International Scholarly Research Network
ISRN Public Health
Volume 2012, Article ID 241967, 7 pages
doi:10.5402/2012/241967

Clinical Study

Acute, Repeated Exposure to Mobile Phone Noise and Audiometric Status of Young Adult Users in a University Community

Godson R. E. E. Ana,[1] Anthony E. Ukhun,[1] Derek G. Shendell,[2,3,4] and Patience A. Osisanya[5]

[1] *Department of Environmental Health Sciences, Faculty of Public Health, University of Ibadan, Ibadan, Nigeria*
[2] *Department of Environmental and Occupational Health, School of Public Health, University of Medicine & Dentistry of New Jersey (UMDNJ), Piscataway, NJ 08854, USA*
[3] *New Jersey Safe Schools Program, Center for School and Community-Based Research and Education, School of Public Health, UMDNJ, New Brunswick, NJ 08903-2688, USA*
[4] *Environmental and Occupational Health Sciences Institute, Robert Wood Johnson Medical School, UMDNJ and Rutgers University, Piscataway, NJ 08854, USA*
[5] *Department of Ear, Nose and Throat, University College Hospital, Ibadan, Nigeria*

Correspondence should be addressed to Derek G. Shendell, shendedg@umdnj.edu

Received 6 August 2012; Accepted 26 August 2012

Academic Editors: M. Askarian and O. Zurriaga

Background. Exposure to noise from mobile devices is suspected to affect hearing. Data are limited, particularly in less developed countries. We assessed noise levels from mobile phones and user audiometric status at University of Ibadan, Nigeria, in an initial cross-sectional study. *Methods*. Fifty-eight staff and 45 young adult students owning mobile phones were selected. A pretested questionnaire assessed demographics, phone attributes, and predominant ear used for making and receiving calls. Noise was measured in A-weighted decibels. Pure tone audiometry was conducted at varying frequencies. Statistics computed included Chi-square and t-tests. *Results*. Certain phone brands used by students were commonly reported. More utilized right ears to make or receive calls. Mean reported mobile phone use duration by students was 2.9 ± 1.7 years, lower than among staff, 3.4 ± 1.9 years ($P < 0.05$). There were differences in use of head phones (22.2%, 12.1%) and speakers (51.1%, 15.5%) by students and staff, respectively ($P < 0.05$). Mean measured noise levels of phones when ringing, per user settings, were high 91.9 ± 16.1 dBA (students) and 93.3 ± 10.9 dBA (staff). Audiometry suggested 22.2% students and 28.0% staff had some evidence of hearing impairment. *Conclusions*. Mobile phones noise levels were high, but exposures though frequent were of short duration. Larger, longitudinal studies are needed on phone use and hearing impairment.

1. Introduction

In general, less developed countries are establishing mobile (cellular) phone technology in preference to the traditional, and relatively more expensive, fixed line systems. Therefore, if there are any adverse health risks—potential biological effects—due to acute, repeated (or chronic) personal exposure to radiofrequency radiation from the use of mobile phones, then it will be a global concern; small impacts could have important public health consequences. This may be particularly true among younger adults using mobile phones for calls, music, e-mail, and so forth.

According to WHO [1] and Nelson et al. [2], global prevalence of disabling hearing loss in adults was 16%, which may vary from 7% to 21% in various subregions of the world, and was attributable mainly due to occupational noise. However, with approximately four billion users of mobile phones worldwide [3], and with a significant proportion incorporating media playing capability and speakers, mobile phones are among the most popular portable media players (PMP) on the market and present an emerging health concern in both occupational and nonoccupational settings. Ear pieces, as mobile phone accessories, and most especially the ear bud style of ear phones [4], are able to deposit sounds within the range of maximum levels around 80–115 dBA (A-weighted decibels) directly into the ear canal. The insertion depth of the ear bud of the ear phone into the ear canal, the maximum output provided by the device, and the type of music are factors affecting the amount of sound deposited in the ear canal [5]. Katz et al. [6] reported stereo earphones could deliver acoustic sound levels up to 120 dBA.

