Prevalence of Headache among Handheld Cellular Telephone Users in Singapore: A Community Study

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We carried out a cross-sectional community study in Singapore to determine the prevalence of specific central nervous system (CNS) symptoms among handheld cellular telephone (HP) users compared to nonusers and to study the association of risk factors and CNS symptoms among HP users. A total of 808 men and women between 12 and 70 years of age, who lived in one community, were selected using one-stage cluster random sampling and responses to a structured questionnaire. The prevalence of HP users was 44.8%. Headache was the most prevalent symptom among HP users compared to non-HP users, with an adjusted prevalence rate ratio of 1.31 [95% confidence interval, 1.00–1.70]. There is a significant increase in the prevalence of headache with increasing duration of usage (in minutes per day). Prevalence of headache was reduced by more than 20% among those who used hand-free equipment for their cellular telephones as compared to those who never use the equipment. The use of HPs is not associated with a significant increase of CNS symptoms other than headache. ***Key words*****: cellular telephones, community, cross-sectional study, headaches.** ***Environ Health Perspect*** **108:1059–1062 (2000). [Online 16 October 2000]**

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The use of handheld cellular telephones (henceforth referred to as hand phone; HP) has been on the increase, with more and more individuals using HPs because of the convenience they offer over other modes of telecommunication. In Singapore, 4 out of 10 people own an HP. The market is largely dominated by the digital system (GSM). More than 80% of these HPs operate using the GSM 900 system, with another 12% using the GSM 1800 system; both are digital systems. In the digital system, the information is sent via pulse-modulated signals of frequency between 870 and 995 MHz. Within this frequency band, the wave is nonionizing.

Present knowledge of health effects on humans from this frequency band (870–995 MHz) is limited. Most researchers have reported the effects of radio-frequency radiation (RFR) on laboratory animals and cell cultures. Salford et al. (*1*) demonstrated that low levels of RFR can alter the blood-brain barrier in mice, and Hocking (*2*) has preliminary evidence of an effect by 830 MHz RFR on endothelial cell cultures. Lai et al. (*3*) reported that rats exposed to low levels of RFR have impaired learning and an associated change in acetylcholine receptor levels.

In humans, health symptoms have previously been described in connection with work-related exposure to low-level radio frequency fields or microwaves (*4*). People who have been occupationally exposed to these fields have complained of heavy feelings in the head, headaches, fatigue, and poor memory more often than controls (*4*). The number of anecdotal reports of symptoms experienced by HP users around the world is increasing. These symptoms include headaches, dizziness, warmth or tingling around the ear and face, and difficulties concentrating (*2,5,6*).

In a case series of 40 mobile phone users, Hocking (*2*) reported that 35 of them complained of cranial symptoms such as a burning feeling or dull ache, mainly in the temporal, occipital, and auricular areas; 11 reported visual effects; 15 reported nausea, dizziness, or "fuzziness" in the head that made thinking difficult; and 75% of the cases were associated with digital mobile phones. A large cross-sectional, Swedish–Norwegian epidemiologic study was conducted by Mild et al. (*6*) in 1995. The authors studied 8,879 GSM phone users and 8,113 NMT (analog system operating at 900 MHz). Generally, the GSM phones have a lower power output than the NMT phones. The researchers' main hypothesis was that GSM users experience more symptoms than NMT users. Mild et al. (*6*) reported that among GSM users there were significant statistical associations between calling time and number of calls per day and the occurrence of warmth behind, around, and on the ear; headache; fatigue; burning facial skin sensation; and dizziness.

There are shortcomings in both studies. Hocking's study (*2*) is only a case series and does not point to an association between mobile phone use and symptoms. In addition, the study have been biased given that "respondents were recruited by a notice in a medical journal in 1996 which led to some media publicity" (*2*). Although the study by Mild et al. (*6*) is a large cross-sectional study, it involved subjects who used GSM or NMT HPs (*6*). There was no comparison between the HP users and non-HP users with regard to health symptoms. Mild et al. (*6*) stated that

> The media has focused on possible health effects caused by microwaves emitted by mobile phones (MP). It is possible that fear or awareness might cause MP users to report more symptoms than people not using MPs even if the prevalence of symptoms were equal.

This reasoning is valid; thus they were only able to compare the symptoms of two types of HP users, that is, one involving the use of the analog system (NMT) and the other the digital system (GSM). Both of these studies (*2,6*) are not community based in spite of the common use of HPs in the community.

