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A follow-up study of the association between mobile phone use and symptoms of ill health

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The duration and frequency of mobile phone calls, and their relationship with various health effects, have been investigated in our previous cross-sectional study. This 2-year period follow-up study aimed to assess the changes in these variables of same subjects. The study population comprised 532 non-patient adult subjects sampled from the Korean Genome Epidemiology Study. The subjects underwent a medical examination at a hospital in 2012/2013 and revisited the same hospital in 2014/2015 to have the same examination for the characteristics of mobile phone use performed. In addition, to evaluate the effects on health, the Headache Impact Test-6 (HIT-6), Psychosocial Well-being Index-Short Form, Beck Depression Inventory, Korean-Instrumental Activities of Daily Living, Perceived Stress Scale, Pittsburgh Sleep Quality Index, and 12-item Short Form Health Survey were analyzed. For all these tests, the higher the score, the greater the effect on health. Variances between scores in all the indices in the baseline and follow-up surveys were calculated, and correlations of each index were analyzed. The average duration per call and HIT-6 score of the subjects decreased significantly compared with those recorded two years ago. The results showed a slight but significant correlation between call duration changes and HIT-6 score changes for female subjects, but not for males. HIT-6 scores in the follow-up survey significantly decreased compared to those in the baseline survey, but long-time call users (subjects whose call duration was ≥5 minutes in both the baseline and follow-up surveys) had no statistically significant reduction in HIT-6 scores. This study suggests that increased call duration is a greater risk factor for increases in headache than any other type of adverse health effect, and that this effect can be chronic.

Keywords: Mobile phones, Headaches, Headache Impact Test-6, Non-specific symptoms

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INTRODUCTION

Due to the rapid rise in popularity of mobile phones globally, concerns about the health effects of mobile phone use on the general population have increased. Several studies reported that the use of mobile phones could be related to non-specific symptoms as well as brain tumors [1-3]. Since then, several studies have reported that the duration of mobile phone calls was associated with increased non-specific symptoms which include headaches, migraine, sleep disorder, anxiety, nausea, skin irritation, etc. in mobile phone users [4-6].

In contrast, other studies reported no significant correlation between the use of mobile phones and headache or other effects [7,8]. A number of studies that evaluated acute reactions of the human body to exposure to the radiofrequency-electromagnetic field (RF-EMF) also reported that no significant correlations were found between RF-EMF and headache or other symptoms [9-11]. In contrast to experimental study results evaluating the effects of short-term RF-EMF exposure, observational studies evaluating the health effects of low-level and long-term exposure to RF-EMF have tended to report a significant correlation between the use of mobile phones and adverse health effects [5,6,12].

The exposure to RF-EMF resulting from mobile phone calls is considered to have chronic health effects, related to using mobile phones for a long time, rather than acute health effects due to short term exposure [12,13]. However, most studies on the relationship between mobile phone calls and non-specific symptoms have applied a cross-sectional study design.

In our previous study [14], correlations between mobile call patterns of subjects and health effects were analyzed using a cross-sectional study design. Adding to the previous study, in this study, changes in health effect patterns were analyzed according to changes in patterns of mobile phone use over a 2-year period. These two studies aimed to find associations between mobile phone use and symptoms of ill health by both cross-sectional and follow-up designs.

METHODS

Study Subjects

The subject group for this study was introduced in our previous cross-sectional study [14]. Briefly, the study subjects comprised a population group who gave consent to participate in the present study among the non-patient adult population in the Korean Genome and Epidemiology Study (KoGES)–Ansan, which was a community-based prospective cohort study. KoGES–Ansan had tracking observations performed on the same subjects every two years [15]. The 532 subjects visited a hospital to undergo a medical examination in 2012/2013; the same medical examination was performed two years later, in 2014/2015. They were all adults aged more than 40 years who had used mobile phones for several years. Ethics approval for the contents of this study was given by the Centers for Disease Control and Prevention (KCDC) and the Human Subjects Review Committee at Korea University. In addition, all participants gave informed consent.