Rice et al. [7] examined over 60 users of personal cassette players (PCP) and reported the range of measured sound pressure levels was between 60 and 108 dBA. Another study by Wong et al. [8] reported the equivalent measured music noise levels ranged 56–116 dBA among 394 PMP users. In the same Wong et al. study [8], the prevalence of regular use of PCP in Hong Kong—for at least three days a week for six months—among 487 individuals age 18–24 years was 81%. Ising et al. [9] reported among 681 pupils who used minicassette players (MCS), a type of PCP, equivalent measured music noise levels were 60–110 dBA. Smith et al. [10] reported in their study of social noise among 18–25 year olds in the UK that the preferred average sound level (volume) for listening to PMP was 74 dBA. Catalano and Levin [11] reported in their study of 154 college students in New York City a prevalence of portable radios (PR) with headphones of 31.4%, with mean duration use for females 8 ± 10 hours/week and among males 14 ± 10 hours/week. Overall, PR, PCP, and PMP with head phones may be capable of causing permanent hearing loss in a large population of users [11, 12], and now mobile phones with ear pieces are replacing them.

In a study [13] to determine the hearing threshold of mobile phone users who had used a mobile phone for a minimum of one year, a significant difference in the mean threshold levels of users (0.12 ± 5.9 dB) and nonusers (-3.0 ± 4.7 dB) was reported ($P < 0.05$), with detectable responses found at each frequency (500 to 8000 Hz) except at 250 Hz. Duration of mobile phone use was also related to these threshold changes ($P < 0.05$) [13].

According to Welleschik [14], 85 dBA is regarded as the critical intensity; exposures below this have lower rates of hearing impairment. International standards recommend the sound pressure level equivalent for an 8-hour (*L*eq, 8 h) working day weighted average of 85 dBA as the exposure limit for occupational noise [15, 16]. However, this limit may not guarantee the safety of the worker's auditory system. The regulations of the European Commission (EC) on noise at work (Directive 2003/10/EC) [16] thus recommended three action levels for occupational settings depending on equivalent noise levels for an 8-hour working day. Equivalent values (see Table 1) result when values are converted using a time-intensity tradeoff of a 3 dB increase for cutting the time in half. For example, listening to music on a PMP or mobile phone at 95 dBA for 15 minutes a day would equate to the first action level, assuming repeated exposure.

Constant exposure to noise from mobile phone sources is suspected to adversely affect hearing and potentially lead to other adverse outcomes like cancers [17, 18], but data are limited, particularly in rapidly urbanizing and growing areas of less developed countries. To date, exposure science research on mobile phones focused on radiofrequency (RF) radiation measures [19, 20], mobile phone attributes potentially affecting exposure [21], and potential recall bias in surveys in retrospective epidemiologic study designs [22].

Therefore, this pilot study's quantitative measures assessed noise levels from mobile phones and user audiometric status at University College Hospital, Ibadan, Nigeria.

2. Materials and Methods

This study went through proper required institutional review board procedures at the College of Medicine, University of Ibadan, Nigeria, prior to its initiation, and informed consent was obtained from study participants. Approval for the study was also obtained from the University College Hospital Ethics Committee (UI/EC/08/0134).

2.1. Study Design. A cross-sectional design was adopted for this pilot study. The goal was to achieve a total sample size of at least 100 people; 103 participants consented to participate in this pilot study using a stratified random-sampling technique in the University of Ibadan community. The exclusion criteria implemented after originally identifying these potential participants included history of chronic ear disease; recent upper respiratory infection; exposure to loud noise from clearly identified sources at work and/or at home beyond mobile phones and use of PMPs, PCPs, and PRs; a history of any chronic medication within the last three months. Thus, 58 staff and 45 students who owned mobile phones and used them for at least one year were included.

