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Changes in Accommodative Function of Young Adults in their Twenties following Smartphone Use

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Purpose: The present study was conducted to investigate whether near work with smartphone could induce the change of accommodative function. **Methods:** Total 63 subjects(26 male and 37 female) in their 20s were firstly examined their visual functions related to accommodation and uncorrected spherical equivalent power as the control. After that, the subjects were asked to read a book for 30 min and sequentially watch a movie on smartphone for the same time after 30 min-break under the indoor light or as it was in the reverse order to avoid time-ordered effect. Their accommodative functions, 1) accommodative amplitude, 2) accommodative facility, 3) relative positive/negative accommodation, and 4) accommodative lag and their uncorrected spherical equivalent power were examined again following each task and compared with the control values. **Results:** The monocular accommodative amplitude was significantly decreased after smartphone watching compared with it after reading. The monocular and binocular accommodative facilities were tended to reduce after smartphone watching and book reading but were not significantly different. Neither significant change in positive relative accommodation was determined after smartphone watching nor book reading. Negative relative accommodation after smartphone watching was almost unchanged unlike reading a book. The accommodative lag after smartphone work was significantly higher than after book reading. **Conclusions:** The near work with a smartphone for 30 min induced the change of some accommodative functions, which was significantly greater than when reading under the same working environment.

Key words: Accommodative amplitude, Accommodative facility, Accommodative lag, Near work, Relative accommodation, Smartphone

INTRODUCTION

In recent years, the use of small electronic devices such as tablet computers, PDAs, and smartphones has increased worldwide as easier and faster execution of various tasks such as information retrieval by internet access and schedule management is possible without any restrictions by time or place. An estimated 32.7% of the world's population are now internet users, ranging from 78.4% of the population of North America to 13.5% of that of Africa, which is a 4% increase from 2010.[1,2] The rapid expansion of internet usage has been facilitated by the increased penetration rates of mobile phones, including smartphones. The world's top mobile phone markets are in Europe, America, and Asia and the Pacific.[2] The number of smartphone users in the US reached 38% of mobile phone users and 28.8% of the US population in 2011.[3] Furthermore, in the US, more than 60% of mobile users are expected to use the mobile internet by 2015.[4] According to recent ICT(Information & Communication Technology) facts and figures, mobile-broadband penetration exceeds 90% in the Republic of Korea,[2] where 65.2% of the population aged 12~59 are mobile internet users who access internet services by notebook computers and mobile phones, including smartphones. Thirty-nine percent of the population aged 12~59 in Korea are smartphone users, which represents a 30.9% increase from 8.3% in 2010, and they report spending an average of 1.5~2.5 h daily using their smartphones.[5,6]

Recently, Bababekova et al. reported that the font size of

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hand-held smartphones was the same or smaller than newspaper print and the working distance with smartphones was closer than the typical distance of 40 cm for reading hard-copy text. They hypothesized that the closer distance and smaller font size could exacerbate eyestrain, discomfort, dry eye, diplopia, and blurred vision after prolonged smartphone use.[7] Thus, near work with smartphone use that requires greater accommodation than other types of near work, such as reading books and viewing computer monitors, might induce changes of visual function. However, most recent research on smartphones has focused on medical or physical applications for efficiently managing patients in public health and medicine departments.[8-10] To date, studies about subjective symptoms and visual functions have mainly been conducted to investigate computer vision syndromes associated with computer use and not smartphones.[11-13] In fact, changes of visual function related to accommodation and convergence after smartphone use and/or during the course of smartphone use have not been examined until recently, when Park et al reported that sustained smartphone work for 20 min induced a greater exophoric shift and recession of near-point of convergence (NPC) than were recorded after viewing a computer monitor.[14] However, changes in visual function other than near lateral phoria and NPC induced by smartphone use were not investigated. Only the study related to visual acuity and refractive error after smartphone use were conducted by the other research groups.[15,16] Thus, the present study was conducted to investigate how smartphone use affects accommodation. Accordingly, changes in accommodative function after sustained smartphone work were compared with those induced by near work with reading a book for the same period.