Data Collection and Variables

The survey items of study subjects were also introduced briefly in our previous study [14]. They included: Headache Impact Test-6 (HIT-6), to evaluate the level of aggravation in quality of life due to headache; Psychosocial Well-being Index-short Form (PWI-SF), to evaluate mental health level; Beck Depression Inventory (BDI), to evaluate depression; Korean Instrumental Activities of Daily Living (K-IADL), a dementia prediction too l testing for cognitive impairment; Perceived Stress Scale (PSS), to evaluate a perceived stress level; Pittsburgh Sleep Quality Index (PSQI), to evaluate the quality of sleep; and 12-item Short Form Health Survey (SF-12), to evaluate overall levels of physical and mental health. Reliabilities and validities of these tools are already suggested elsewhere [14]. All of the above tests were scored using continuous variables: the higher the score, the worse the aggravation in health effect. For example, an increase in HIT-6 score meant an increase in the severity level of the headache effect. Similarly, the higher the SF-12 score, the worse the overall health level.

The characteristics of mobile phone use were investigated based on the average frequency of calls per day and the average duration per call. The cutoff value that distinguished long or short call duration was set to five minutes according to the specific absorption rate, which represents the thermal effect of electromagnetic radiation [16].

Professional medical staff performed the survey and examination. The survey of each item was conducted via a one-to-one interview. Mobile phone use included both transmission and reception, but excluded text message transmission and reception, and the use of the Internet and other information services. To reduce recall bias, mobile phone use was assessed as a breakdown of the mobile phone bill provided in a hard copy or through a mobile phone application.

Statistical Analysis

All health effect indices and mobile phone use characteristics (average frequency of calls per day and average duration per call) were represented with continuous variables. A paired *t*-test was performed to compare the results of all variables between the baseline (2012/2013) and follow-up (2014/2015) survey. A change was calculated by subtracting the value obtained in the baseline survey (2012/2013) from the value obtained in the follow-up survey (2014/2015). Thus, if call frequency and duration had increased, a change was expressed as +, whereas, if they had decreased, the change was expressed as –. Regarding the level of health, the higher the index score, the worse the aggravation of health. Thus, as the health level deteriorated, the change was expressed as + and as health level improved, the change was expressed as –. To determine the relationship with the variables regarding the change, Pearson's correlation coefficient was calculated.

A relationship between change in call pattern over 2-year and symptoms was analyzed. Subjects were divided into four groups: a group whose average call duration was < 5 minutes in both of the baseline survey and follow-up survey, a group whose average call duration was ≥5 minutes in both of the baseline survey and follow-up survey a group whose average call duration was ≥5 minutes in the baseline survey but became <5 minutes in the follow-up survey, and vice versa. Then, changes in HIT-6 score were compared between groups. The Wilcoxon signed rank test was applied to compare the HIT-6, BDI, K-IADL, PSS, PSQI, and SF-12 scores in the groups between the baseline and follow-up surveys.

The statistical analysis was performed using SPSS version 23 (IBM Corp., Armonk, NY, USA) and statistical significance was tested at 95% confidence level, p-value <0.05.

RESULTS

The subjects (532 persons) who visited the hospital and underwent health screening in 2012/2013 had the same screening performed in 2014/2015. The average age of 57 years in 2012/2013, had become 59 years in 2014/2015. The median average frequency of calls per day was 5.0 times in 2012/2013; this remained unchanged 2-year later. The median average duration per call was 1.5 minutes in 2012/2013 but had decreased to 1.3 minutes in 2014/2015 (Table 1).

Table 2 shows the values of each variable evaluated in the baseline survey (2012/2013) and follow-up survey (2014/2015). The average duration per call reduced by approximately 30% from 2012/2013 to 2014/2015. The paired t-test result showed that HIT-6 scores had significantly reduced over the period of 2-year. In addition, BDI and K-IADL had also reduced, while the average frequency of calls per day, PSQI, and SF-12 had increased slightly, but not to a statistically significant level.

The correlation analysis showed a significant correlation between HIT-6 score changes and average duration per call changes among women (Pearson's correlation coefficient=0.125;

Table 1. General characteristics of the subjects

Variable		Baseline survey (2012/2013)		Follow-up survey (2014/2015)	
		n (%)	Median (1st – 3rd quartile)	n (%)	Median (1st – 3rd quartile)
Gender	Women	298 (56.0)	-	298 (56.0)	-
	Men	234 (44.0)	-	234 (44.0)	-
Age		-	57.0 (53.0-63.0)	-	59.0 (55.0-65.0)
Average frequency of calls (n/d)		-	5.0 (3.0-10.0)	-	5.0 (3.0-10.0)
	<5	214 (40.2)	-	218 (41.0)	-
	5 - <10	156 (29.3)	-	148 (27.8)	-
	≥10	143 (26.9)	-	153 (28.8)	-
Average call duration (min/call)		-	1.5 (1.0-3.0)	-	1.3 (1.0-3.0)
	<5	426 (80.1)	-	466 (87.6)	-
	5 - <10	35 (6.6)	-	39 (7.3)	-
	≥10	47 (8.8)	-	14 (2.6)	-