2.2. Preliminary Survey. Participants completed a questionnaire which elicited information on demographic characteristics (e.g., birth year, gender) and sought to identify the ear (right or left) typically used for making and receiving calls. Mobile phone types (e.g., brand, size, accessory, and headphone compatibility) and other user practices were also assessed using an observation checklist.

2.3. Noise Measurements. In this pilot study, acute, repeated exposure referred to use of mobile phones, that is, personal contact with RF radiation. Noise (sound levels) of mobile phones during inactive and active modes was determined using a calibrated AMEC sound level meter. The calibration tool was NIST certified at 94 dBA. This sound level meter could measure noise, in dBA (used) or C-weighted decibels, at a fast or slow response time and between 35 and 130 dBA in three expected noise ranges; the fast response time and mid-high ranges of expected noise (50–100 and 85–130) were used. Noise levels were compared to aforementioned EC and World Health Organization (WHO) occupational exposure limit [1, 15, 16] as no other personal exposure standards yet exist.

2.4. Audiometric Assessment. Pure tone audiometry (PTA) was performed bilaterally on study participants at frequencies 500, 1000, 2000, 4000, and 8000 Hz. The dominant ear PTA results were compared with the nondominant ear PTA

Table 1: The equivalent time-intensity levels, in A-weighted decibels (dB (A)), referenced to the action levels according to the Directive 2003/10/EC (SCIENIHR, 2008).

Action level	L_{Aeq}, 8 h	Equivalent levels for time indicated (tradeoff 3 dB)
First action level (minimum)	80 dB (A)	83 dB (A)—4 hr; 86 dB (A)—2 hr; 89 dB (A)—1 hr; 92 dB (A)—30 min; 95 dB (A)—15 min; 98 dB (A)—8 min; 101 dB (A)—4 min; 104 dB (A)—2 min; 107 dB (A)—1 min
Second action level mandatory protection	85 dB (A)	88 dB (A)—4 hr; 91 dB (A)—2 hr; 94 dB (A)—1 hr; 97 dB (A)—30 min; 100 dB (A)—15 min; 105 dB (A)—5 min; 111 dB (A)—1 min
Maximum exposure limit value	87 dB (A)	90 dB (A)—4 hr; 93 dB (A)—2 hr; 96 dB (A)—1 hr; 99 dB (A)—30 min; 102 dB (A)—15 min; 107 dB (A)—5 min; 113 dB (A)—1 min

results. Audiologic examination was performed by experienced audiologist in University College Hospital, Ibadan, Nigeria, after screening using an otoscopic examination. The audiologist was blinded and thus did not know which ear was stated by the participant as being preferred or dominant.

2.5. Data Analysis. Data analysis was performed using SPSS version 15.0 after data entry and management in Microsoft Excel. Independent t-tests and Chi-square tests were used for the analysis of statistical significance at $P < 0.05$.

3. Results

3.1. Demographic Information of Study Participants. The study population comprised students (43.7%, $n = 45$) and staff (56.3%, $n = 58$), of which overall 69% were single and 31% were married. The mean age of students was 23.8 ± 2.9 years compared to staff 35.5 ± 7.6 years ($P < 0.05$).

3.2. Mobile Phone Profile. Nokia, Samsung, Sagem, and Sony Ericsson were the major phone types used by both students and staff (Table 2). The mean duration of mobile phone use for students was 2.9 ± 1.7 years compared to staff 3.4 ± 1.9 years ($P < 0.05$).