The objectives of our study, therefore, were to study the prevalence of specific central nervous system (CNS) symptoms among HP users compared to non-HP users and to determine the association of risk factors and CNS symptoms among HP users.

Methods

Study design and subjects. To reduce subject bias, we told subjects that we were studying the prevalence of headache and the associated risk factors in the community. Thus, study subjects were not aware that we were studying the effects of HP use and CNS symptoms.

We conducted a cross-sectional study in a housing estate (Bishan) in the northeastern sector of Singapore. The study location was chosen because of demographic factors. Because it is growing estate, established about 10–15 years ago, there would be a suitably large proportion of younger families. Therefore, we could find a respectable mix of HP and non-HP users there. It is a typical Singaporean urban area and reflects a typical Singaporean living standard.

Estimating the difference of prevalence of headache among HP users and non-HP users to be approximately 10% and an α of 0.05, we needed approximately 800 individuals to achieve a power of 0.8 for the study.

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From our pilot study, the household and individual response rates were 60% and 70%, respectively. We also found out that the average household size, with eligible individuals, was three. These figures were used in our computation to determine the number of households (635) needed to obtain 800 individuals.

We used a one-stage random cluster sampling procedure to draw a random sample of 635 households, targeting at 800 individuals, from all of the Housing Development Board flats in Bishan, Singapore. The eligible subjects were all Singaporeans and permanent residents between the ages of 12 and 70 years who resided in Bishan during the time of the survey (12–16 January 2000) and who were healthy and had no known medical problems. The household participation rate was 66.6%, and the individual participation rate was 67.4%, giving an effective sample of 808 respondents. Participation rates for both housholds and individuals exclude subjects who could not be contacted and those who refused to participate.

Questionnaire. All respondents were interviewed by a team of trained medical students using a structured questionnaire (with English, Chinese, and Malay translation), which had been field-tested in a pilot study. Interviewers who were fluent in a particular language were asked to interview the respondents who spoke that language. The interview was conducted at the respondents' house with informed consent.

Components of the questionnaire. The questionnaire included *a*) personal information (age, sex, occupation, marital status, and ethnic group); *b*) questions on general health status and any diagnosed medical conditions; and *c*) nature and severity of CNS symptoms. We used a two-tier approach in our questionnaire to minimize recall bias. Before asking the individuals about the use of HPs, interviewers first asked about their headache problems in terms of frequency, nature, and severity. Because headache is a common public health concern and is a topic of interest among the public, the topic would engage participants in the survey but would mask the actual survey goal of determining the relationship of the symptoms with HP use.

Headaches were classified according to International Headache Society (IHS) criteria (*7*). The IHS diagnostic criteria require secondary pathology by a physical examination and appropriate tests. This was not possible in our community study. Only "primary headache disorders," as classified by the IHS criteria (*7*) were included in the study. We excluded "secondary headache disorders" from the study because our objective was to study the association of primary headache disorders and HP usage.

Other CNS symptoms of interest included in the study based on literature review were dizziness, difficulties in concentration, loss of memory, unusual drowsiness or tiredness, sense of warmth behind or around the ear, burning sensation to the ear and face, tingling sensation to the face, and visual disturbances (e.g., flashes). The respondents were asked how often they experienced the listed symptoms during the past year, at what frequency they experienced each symptom, and if they used HPs. We defined an HP user as one who uses the HP at least once each day on average.

Data analysis. Statistical analysis was carried out using SPSS 9.0.1 on a personal computer(*8*). Statistical analysis involved descriptive summary measures of central tendency, frequencies, and associations with tests of significance where appropriate. Bivariate analysis was carried out to determine the association between CNS symptoms among HP users and various predictor variables. The predictor variables in our study included age, sex, occupations, and exposure to video display terminals. We used prevalence rate ratios (the relative likelihood of having symptoms associated with HP use) and the chi-square test to determine the relationship between these predictor variables and the likelihood of having CNS symptoms among HP users.

Because bivariate analysis does not take into account the potential confounding effect of other variables, we further estimated the prevalence rate ratios with adjustment for confounding. We adopted stepwise regression using the proportional hazards model, a multivariate model (*9*) because it allowed us to compute directly the adjusted prevalence rate ratios for the independent predictors retained in the final model.