Table 2. Comparison of baseline survey (2012/2013) and follow-up survey (2014/2015) with regard to the investigated variables

Variable		n	Mean±SD	p-value[a]	Variance
Frequency	2012/2013	508	6.77±5.84	0.31	1.000
	2014/2015	508	6.98±5.95		1.031
Call duration	2012/2013	497	2.82±3.86	<0.001	1.000
	2014/2015	497	2.02±1.88		0.716
HIT-6	2012/2013	521	43.43±7.81	<0.001	1.000
	2014/2015	521	39.11±5.18		0.901
BDI	2012/2013	513	6.98±6.63	0.05	1.000
	2014/2015	513	6.50±6.67		0.932
K-IADL	2012/2013	339	0.56±1.04	0.002	1.000
	2014/2015	339	0.42±0.78		0.754
PSS	2012/2013	410	15.22±5.59	0.003	1.000
	2014/2015	410	14.28±5.67		0.939
PSQI	2012/2013	120	4.73±2.72	0.65	1.000
	2014/2015	120	4.83±2.79		1.021
SF-12	2012/2013	528	24.02±5.99	0.95	1.000
	2014/2015	528	24.03±5.81		1.001

SD, standard deviation; Frequency, average frequency of calls (n/d); Call duration, average call duration (min/call); HIT-6, Headache Impact Test-6; BDI, Beck Depression Inventory; K-IADL, Korean-instrumental Activities Of Daily Living; PSS, Perceived Stress Scale; PSQI, Pittsburgh Sleep Quality Index; SF-12, 12-item Short Form Health Survey.
[a]by paired t-test.

Table 3. Pearson's correlation coefficient with regard to changes in 2012/2013 and 2014/2015

	Frequency	Call duration	HIT-6	BDI	K-IADL	PSS	PSQI	SF-12
Women								
Frequency	1							
Call duration	0.052	1						
HIT-6	0.065	0.125*	1					
BDI	0.013	-0.016	-0.001	1				
K-IADL	0.184*	0.045	0.001	0.155*	1			
PSS	-0.002	0.026	0.011	0.241**	0.038	1		
PSQI	-0.033	0.186	0.166	0.225	-0.119	-	1	
SF-12	0.054	-0.005	-0.106	0.229**	0.137	0.065	-0.108	1
Men								
Frequency	1							
Call duration	-0.115	1						
HIT-6	0.081	0.088	1					
BDI	-0.030	0.028	0.065	1				
K-IADL	0.048	-0.045	0.005	-0.026	1			
PSS	-0.032	0.107	0.081	0.231**	-0.130	1		
PSQI	-0.046	-0.016	-0.098	0.080	-0.149	-	1	
SF-12	-0.099	-0.011	-0.131	0.336**	0.017	0.026	-0.008	1

Each of the investigated variables refers to a change in investigated value over two measurements. It is a value that calculated by subtracting a value studied in 2012/2013 from a value studied in 2014/2015. For example, if average call duration per call is five minutes in 2012/2013 and 10 minutes in 2014/2015, a change in average call duration per call is +5 minutes and this value is applied in the Pearson's correlation analysis.
Frequency, average frequency of calls (n/d); Call duration, average call duration (min/call); HIT-6, Headache Impact Test-6; BDI, Beck Depression Inventory; K-IADL, Korean-instrumental Activities Of Daily Living; PSS, Perceived Stress Scale; PSQI, Pittsburgh Sleep Quality Index; SF-12, 12-item Short Form Health Survey.
*$p<0.05$, **$p<0.01$.