3.3. Noise (Sound Levels) from Mobile Phone. Mean noise produced by mobile phones of students was 93.1 ± 16.1 dBA compared to staff 88.6 ± 11.0 dBA (Table 3). Mean noise produced by mobile phones of both staff and students exceeded the WHO limit for occupational exposure (85 dBA) even though they were of short duration; in this study, dose appears to be driven by intensity (sound level) and frequency of phone use, not duration of exposure. There was a borderline statistically significant difference ($P = 0.05$) in the ear used in making or receiving a call among students and staff (Table 4). Table 4 shows 38/45 (84%) students and 36/58 (62%) staff in this pilot study that reported a preference for using their right ear when receiving calls. There was also a significant difference ($P < 0.01$) in the use of mobile phone accessories among students and staff (Table 5). Table 5 shows half of students reported a preference for using the speakers, and another 22% (10/45) ear pieces, whereas most staff (42/58, 72%) reported using no accessory with phones.

Table 2: Major manufacturers of mobile phones reported as used by respondents.

Phone types	Students		Staff	
	Frequency (n)	(%)	Frequency (n)	(%)
Nokia	35	60.3	32	42.7
Samsung	5	8.6	7	9.3
Sagem	4	6.9	4	5.3
Sony Ericsson	3	5.2	5	6.7
Motorola	0	0.0	4	5.3
Huawei	0	0.0	4	5.3
Others	11	18.9	19	25.3
Total	58	100.0	75	100.0

Note: some of the 58 students and the 45 staff reported more than one phone owned and used.

Table 3: Mean noise levels (in A-weighted decibels, dBA) of respondent mobile phones.

	N	Mean	Standard deviation	P value
Students	58	93.1	16.1	> 0.05
Staff	75	88.6	11.0	

Note: some students and staff reported more than one phone owned and used.
N: number phones sampled (there were 45 staff and 58 students).

3.4. Hearing Threshold. A total of 34 students and 40 staff had hearing values considered as normal, based on PTA results, while 12 students and 17 staff had evidence of impaired hearing (Table 6). There was, however, no statistical difference in the hearing of students and staff ($P > 0.05$) (Table 6).

Table 4: Ear reported used in making or receiving a call by occupational status.

	Ear used in making or receiving a call			Total
	Right	Left	No preference	
Students	38 (51.4%)	7 (28.0%)	0 (0.0%)	45 (43.7%)
Staff	36 (48.6%)	18 (72.0%)	3 (100%)	58 (56.3%)

Note: as each ear was assessed separately during pure tone audiometry, percentages were summed down columns, that is, by ear, and then overall by occupational status. Comparison between occupational status and the ear used in making or receiving a call showed a borderline statistically significant difference at $P = 0.05$ under Chi-square tests.

Table 5: Mobile phone accessories reported used by occupational status.

	Accessories used			Total
	Ear piece	Speaker	None	
Students	10 (58.8%)	23 (71.9%)	12 (22.2%)	45 (43.7%)
Staff	7 (41.2%)	9 (28.1%)	42 (77.8%)	58 (56.3%)

Note: as each accessory was assessed separately with the questionnaire, percentages were summed down columns, that is, by accessory, and then overall by occupational status. Comparison between mobile phone accessories used and occupational status showed a statistically significant difference at $P < 0.01$ under Chi-square test.

Table 6: Hearing status per pure tone audiometry by occupational status.

	Occupational status		Total
	Students	Staff	
Normal hearing	34 (73.9%)	40 (70.2%)	74 (71.8%)
Impaired hearing	12 (26.1%)	17 (29.8%)	29 (28.2%)

Note: percentages were summed down columns, that is, by occupational status, and then overall by hearing status. Comparison between occupational status and hearing status showed no statistically significance under Chi-square test.

3.5. Audiometric Status of Study Participants. Some evidence of hearing impairment of 27.0% was noticed on the right ear, while 38.5% was noticed on the left ear, as compared to no hearing impairment for those who had no reported preference (Table 7). A comparison of the hearing status of respondents by gender, across occupational status, suggested greater hearing impairment among females as compared to males (Table 8)—6/40 (15%) males versus 24/63 (38%) females showed some evidence of hearing impairment via audiometry. This difference was statistically significant ($P < 0.01$). A comparison of the mean hearing levels on the left ear of students and staff across frequencies used in PTA (Figure 1) revealed declines in high frequencies notes heard by staff, which suggested noise-induced hearing loss (NIHL) at frequencies above 4000 Hz. We also observed the mean pure tone heard by students at 500 Hz was 30 dBA, which indicated a 5 dB loss at 500 Hz relative to the standard (Figure 1). On the right ear, mean hearing levels heard by both student and staff were below the hearing threshold for frequencies used in PTA in this study (Figure 2).