SUBJECTS AND METHODS

1. Subject

Sixty three healthy volunteers aged between 20 and 28 years (male 26, female 37; averaged 22.5±3.7 years) without ocular disease, ocular surgery history, or accommodative dysfunction as evidenced from eye examination by an ophthalmologist were participated into the study from June 2012 to May 2013. All subjects had a decimal visual acuity of at least 0.8 with their habitual refractive corrections. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Seoul National University of Science and Technology. Written informed consent was obtained from all participants.

2. Working environment for book reading and smartphone use

Sixty three subjects were firstly examined their accommodative function as control value and then asked to sequentially conduct a book reading and smartphone use for 30 minutes with the 30 minute-break between two works in a room sized 8×7 m. illuminated with 370 lux to avoid the subjects' distraction due to other cues during each work. The order of book reading and smartphone use was randomly determined in order to avoid time-ordered effect. When the subjects were asked to read a book, "Harry Potter and the Sorcerer's Stone" (book size, 15×23 cm; font size, 3.5 mm as the height of a Korean letter) was given at a distance of 40 cm in the same room. When asked to use a smartphone, the 63 subjects were asked to watch the movie "Iron Man" (SF Film, Paramount Pictures) with subtitles in Korean (font size, 3.5 mm as the height of a Korean letter) for 30 min at a viewing distance of 40 cm (smartphone screen size 10.2 cm in diagonal, resolution of monitor 480×800, luminance of monitor 290 cd/m^2) in the same room illuminated with 370 lux. The viewing distance for reading and smartphone watching was determined to be a visual angle of ~30 arcminutes when the subjects read the Korean font during each task. The lighting condition was determined based on results of a survey conducted by the Korea Internet and Security Agency in 2011.[5,6] Based on data from a previous study[7] and the recommendation from the Korea Ministry of Employment and Labor,[17] the working angle for reading a book or viewing a smartphone was fixed at 20~25^o below the eye by using a holder. All tasks were performed in the same room under indoor lighting of 370 lux and monitored by an examiner.

3. Questionnaire

After each task, the subjects were asked to answer a simple questionnaire to evaluate any subjective symptom noted during reading or watching. Each question was fully explained to ensure understanding. The symptoms were: (1) watery eye, (2) dry eye, (3) burning eye, (4) eyestrain, (5) headache, (6) blurred vision, and (7) diplopia. The subjects were asked to answer either yes or no to each symptom on the list, and they were allowed to choose as many symptoms as they experienced during reading or watching. A symptom that was marked as at least two times and more present was also considered a positive response.

4. Subjective evaluation of accommodative function[18,19]

Each subject's accommodative function was evaluated prior to doing book reading or smarphone use. The accommodative amplitude, accommodative facility, relative accommodation and accommodative lag with habitual refractive correction by using a trial frame were recorded as control values. For examining the subjects with emmetropia and contact lens wear, the trial frame was used as the reference plane. Afterwards, the subjects were asked to do book reading or smartphone use and the accommodative functions listed above were re-examined and compared with the control values. The examinations of visual function were performed in the same 8×7 m. room illuminated with 370 lux, except for the accommodative lag examination (50 lux).

1) Accommodative amplitude

The accommodative amplitude (AA) was determined by the push-up method of Donders. For measuring monocular AA, a small letter (corresponding to decimal visual acuity of 0.7) from a card was placed in front of an open eye while covering the other eye. The card was gradually moved closer to the subject by an examiner until the first sustained blur point was notified by the subject. The AA (in diopters) was recorded as the reciprocal of the distance (in m) from the card to the subject at the first sustained blur. The examination was repeated 3 times and averaged.

2) Accommodative facility

The subjects were asked to hold a +2.00 D flipper in front of their trial frame with their habitual refractive correction. When the subjects clearly read a small letter corresponding to 0.7 visual acuity in decimal from a high contrast black and white card at a distance of 40 cm, they were asked to notify to an examiner and invert their flipper to −2.00 D and then to read the letter clearly again. When the subject clearly read the letter through both sides of the flipper, it was regarded as 1 cycle. The total number of cycles per min was recorded as accommodative facility. Both monocular and binocular (with no suppression) examinations were repeated 3 times and averaged.