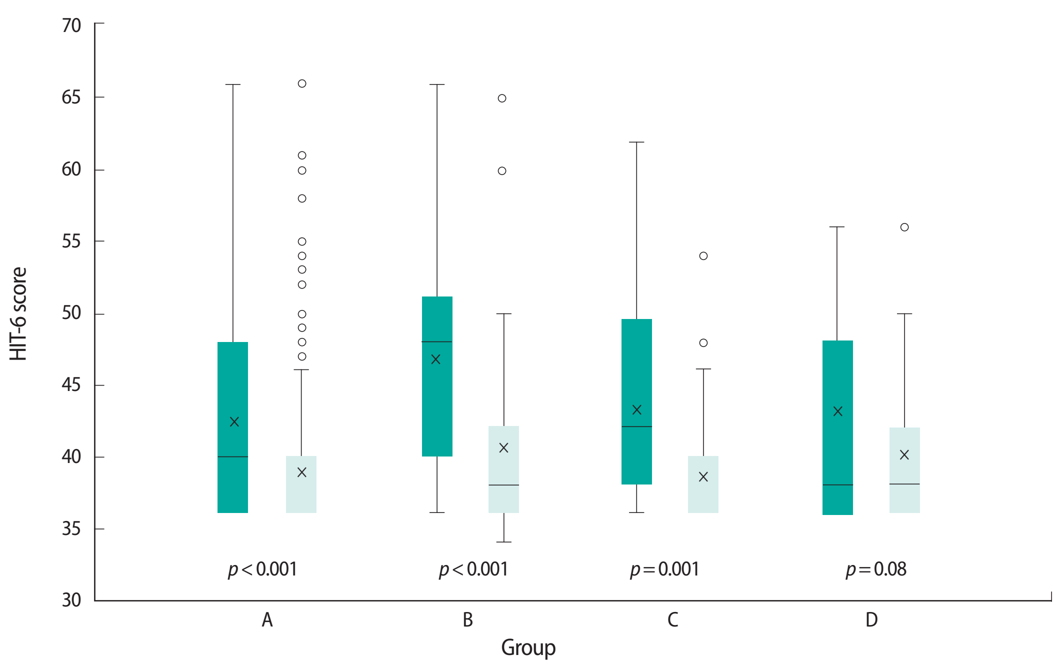

Figure 1. Distribution of Headache Impact Test-6 (HIT-6) score according to call duration (on the basis of 5 minutes) in baseline survey and follow-up survey. Group A, subject group whose average call duration per call was <5 minutes at baseline and follow-up survey (n=382); Group B, ≥5 minutes at baseline survey but <5 minutes at follow-up survey (n=58); Group C, <5 minutes at baseline survey but ≥5 minutes at follow-up survey (n=28); Group D, ≥5 minutes at both of baseline and follow-up survey (n=19). White solid box, baseline survey (2012/2013); Slash box, follow-up survey (2014/2015); Line in the box refers to the median; x mark in the box refers to arithmetic mean; *p* refers to *p*-value, which compares HIT-6 scores in the baseline and follow-up surveys through the Wilcoxon signed rank test.

$p<0.05$), but not among men. Other indices showed significant correlations between BDI (index for depression) and PSS (index for stress) and between BDI and SF-12. The average frequency of calls per day among women was significantly correlated with K-IADL, an index of cognitive function of daily living. However, this was not demonstrated for men (Table 3).

The HIT-6 scores were compared between the baseline and follow-up surveys using the Wilcoxon signed rank test. Mean and median scores of HIT-6 in the baseline survey among the group whose average duration per call was < 5 minutes in both surveys (n = 382) were 42.4 and 40.0, respectively, whereas they were 38.8 and 36.0, respectively, in the follow-up survey. This difference was statistically significant ($p < 0.001$). Mean and median HIT-6 scores in the group whose average call duration per call was ≥ 5 minutes in the baseline survey but became < 5 minutes in the follow-up survey (n = 58) were 46.8 and 48.0, respectively. Their mean and median scores in the follow-up survey were 40.6 and 38.0, respectively; this was a statistically significant reduction ($p < 0.001$). Mean and median HIT-6 scores in the group whose average call duration per call was < 5 minutes in the baseline survey but became ≥ 5 minutes in the follow-up survey (n = 28) were 43.4 and 42.0, respectively, and were 38.5 and 36.0, respectively, in the follow-up survey. This reduction was significant ($p = 0.001$). Mean and median HIT-6 scores in the baseline survey at group whose average call duration per call was ≥ 5 minutes in both surveys (n = 19) were 43.2 and 38.0, respectively, and were 40.2 and 38.0, respectively, in the follow-up survey: There was no statistically significant difference ($p = 0.08$) (Figure 1). Other factors except HIT-6 did not show any differences between four groups (data not shown).