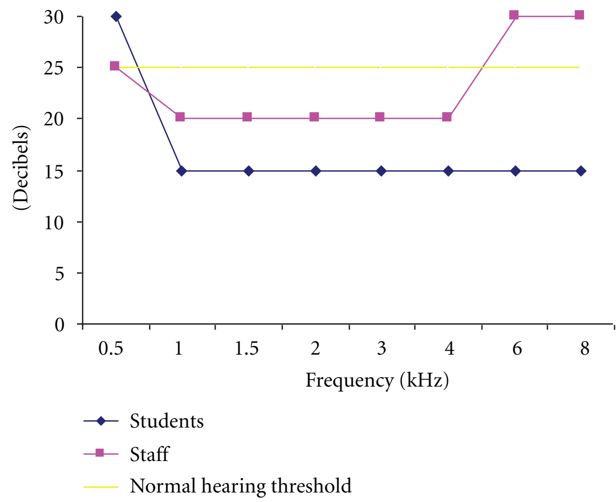

Figure 1: Mean hearing level of the left ear of respondents at various frequencies.

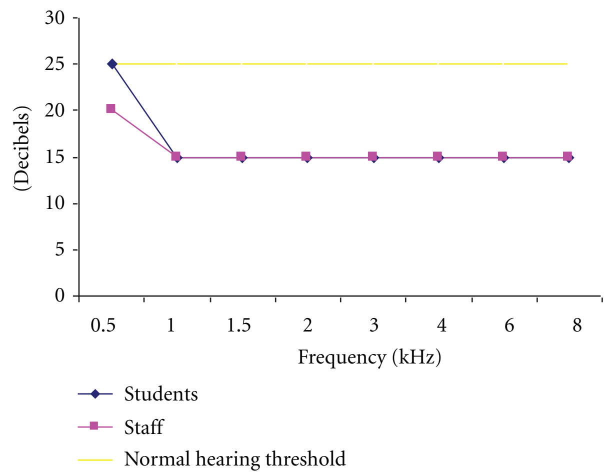

Figure 2: Mean hearing level of the right ear of respondents at various frequencies.

4. Discussion

Mobile phones play an important role in providing the fastest means of communication amongst populations globally, yet its usage is also associated with potential public health hazards. Our study to the best of our knowledge is one of the first on health-related hazards associated with acute, repeated exposure to noise from mobile phone and music player use, and the first in a less developed country. In this study, phone types, phone-related noise levels, and audiometric status of phone users were assessed. Though this pilot study had known limitations like a cross-sectional design, which precluded more rigorous assessment of chronic exposure and past occupational and/or residential exposure, and a relatively small sample size due to limited resources available, selection (exclusion) criteria attempted to minimize bias. The data are novel and will inform future research—a recent US Government Accountability Office report on mobile

Table 7: Hearing status of respondents by reported ear of preferred use.

	Preferred ear used in making or receiving a call			Total
	Right	Left	No preference	
Normal hearing	54 (73.0%)	16 (61.5%)	3 (100%)	73 (70.9%)
Impaired hearing	20 (27.0%)	10 (38.5%)	0 (0.0%)	30 (29.1%)

Note: percentages were summed down columns, that is, by preferred ear used, and then overall by hearing status. Comparison between the dominant ear and the nondominant ear showed no statistically significance under Chi-square test (i.e., $P > 0.05$).

Table 8: Hearing status of respondents across occupational status and age by gender.