3) Relative accommodation

Relative accommodation was examined with the vergence stimulus held constant by placing a card at a distance of 40 cm from the eyes. Accommodative stimulus was binocularly decreased by adding (+) lenses in +0.25 D steps over a trial frame with the habitual refractive correction until the subject was unable to read. The total amount of the (+) lenses at this point was referred to as the negative relative accommodation (NRA) value. For examining positive relative accommodation (PRA), the accommodative stimulus was binocularly increased by adding (−) lenses in −0.25 D steps until the first illegible point was noticed by the subject. The total amount of (−) lenses added at this point was referred to as the PRA value.

4) Accommodative lag

A cross-cylinder with 0.50 D was placed in the phoropter (JP/RT-600, NIDEK) with the minus axes in the 90 degree position, and the subject viewed a cross-grid chart (white background; Topcon NEAR-POINT CARD NC-3) at a distance of 40 cm from the eyes in a room illuminated with 50 lux. Then, an additional +2.00 D was placed to suppress some possible over-accommodation in front of the subject's eyes. The subject was asked to state which lines were darker or more distinct. The addition was then reduced binocularly in 0.25 D steps until the subject answered that the vertical and horizontal lines were equally distinct. The difference between accommodative stimuli and response was regarded as the accommodative lag.

5. Objective examination of spherical equivalent refractive error

The uncorrected refractive errors (spherical and cylindrical) of subjects were measured 3 times before each task without cycloplegia by an auto-refractometer (SHIN-NIPPON JP/SR-7000, JAPAN), averaged, and calculated as spherical equivalent diopters. After each task, the subjects were asked to remove the habitual correction with the trial frame and their refractive errors were measured 3 times and compared with the uncorrected spherical equivalent diopter measured before the task to investigate whether some myopic shift occurred.

6. Statistical analysis

All results were expressed as mean ± standard deviation. Their statistical significance between before and after each task was determined by one-way ANOVA test using GraphPad Prism 5 (GraphPad Software, Inc., San Diego) and if significant ($p<0.05$), group means were compared by post hoc analysis using Newman-Keuls Multiple Comparison test.

RESULTS

1. Subjective symptoms

After each task, the subjects answered the simple questionnaire described above, which comprised a series of subjective symptoms that they might have experienced during each task. After each work, 11.2% and 18.4% of the subjects responded that they occasionally felt some symptoms at last 10 min during reading and watching sustained for 30 min, respectively. The most frequently reported symptoms were dryness (43.4%) and eyestrain (24.2%) among the symptoms surveyed. However, the symptoms were not severe enough to cause any of the subjects to stop their tasks before 30 min.

2. Accommodative amplitude

The monocular accommodative amplitude (AA) of 63 subjects was measured as 9.30 ± 1.21 D. The monocular AA was not significantly changed by the 30 minute-book reading (Table 1) under the indoor lighting. The monocular AA after watching a dynamic movie on the smartphone significantly decreased, to 8.16 ± 2.43 D under the illumination of 370 lux (Table 1). When comparing the changes of monocular AA between book reading and smarphone use, the change of monocular AA after smartphone work was significantly greater than the change after book reading under same working environment ($p<0.05$ by one-way ANOVA and Newman-Keuls Multiple Comparison). Meanwhile, the binocular AA was 10.62 ± 1.66 D before either book reading or smarphone use (Table 1). The binocular AA was significantly changed only after smartphone use not by book reading. There was no significant difference in binocular AA between smartphone use and book reading (Table 1).

Table 1. The change of monocular and binocular accommodative amplitude after book reading or smartphone use for sustained 30 minutes

Working group / Accommodative amplitude (D)	Control	After reading a book	After watching a movie
Monocular	9.30±1.21	8.90±2.27	8.16±2.43[*,#]
Binocular	10.62±1.66	10.06±1.71	9.45±2.20[*]

Values are expressed as Mean ± SD (n=126, monocular AA; n=63, binocular AA).
[*], Significantly different from the control value at $p<0.05$; #, Significantly different from the value of book reading at $p<0.05$ (one-way ANOVA AND Newman-Keuls Multiple Comparison Test)

Table 2. The change of monocular and binocular accommodative facility after book reading or smartphone use for sustained 30 minutes

Working group / Accommodative facility (cpm[a])	Control	After reading a book	After watching a movie
Monocular	13.57±3.11	12.45±3.48	13.10±4.98
Binocular	12.98±3.93	11.31±3.31	12.09±4.34

[a]cpm stands for 'cycles per a minute'.
Values are expressed as Mean ± SD (n=126, monocular AF; n=63, binocular AF).