DISCUSSION

This study which was divided into two articles aimed to calculate the association between the frequency and intensity of mobile phone use and symptoms of ill health by structured clinical questionnaires. The cross-sectional study performed earlier than this article has already reported that only headache among investigated symptoms had a significant relationship with call duration of mobile phones [14]. Above and beyond this cross-sectional study, in this follow-up study, we carried out repeated tests on the same 532 adults 2-year later to calculate and compare the variation of each factor.

In the previous work, the frequency of mobile phone calls did not correlate with various ill health factors. An increase in call duration was related with an increase in headache, but was not shown to be correlated with other health factors. In this follow-up study, the duration of mobile phone calls had reduced over the 2-year period, as shown in the re-examination result. However, the reduction in average call duration was related to a decrease in headache among women only. The criterion of call duration longevity was set to 5 minutes, and headache effects were evaluated based on this cutoff. When the call duration was ≥ 5 minutes, headache effects became more severe.

The subjects in the present study were middle-aged persons whose mean age was late fifties. An investigation study performed in Korea reported that with increased age, call frequency and duration using mobile phones reduced, in particular for the period from middle-age to elderly [17]. Although the result was not presented in the section above, call frequency and duration were shown to reduce as age increased; call duration in the same subjects had significantly decreased after 2-year. In addition, the headache effect had decreased during the 2-year period. Tension type headaches, which were the most common type of headache experienced by the study subjects, has been reported to be most severe in men and women in their thirties [18]. Thus, the headache effect may have reduced because of the increased age of the subjects.

It is necessary to identify whether the reduction in the headache effect was really due to the reduction in call duration. In the present study, a difference in call duration during a period of 2-year was significantly correlated with a difference in the headache effect, although this finding was limited to women. Furthermore, no statistically significant reduction in headache effect during the period of 2-year was revealed in the group whose average duration per call was ≥ 5 minutes in both of the baseline and follow-up surveys, despite the overall reduction in headache effect.

A relationship between call duration and headache could be due to a thermal sense effect caused by exposure to RF-EMF, as mentioned in our previous study. Several studies have proven that the thermal sense effect increases around the ear as mobile phone call duration increases [19-22]. It was also now well-known that when the call duration increases to ≥ 5 minutes, a thermal sense is generated from the near-field, affected by the RF-EMF via mobile phone [16]. However, the effect of thermal sense on human body, and the mechanism through which health endpoints can result, are not yet clearly identified. As revealed in other studies, the present study showed that increases in mobile call duration increased the risk of headache effect with regard to health effects perceived by mobile phone users.

The present study has several limitations. This study did not measure RF-EMF, so it cannot be concluded that the relationship between increases in call duration and headache was due to the exposure to RF-EMF. The present study only suggested that a habit of long call duration via mobile phone could cause health effects such as headache. The other limitation is that the study result cannot be generalized to the general population due to the mean age of the study subjects (late fifties). However, since the subjects had no specific symptoms and comprised a healthy adult group, they were relatively free from occupational or economic stress, including headache. Furthermore, the average period of mobile phone use was 16 years and most subjects started using mobile phones in the late 1990s and early 2000s, when mobile phones were launched in Korea. Therefore, they had used mobile phones for a sufficient period of time for it to become a habit. Moreover, people in the same generation as the subjects tend to use mobile phones mainly for calls, rather than other functions, such as Internet connection, games, Bluetooth, or multimedia messaging service. Although the present study subject group may not represent the entire population that uses mobile phones, they are also not considered an inappropriate group to verify the relationship between mobile phone use and health effects.

As another limitation, effect sizes in this study were too small. There are a lot of factors that may affect headache symptoms. Although the mobile phone use is not a strong risk factor that may affect headaches, at least it may be one of many factors affecting the headache.

Other than the above limitations, other limitations may be found. Nonetheless, the present study, consisting of cross-sectional design and follow-up study and applied structed clinical tools, suggests that the use of mobile phones (long call duration in particular) can be a risk factor for headache although other symptoms such as depression, stress, sleep disorder, and dementia were not. Further, in the group whose average mobile phone call duration was relatively long, the headache effect seemed to be chronic. Future research is necessary to elucidate and prove mechanisms underlying the apparent correlations between mobile phone use, headache, and other various health risk symptoms.

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CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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