	Hearing status		Total
	Normal	Impaired	
Male	34 (46.6%)	6 (20.0%)	40 (38.8%)
Female	39 (53.4%)	24 (80.0%)	63 (61.2%)

Note: percentages were summed down columns, that is, by hearing status, and then overall by gender. Comparison between hearing status of respondents and gender showed a statistically significant difference at $P < 0.01$ under Chi-square test.

phone RF radiation exposure and testing requirements concluded data remain sparse, especially in consideration of when people transport and use mobile phones against bodies [23].

A high prevalence of Nokia branded mobile phones was reported in our study. Similar findings have been reported in studies by Shayani-Nasab et al. [13] and Usikalu and Akinyemi [24]. The mean sound level (noise) produced by mobile phones of participating students was higher than that produced by participating staff mobile phones; however, this difference was not significant. Both the mean sound levels of the mobile phones of students and staff were greater than the critical intensity of 85 dB (A) reported by Welleschik [14]. This is also in line with the conclusions made by Fligor and Cox [4]; that is, PMPs and mobile phones inclusive along with ear phones are able to deposit sounds within the maximum levels around 80–115 dBA directly into the ear canal. In this study, the majority of students utilized an accessory for their mobile phone while only a minority of the staff population utilized any mobile phone accessory. The results of this pilot study can inform future educational interventions, especially with adolescent and young adult students, regarding user mobile phone settings and proper use of the various optional accessories available. It should be noted that a recent study by the US National Institute for Occupational Safety and Health [25] reported the educational services industry ranked fourth among industries with highest percentages of adult workers with measured hearing loss in employer tests conducted 2000–2008. Thus, university settings are appropriate for interventions.

A preference sound level of 74 dBA among 18–25 years old users of PMPs was reported by Smith et al. [10], and sound levels of PCPs [7], PMPs [8], and MCS [9] were reported to be in the range of 50–120 dBA. Noise (sound levels) produced by mobile phones of young adult students and staff in this study was closer to the upper limit of this previously reported range. Furthermore, the majority of participating students and staff had preferences for the right ear in making and receiving calls; similar findings were observed in findings of Shayani-Nasab et al. [13] and Velayutham et al. [26]. These results can again inform future educational interventions; for example, users should alternate ears used and reduce volume.

There was a significant difference in mean duration of mobile phone use among students and staff. Pure tone audiometry revealed there was, however, no statistically significant difference in evidence of hearing impairment over the range of frequencies 500, 1000, 2000, 4000, and 8000 Hz among young adult students and staff. A statistically significant difference was noticed when hearing status was stratified by gender. Longitudinal studies on prevalence of hearing impairment and possible reasons for observed disparities by and across age are needed. It should also be noted that a recent prospective study of noise exposure and hearing damage among 316 construction workers with two or more annual examinations over 10 years further confirmed the standard hearing threshold level evaluation via pure tone audiometry was sufficient [27].

Mean hearing values of young adult students and staff compared over the range of frequencies 500–8000 Hz suggested evidence of a decline in staff hearing above 4000 Hz, suggesting possible NIHL, whereas a 5 dB hearing loss was noticed for students at 500 Hz but not at higher frequencies. In this study, mean reported mobile phone use duration by staff was 3.4 ± 1.9 years and by students was 2.9 ± 1.7 years ($P < 0.05$). An increase in reported mobile phone use duration was also previously observed to be associated with NIHL or threshold shift [13, 26].

5. Conclusions

Our pilot study suggested noise levels in A-weighted decibels from mobile phones of different manufacturers exceeded the critical levels for equivalent noise levels for an 8-hour working day. Evidence of hearing impairment was higher among those reporting longer duration mobile phone use, and among females. A shift in emphasis of future research from cancer promoting effects of mobile phones to noncancer outcomes with longitudinal study designs, including noise-induced hearing loss, in both industrialized and less developed countries, is warranted. Our results can also inform future educational interventions, especially with adolescent and young adult students in university settings, regarding user mobile phone settings, for example, reduce volume, and proper use of the various optional accessories available including alternating ears used.