3. Accommodative facility

The accommodative facility (AF) was examined in monocular and binocular vision. The monocular AF after reading for 30 min was tented to reduce from 13.57 ± 3.11 cpm to 12.45 ± 3.48 cpm. It was slightly larger than the 0.47 D-decrease after smartphone use however, (Table 2) however, the change of monocular AF was not significantly different.

There was no significant change of binocular AF observed in neither book reading nor smarphone use even though the tendency of decrease in binocular AF was shown boh in book reading and smarphone use (Table 2) like shown in monocular AF.

4. Relative accommodation

The maximum ability of the ciliary muscle to stimulate or relax accommodation during clear single binocular vision was examined binocularly by measuring positive or negative relative accommodation (PRA or NRA). The PRA and NRA of the subjects were −3.38 ± 0.51 D and 2.18 ± 0.32 D, respectively, before conducting book reading and smar-

Table 3. The change of binocular relative accommodation after book reading or smartphone use for sustained 30 minutes

Working group / Relative Accommodation	Control	After reading a book	After watching a movie
PRA (D)	−3.38±0.51	−3.19±1.60	−3.10±1.75
NRA (D)	2.18±0.32	2.36±0.43*	2.04±0.58#

Values are expressed as Mean ± SD (n=63 for each group).
*, Significantly different from the control value at p<0.05; #, Significantly different from the value of book reading at p<0.05 (one-way ANOVA AND Newman-Keuls Multiple Comparison Test)

phone use (Table 3). PRA after reading was slightly reduced from −3.38 ± 0.51 D to −3.19 ± 1.60 D, but not significantly different (Table 3). PRA values after watching a movie on the smartphone was changed from −3.38 ± 0.51 D to −3.10 ± 1.75 D however, the decrease was not significant. However, NRA values after reading a book showed a somewhat different result, as NRA of the reading group increased significantly from 2.18 ± 0.32 D to 2.36 ± 0.43 D ($p<0.05$ by one-way ANOVA and Newman-Keuls Multiple Comparison) while NRA values were slightly reduced from 2.18 ± 0.32 D to 2.04 ± 0.58 D after watching a movie on the smartphone (Table 3). The changes in NRA after book reading and smartphone watching were significantly different ($p<0.05$ by one-way ANOVA and Newman-Keuls Multiple Comparison).

5. Accommodative lag

The difference between the accommodative stimulus and the response was binocularly evaluated by measuring the accommodative lag (AL) using a fused cross-cylinder. AL was initially determined as 0.25 ± 0.21 D and no change was observed after book reading for 30 min (Table 4). However, AL after watching a movie on the smartphone for 30 min changed significantly from 0.25 ± 0.21 D to 0.49 ± 0.28 D ($p<0.05$ by one-way ANOVA and Newman-Keuls Multiple Comparison). Furthermore, greater delay in AL was observed when the subjects were conducting the smartphone work rather than when they were reading under the same working environment ($p<0.05$ by one-way ANOVA and Newman-Keuls Multiple Comparison, Table 4).

6. Spherical equivalent refractive error

The uncorrected spherical equivalent refractive errors

Table 4. The change of binocular accommodative lag after book reading and smartphone use for sustained 30 minutes

Working group / Accommodative lag(D)	Control	After reading a book	After watching a movie
Binocular	0.25±0.21	0.30±0.16	0.49±0.28*,#

Values are expressed as Mean ± SD (n=63).
*, Significantly different from the control value at p<0.05; #, Significantly different from the value of book reading at p<0.05 (one-way ANOVA AND Newman-Keuls Multiple Comparison Test)

Table 5. The change of spherical equivalent power after book reading and smartphone use for sustained 30 minutes

Working group	Control	After reading a book	After watching a movie
Spherical equivalent power (D)	−3.28±1.85	−3.36±1.98	−3.45±2.19

Values are expressed as Mean ± SD (n=63 for each group).

was −3.28 ± 1.85 D before their tasks (Table 5). Slight myopic change was observed after reading a book (−0.12 D-shift) and watching a movie on smartphone (−0.17 D-shift), but not significantly different (Table 5).