Results

Table 1 shows the distribution of respondents by demographic characteristics and HP use. Although the population in Singapore is equally distributed between both sexes, there was a higher proportion of female respondents in our study (53%). Of the ethnic groups in our study, the Chinese represented the vast majority of respondents, and the Indian population was twice that of the Malay population. Although this differs from the national ethnic group percentages, our figures closely reflect the ethnicity of the Bishan community. The age distribution also corresponded closely to the general population, with a peak in the 30–40 and 40–50 year age groups. Three percent of the studied population had some history of CNS problems (e.g., brain surgery, stroke, post-trauma headache, etc.). Because these CNS problems could bias our findings, we removed the 27 respondents from all subsequent analyses. The remaining 781 respondents were used in the following analyses.

Figure 1 shows the distribution of symptoms among HP and non-HP users. Headache was the most prevalent symptom among the HP users as compared to non-HP users. The crude prevalence rate ratio of headache among HP versus non-HP users is 1.12 [95% confidence interval (CI), 0.99–1.26]. After adjusting for age, sex, ethnic group, use of video display terminals, and occupational group using the proportional hazards model, the adjusted prevalence rate ratio is 1.31 (95% CI, 1.00–1.70). The prevalence of headache was significantly associated with the duration (minutes) of using the HP per day.

Table 2 shows the association between the use of HPs and the prevalence of headache, and also the association between the use of hand-free equipment and the prevalence of headache. There is no association between the number of times an HP is used per day with the prevalence of headache. However, there is a significant positive trend for increasing time spent on the HP and prevalence of headache (Table 2). HP users who did not use hand-free equipment had the highest prevalence of headache among the HP users. There is a significant negative trend for prevalence of headache with increasing usage of hand-free equipment (Table 2).

Table 1. Demographics of study population.

	No. of individuals	Percent
Sex		
Male	382	47.3
Female	426	52.7
Marital status		
Single	240	29.7
Married	549	67.9
Widowed	12	1.5
Divorced/separated	7	0.9
Ethnic group		
Chinese	662	81.9
Malay	40	5.0
Indian	86	10.9
Other	18	2.2
Age (years)		
12–19	110	13.6
20–29	105	13.0
30–39	216	26.7
40–49	223	27.6
50–59	106	13.1
≥ 60	48	5.9
Occupation		
Professional/managerial	180	22.2
Clerical/sales/services	140	17.3
Technician/factory operator	113	14.0
Other	90	11.2
Homemaker	158	19.6
Student	127	15.7
HP use		
Yes	362	44.8
No	446	55.2
CNS problems		
Yes	27	3.3
No	781	96.7

Discussion

There have been many reports of headache associated with HP use (*5*), but most of these reports are anecdotal and are thus not subjected to the scientific rigor of proper study design. To our knowledge, this is the first reported community study on the prevalence of CNS symptoms related to the use of HPs. The only significant CNS symptom among HP users is headache: HP users have a higher prevalence of headache (60.3%) as compared to non-HP users (54%). The adjusted prevalence rate ratio of headache among HP users compared to non-HP users is 1.31 (95% CI, 1.00–1.70).

There are limitations to the study. The overall participation rate of 45% is low and thus could bias our findings. However, it must be noted that the nonparticipation rate of 55% includes both households and individuals who refused to participate or who could not be contacted; this includes noncontactable households (55%) and individuals (50%). Most of the residences of the noncontactable households were vacant (tenants away temporary or had moved) at the time of the study. Most of the noncontactable individuals were either away from home at the time of the study or at work. The reason for most refusals for nonparticipation of households and individuals was "not interested" or "no time."

Because this questionnaire was administered by an interviewer, there is the inherent subject, interviewer, and recall bias. The individuals in our cross-sectional study were from various educational and socioeconomic backgrounds, and interpretation of the questions was highly subjective and differed from individual to individual. Because of this, most questions were simplified and kept short to minimize confusion. We used standard definitions of symptoms and medical terms and provided a standard translation of the questionnaire in Mandarin and Malay.

In an ideal situation, interviews should be conducted by an impartial interviewer who is not aware of the study's objectives. As a result of logistic constraints, the field work had to be conducted by the research team. To correct for this, we standardized the questions and style of administering the questionnaire and conducted interview–interviewer training. Also, the questionnaire was designed in such a manner that when the interviewers elicited CNS symptoms, they were unaware of whether or not the subjects were HP users. The first response to the questions was accepted where possible, and interviewers were told not to prompt the subjects.

To reduce recall bias among the respondents, because affected individuals would have a higher recall rate of HP exposure, we used title masking, in which our questionnaire was introduced as a "study of headaches in the community." We also used a two-tiered approach in which we attempted to mask the actual purpose of the questionnaire by concentrating on headaches and health symptoms in the earlier sections of the interview before the respondent was asked about the use of HPs.

