ± 1.05	1.55 ± 1.32	0.845
4.	Pain behind eyes	0.15 ± 0.37	0.75 ± 1.21	0.090
5.	Aching eyes	0.40 ± 0.75	0.90 ± 1.17	0.114
6.	Sore eyes	1.15 ± 1.09	1.30 ± 1.13	0.691
7.	Tired eye	3.20 ± 0.62	2.70 ± 1.13	0.095
Visual symptoms				
1.	Blurred vision	1.55 ± 0.76	1.55 ± 1.00	0.931
2.	Double vision	0.2 ± 0.62	0.55 ± 0.83	0.050
Systemic symptoms				
1.	Shoulder pain	0.45 ± 0.89	0.55 ± 0.76	0.433
2.	Neck pain	1.35 ± 1.14	1.50 ± 1.00	0.798
3.	Back pain	1.15 ± 1.18	1.15 ± 1.18	0.989
4.	Headache	1.45 ± 1.19	1.70 ± 0.92	0.474

Confidential interval 95%; p: Value significant at level 0.05.
Mann-Whitney Test

results showed that all symptoms scores following 20 minutes of smartphone usage were significantly higher than those reported before usage of smartphone except for shoulder pain which has no significant difference between before and after smartphone usage. Among all, tired eyes, dry eyes, blurred vision and headache were the most reported by the respondents after exposure to smartphone. Continuous reading for 20 minutes from smartphone increases symptom including blurred vision while viewing the text, blurred distance vision after the task, difficulty in refocusing from one distance to another, irritated or burning eyes, dry eyes, eyestrain, sensitive to bright lights and eye discomfort (5). While a previous study found that the dry eyes symptoms have no significant difference after sustained of viewing iPad® (6). This might be due to smaller font size and screen display of smartphone in this study compared to iPad®. Even only 20 minutes of smartphones usage, the symptoms reported worsening, what if they used smartphones continuously over 20 minutes?

There were significant changes to accommodation status after smartphone usage of 20 minutes except for NRA. In a study that investigate the effect of

Table V: Mean accommodation status before and after smartphone usage

		Before	After	p-value
Amplitude of Accommodation	Monocular	9.90 ± 1.90 D	8.76 ± 2.50 D	0.000
	Binocular	12.02 ± 1.95 D	10.96 ± 2.16 D	0.000
Lag of Accommodation		0.48 ± 0.26 D	0.93 ± 0.48 D	0.000
Monocular Accommodative Facility		13.93 ± 3.17 cpm	11.10 ± 4.32 cpm	0.000
Binocular Accommodative Facility		12.70 ± 3.57 cpm	9.70 ± 4.21 cpm	0.000
Negative Relative Accommodation		+2.38 ± 0.53 D	+2.89 ± 0.78 D	0.321
Positive Relative Accommodation		-2.72 ± 0.87 D	-2.13 ± 1.28 D	0.001

Table IV: Distribution of accommodation anomalies.

Accommodation anomaly	Before	After
No accommodation anomaly	36 (90%)	0
Accommodative insufficiency	2 (5%)	25 (62.5%)
Accommodative fatigue (ill-sustained)	2 (5%)	7 (17.5%)
Accommodative infacility	0	4 (10%)
Accommodative excess	0	4 (10%)

excessive near work by using smartphone on subjective symptoms and vergence and accommodation function in mid-forties, the researcher discover that amplitude of accommodation and relative accommodation reduced after watching movie on the smartphone screen for 30 minutes. In non-presbyopia subjects, only the amplitude of accommodation reduced (8). In other study, the monocular amplitude accommodation was significantly decrease after smartphone watching for 30 minutes compared with after reading book which lag of accommodation significantly increased in young adults in twenties (9). This change might affect normal accommodation system and lead to accommodation anomalies. Many smartphone users later could suffer from these anomalies and affect the visual function performance.

Previous study (4) stated that accommodative changes comprising of accommodation infacility (35.5%), lag of accommodation (13.6%) and accommodation insufficiency (9.7%) were found in 58.8% total abnormalities diagnosed in visual problem among visual display terminals (VDT) user in Nepal. Unfortunately, this only measured the existing VDT users which are enrolled based on work on computer minimum 2 hours/ day. This was incomparable with this study which had longer average hours of smartphone usage. Even only 20 minutes of smartphone usage of VDTs.

CONCLUSION

There were significant changes on accommodation status after 20 minutes of smartphone usage which lead to weakness of accommodation.

ACKNOWLEDGEMENTS

This research was supported by Department of Optometry and Vision Science, Management and Science University.

REFERENCES

1. Number of mobile phone users worldwide 2013-2019 | Statista. (2015). Retrieved February 24, 2018, from https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/
2. Newzoo's Global Mobile Market Report | Newzoo. (2017). Retrieved April 15, 2018, from https://newzoo.com/insights/rankings/top-50-countries-by-smartphone-penetration-and-users/
3. Glasser A, Kaufman PL. Accommodation and presbyopia. In: Kaufman PL, Alm A, eds. Adler's Physiology of the Eye: Clinical Application. 10th ed. St Louis: Mosby; 2003:197-233.
4. Shrestha GS, Mohamed FN, & Shaha DN. Visual problems among video display terminal (VDT) users in Nepal. Journal of Optometry. 2011; 4(2), 56–62. https://doi.org/10.1016/S1888-4296(11)70042-5
5. Antona B, Barrio AR, Gascy A, Pinar A., Gonzɓlez-Pérez M, & Puell MC. Symptoms associated with reading from a smartphone in conditions of light and dark. Applied Ergonomics, 2018; 68(May 2017), 12–17. https://doi.org/10.1016/j.apergo.2017.10.014
6. Phamonvaechavan, P., & Nitiapinyasagul, R. A comparison between effect of viewing text on computer screen and iPad ® on visual symptoms and functions. 2017; 69(4), 185–189. https://doi.org/10.14456/smj.2017.37
7. Wajuihian SO, & Hansraj R. Accommodative anomalies in a sample of black high school students in South Africa. Ophthalmic Epidemiology. 2016; 23(5), 316–323. https://doi.org/10.3109/09286586.2016.1155715
8. Kwon K, Kim HJ, Park M, & Kim SR. The functional change of accommodation and convergence in the mid-forties by using smartphone. 2016; 21(June), 127–135.
9. 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 Jun; 19(2), 253-60.