DISCUSSION

The present study was conducted to investigate whether short-term smartphone use could induce changes in accommodative function. According to a previous study, the mean working distance for smartphones was closer than the near working distance of 40 cm when compared with reading books.[7] The closer distance will increase demands on both ocular accommodation and convergence, especially if maintained for an extended period of time, which could exacerbate symptoms when compared with longer viewing distances.[20]

Smartphones can be classified among video display terminals (VDT) since they display their screen content by either liquid crystal display or organic light emitting diodes and radiate electromagnetic waves.[21] It has been well documented that VDT workers suffer from eyestrain and visual stress such as tired eyes, irritation, redness, blurred vision, and double vision during or after work.[22-24] Yoo et al reported that less blinking during computer work for 90 min caused prolonged near-point distance of accommodation (NPA), reduced AA and an elongated period of accommodative tension in Korean adults immediately after computer work.[25] Some decrease of AA and AF after computer work for 2 h was also reported by Saito et al.[26] In addition, it was found that a shorter interval of computer work, such as 20 min, induced dry eye, which can lead to severe asthenopia.[27] However, findings obtained after a VDT work such as a CRT monitor may not be directly applied for suggesting the change of accommodative function after smartphone use because ergonomic workstation and video display technology have been continuously improved since these earlier studies.

Even though some subjects reported a few subjective symptoms during or after smartphone watching or reading, none of the subjects abandoned any task before 30 min because of the symptoms in our present study. Monocular AA was significantly reduced immediately after smartphone watching. The change of monocular AA after smartphone watching was significantly greater than by reading a book. Smartphone work for 30 min also induced higher AL and slight lower relative accommodation in binocular evaluation compared with reading. However, the changes in monocular and binocular AFs after smartphone use were slightly smaller than by the reading. Uncorrected spherical equivalent powers were not significantly changed by watching the smartphone for 30 min at the distance of 40 cm.

Altogether, our results regarding monocular AA changes after watching a smartphone for 30 min was well correlated with a previous report demonstrating that smartphone watching for 20 min induced prolonged NPC and exophoric shift.[14] Furthermore, our results indicate that the change in some accommodative functions is more specific to smartphone use than other near work such as reading a hard copy or watching a computer monitor under the same working environment. The significant change of AA in our study was also comparable to the results with computer work cited above, possibly since near work with the smartphone could cause ongoing tension of the lens followed by excessive accommodation.

Seo and Choe previously reported that computer work induced the decrease of both PRA and NRA in Korean adults.[27] However, in our study, a PRA (-3.38 ± 0.51 D) higher than the expected value of Morgan's norms (-2.37 ± 1.00 D) was recorded before the tasks and was slightly changed as 0.28 D of PRA decrease after smartphone use. NRA also showed only slight decrease of 0.14 D after smartphone use. In our study, the subjects had relatively high AA (9.30 ± 1.21 D) when considering their average age, and showed some reduced ability to accommodation of stimuli showing reduced monocular AA and PRA after sustained smartphone watching for 30 min under indoor light. However, their ability to relax accommodation, NRA value, was less affected by smartphone work for 30 min. This may partially explain why monocular and binocular AFs were affected only to a minimum by the smartphone use in our study. Indeed, some subjects showed non-equivalent ability to adjust their lenses to the +2.00/–2.00 D flipper during the examination of AFs in monocular and binocular after smartphone use. On the other hand, reading a book for a sustained 30 min induced a significant increase in the ability to relax accommodation compared with the effect of smartphone watching under the same working environment. These results propose that the ability to stimulate and relax accommodation is more affected by smartphone use than by reading a book. However, the possibility can not be fully excluded that effect of smartphone use on relative accommodation may be changeable according to the increasing working time and/or working environment since the previous research with CRT monitor showed that longer near work could induce greater change in PRA and NRA.[11]

In another recent study, Tosha et al. noted an increased AL in subjects reporting more discomfort, which became manifest with extended viewing, typically after at least 30 seconds of sustained fixation.[29] Accordingly, closer distance and smaller screen when watching smartphone for sustained 30 min might induce a larger AL and greater eye fatigue. Indeed, the increase of AL was significantly greater after smartphone use than after reading a book, even though participants conducted each task with the same posture in the same room for the same duration in our study.