Because headache is a very common occurrence, it would be difficult to draw a definite association between the use of HPs and the increased risk of headache. However, it is interesting to note that Frey (*5*) postulated the mechanism for the headache; he stated,

> First headaches as a consequence of exposure to low intensity of microwaves were reported in the literature 30 years ago… Second, the blood–brain barrier appears to be involved in headaches, and low intensity microwave energy exposure affects the barrier. Third, the dopamine–opiate systems of the brain appear to be involved in headaches, and low intensity electromagnetic exposure affects those systems. In all three lines of research, the microwave energy used was approximately the same—in frequencies, modulations, and incident energies—as those emitted by present day cellular telephones.

It would suggest that headache associated with the use of HPs is plausible. We were also able to show a dose–response relationship. There is a significant increase in the prevalence of headache with increasing duration of use (in minutes per day) (Table 2).

The amount of microwave radiation absorbed by the HP user is described by the term specific absorption rate (SAR) given in W/kg. Kuster (*10*) measured 16 different European digital telephones and found a wide variation in SAR values. Telephones, when averaged over 10 g of tissue, had SAR values ranging from 0.28 W/kg to a maximum value of 1.33 W/g. All data were normalized to an antenna output power of 0.25 W, which is the maximal value for a GSM telephone (*10*). Salford et al. (*11*) showed effects on the blood–brain barrier in rats with both continuous and pulse-modulated microwave fields at 915 MHz and with SAR values well below 1 W/kg. Frey (*5*) also pointed to the blood–brain barrier; he showed that electromagnetic energy with similar characteristics to HP emissions

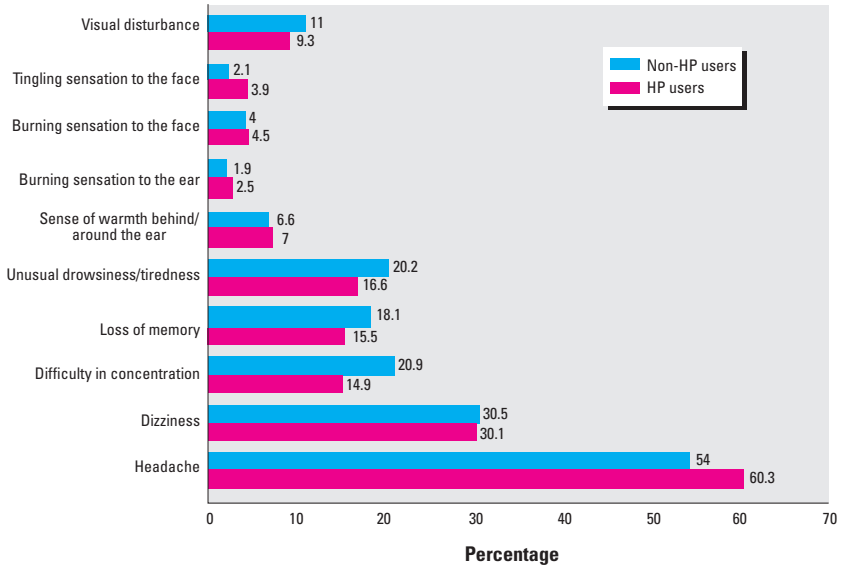

Figure 1. Prevalence of symptoms among HP (n = 426) and non-HP (n = 355) users.

Table 2. Use of HP and hand-free equipment and the prevalence of headache.

Use of HP	Headache prevalence (%)	Sample size	p-Value for trend
Duration per day (min)			
< 2[a]	53.9	253	
2–60	60.6	163	
> 60	65.1	28	0.038
Times per day			
0[a]	54.0	230	
< 5	61.8	105	
5–10	62.0	62	
> 10	55.3	47	0.30
Hand-free equipment used			
Never	65.4	142	
Some of the time	54.4	62	
All the time	41.7	10	0.006

[a] Includes individuals who do not use HPs.

resulted in the breakdown of the blood–brain barrier. This critical interface controls what gets into the brain from the blood, and it may well be causal for headache (*5*).

Our finding is further substantiated by the observation that the prevalence of headache was reduced by > 20% among those who used hand-free equipment for their HPs compared to those who never used the equipment (Table 2). The use of hand-free equipment would reduce the exposure to the RFR because the antenna is kept farther from the head.

Because this is a cross-sectional study, our findings lacked temporality in that a time relationship between the development of symptoms and the advent of HP use could not be ascertained. We could not therefore draw any causal relationship from our data. It will be important to proceed with a follow-up study to establish causal relationships between HP use and CNS symptoms.

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