Insignificant change of uncorrected spherical equivalent powers following smartphone watching for 30 min was comparable to a recent report showing that smartphone viewing at a distance of 40 cm for 30 min didn't change aided distance visual acuity and refractive error.[16]

CONCLUSIONS

The short-term work using a smartphone induced the following changes of accommodative function: 1) reduced accommodative amplitude in monocular and binocular, 2) reduced positive relative accommodation, and 3) higher accommodative lag when compared with measurements after reading a book. Therefore, most change of accommodative function was greater after smartphone use than after reading a book in a similar workstation. However, the relationship between surrounding illuminations and visual functions during smartphone work was not clearly determined by our present results. Even though the change of accommodative convergence can be indirectly assumed by the result of relative accommodation, it should be separately examined to determine the visual function during synkinetic eye movement. Thus, further studies about visual functions in binocular viewing such as positive/negative fusional vergences, fusional vergence amplitude, relative vergence and vertical phoria, etc., are necessary to fully understand the correlation between subjective/objective symptoms and effects on visual function caused by use of smartphones for extended periods.

REFERENCES

[1] Internet World Stats. Usage and Population Statistics. World Internet Users and Population Stats. Available at: http://www.internetworldstats.com/stats.htm. Accessed May 9, 2013.

[2] International Telecommunication Union. The world in 2011. ICT Facts and Figures. Available at: http://www.itu.int/ITU-D/ict/facts/2011/index.html. Accessed May 12, 2013.

[3] Internet World Stats. Usage and Population Statistics. Internet Usage Statistics for the Americas. Available at http://www.internetworldstats.com/america2.htm. Accessed May 12, 2013.

[4] The eMarketer Daily Newsletter. Two in five Mobile Owners Use Internet on the Go. Available at http://www.emarketer.com/Article.aspx?R=1008553. Accessed May, 2012.

[5] Korea Internet and Security Agency. 2011 Survey on wireless internet usage. Available at http://isis.kisa.or.kr/board/index.jsp?pageId=040100&bbsId=7&itemId=779&pageIndex=1. Accessed June 17, 2013.

[6] Korea Internet and Security Agency. Survey on smartphone usage in the second half of 2011. Available at http://isis.kisa.or.kr/board/?pageId=060200&bbsId=3&item Id=795. Accessed August 7, 2013.

[7] 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.

[8] Miller KH, Ziegler C, Greenberg R, Patel PD, Carter MB. Why physicians should share PDA/smartphone findings with their patients: A brief report. J Health Comm. 2012; 17:54-61.

[9] Svoboda E, Richards B, Leach L, Mertens V. PDA and smartphone use by individuals with moderate-to-severe memory impairment: Application of a theory-driven training program. Neuropsycho Rehab. 2012;22(3):408-427.

[10] Takao H, Murayama Y, Ishibashi T, Karagiozov KL, Abe T. A new support system using a mobile device (smartphone) for diagnostic image display and treatment of stroke. Stroke 2012;43(1):236-239.

[11] Kwon KI, Woo JY, Park M, Kim SR. The change of accommodative function by the direction of eye movements during computer game. J Korean Oph Opt Soc. 2012;17(2):177-184.

[12] Blehm C, Vishnu S, Khattak A, Mitra S, Yee RW. Computer vision syndrome: A review. Surv Ophthalmol. 2005; 50(3):253-262.

[13] Collier JD, Rosenfield M. Accommodation and convergence during sustained computer work. Optometry 2011;88(7):434-440.

[14] 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 Oph Opt Soc. 2012;17(2):171-176.

[15] Kim B-H, Han S-H, Kwon S-J, Kim M-S, Jeong H-S, Kim H-J. Change of refractive error after watching smartphone under low intensity of illumination. J Korean Ophthalmic Opt Soc. 2014;19(1):105-109.

[16] Kim B-H, Han S-H, Shin YG, Kim DY, Park JY, Shin WC, Yoon JH. Aided distance visual acuity and refractive error changes by using smartphone. J. Korean Oph Opt Soc. 2012;17(3):305-309.

[17] Korea Ministry of Employment and Labor. Employment and Labor Policy in Korea (No. 2004-50); The management guideline for the VDT task workers. Available at http://www.moel.go.kr/view.jsp?cate=4&sec=4&mode=view&bbs_cd=116&state=A&seq=8355. Accessed March 7, 2013.

[18] American Optometric Association. Care of the patient with accommodative and vergence dysfunction. 2010. St. Louis (MO): American Optometric Association. Available at http://www.aoa.org/documents/CPG-18.pdf. Accessed March 7, 2013.

[19] Shin J, Lee O. Relationship between subjective symptoms with near work and binocular function. J Korean Oph Opt Soc. 2007;12:125-130.

[20] Rah MJ, Mitchell GL, Bullimore MA, Mutti DO, Zadnik K. Prospective quantification of near work using the experience sampling method. Optom Vis Sci. 2001;78: 496-502.

[21] Bornkessel C. Assessment of exposure to mobile telecommunication electromagnetic fields. Wien Med Wochenschr. 2011;161(9-10):233-239.

[22] Hedman LR, Briem V. Short term changes in eyestrain of VDU users as a function of age. Hum Factors 1984; 26(3):357-370.
[23] Hayes JR, Sheedy JE, Stelmack JA, Heaney CA. Computer use, symptoms, and quality of life. Optom Vis Sci. 2007;84(8):E738-755.
[24] Nakazawa T, Okubo Y, Suwazono Y, Kobayashi E, Komine S, Kato N, Nogawa K. Association between duration of daily VDT use and subjective symptoms. Am J Ind Med. 2002;42(5):421-426.
[25] Yoo JS, Yoon JW, Kim JH. Influence of VDT work on accommodative function. J Korean Ophthalmol Soc 1992; 33(7):693-697.
[26] Saito S, Sotoyama M, Saito S, Taptagaporn S. Physiological indices of visual fatigue due to VDT operation: pupillary reflexes and accommodative responses. Ind Health 1994;32(2):57-66.
[27] Cho YA, Won JS, An GJ. The effect on the dryness of eye during VDT work. J Korean Ophthalmol Soc. 1996; 37(12):1991-1995.
[28] Seo YW & Choe YJ. Visual problems and refractive error at video display terminals. J Korean Oph Opt Soc. 1998; 3(1):75-86..
[29] Tosha C, Borsting E, Ridder WH III, Chase C. Accommodation response and visual discomfort. Ophthalmic Physiol Opt. 2009;29(6):625-633.

스마트폰 사용에 따른 20대 성인의 조절기능 변화

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목적: 본 연구에서는스마트폰을 이용한 근거리 작업 시 조절 기능의 변화가 유도되는가를 알아보고자 하였다. **방법:** 20대의 총 63명 (남성 26명, 여성 37명)을 대상으로 조절 기능과 교정 전 등가구면도수를 측정하여 대조군 값으로 하였다. 실내조명 아래에서 연구대상자들에게 30분 동안 책을 읽게 한 후 30분간의 휴식 시간을 가지게 하고 순차적으로 동일한 시간 동안 스마트폰으로 영화를 보게 하거나 작업순서에 따른 오차를 배제하기 위하여 반대의 순서로 영화보기와 책읽기를 하게 하였다. 연구대상자들의 조절기능은 1) 최대조절력, 2) 조절 용이성, 3) 양성 및 음성상대조절, 4) 조절 래그 및 교정하지 않은 등가구면도수를 각 작업 후에 다시 검사하고 대조군 값과 비교하였다. **결과:** 단안 최대조절력은 독서 후와 비교하여 스마트폰 시청 후 유의하게 감소하였다. 단안 및 양안 조절용이성은 독서나 스마트폰 사용 후 모두 감소하는 경향을 보였으나 통계적으로 유의한 차이는 아니었으며, 양성상대조절 값은 독서나 스마트폰 사용 후 모두 유의한 변화가 없었다. 스마트폰 사용 후 음성상대조절 값은 독서 후와는 달리 거의 변화가 없었다. 스마트폰 사용 후 조절래그 값은 독서 후의 경우보다 유의하게 높았다. **결론:** 30분 동안의 스마트폰을 사용한 근거리 작업은 일부 조절기능의 변화를 유발하였으며, 그 변화는 동일한 작업 환경에서의 독서 시보다 유의하게 컸다.

주제어: 최대조절력, 조절용이성, 조절래그, 근거리 작업, 상대조절, 스마트폰