Conflict of Interests

The authors affirmed they have no conflict of interests to report regarding this research.

Acknowledgments

The authors acknowledge with thanks the support provided by all staff and students towards the successful conduct of this study and to the staff of the Ear, Nose and Throat Department, University of Ibadan, for the technical support during the audiometric assessment. A. Miller (UMDNJ-SPH) is acknowledged for internal reviews of the draft manuscript. This project was completed during the MPH program of E. A. Ukhun. D. G. Shendell was supported—equipment used was purchased and brought by D. G. Shendell to UI for future use—by funding from the Georgia State University International Strategic Initiative and the Atlantic Philanthropies-Bermuda/UK office, 2006–2008.

References

[1] World Health Organization (WHO), "Grades of hearing impairment," http://www.who.int/pbd/deafness/hearing_impairment_grades/en/index.html, 2008.

[2] D. I. Nelson, R. Y. Nelson, M. Concha-Barrientos, and M. Fingerhut, "The global burden of occupational noise-induced hearing loss," *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458, 2005.

[3] WHO, "Electromagnetic fields and public health: mobile phones," World Health Organization Factsheet 193, World Health Organization, Geneva, Switzerland, 2010, http://www.who.int/mediacentre/factsheets/fs193/en/print.html.

[4] B. J. Fligor and L. C. Cox, "Output levels of commercially available portable compact disc players and the potential risk to hearing," *Ear and Hearing*, vol. 25, no. 6, pp. 513–527, 2004.

[5] Scientific Committee on Emerging and Newly Identified Health Risk (SCENIHR), "Potential health risks from exposure to noise from personal music players and mobile phones including a music playing function," SCENIHR, http://ec.europa.eu/health/ph_risk/risk_en.htm, 2008.

[6] A. E. Katz, H. L. Gerstman, R. G. Sanderson, and R. Buchanan, "Stereo earphones and hearing loss," *New England Journal of Medicine*, vol. 307, no. 23, pp. 1460–1461, 1982.

[7] C. G. Rice, M. Breslin, and R. G. Roper, "Sound levels from personal cassette players," *British Journal of Audiology*, vol. 21, no. 4, pp. 273–278, 1987.

[8] T. W. Wong, C. A. Van Hasselt, L. S. Tang, and P. C. Yiu, "The use of personal cassette players among youths and its effects on hearing," *Public Health*, vol. 104, no. 5, pp. 327–330, 1990.

[9] H. Ising, J. Hanel, M. Pilgramm, W. Babisch, and A. Lindthammer, "Risk of hearing loss caused by listening to music via headphones," *HNO*, vol. 42, no. 12, pp. 764–768, 1994.

[10] P. A. Smith, A. Davis, M. Ferguson, and M. E. Lutman, "The prevalence and type of social noise exposure in young adults in England," *Noise Health*, vol. 2, no. 6, pp. 41–56, 2000.

[11] P. J. Catalano and S. M. Levin, "Noise-induced hearing loss and portable radios with headphones," *International Journal of Pediatric Otorhinolaryngology*, vol. 9, no. 1, pp. 59–67, 1985.

[12] W. Williams, "Noise exposure levels from personal stereo use," *International Journal of Audiology*, vol. 44, no. 4, pp. 231–236, 2005.

[13] M. Shayani-Nasab, S. A. Safavi Naiianni, M. R. Fathol Alolomi, and A. Makaremi, "Effects of mobile telephones on hearing," *Acta Medica Iranica*, vol. 44, no. 1, pp. 46–48, 2006.

[14] B. Welleschik, "The effect of the noise level on the occupational hearing loss. Observations carried out in 25,544 industrial workers," *Laryngologie Rhinologie Otologie*, vol. 58, no. 11, pp. 832–841, 1979.

[15] ISO 1999:1990 Acoustics, *Determination of Occupational Noise Exposure and Estimation of Noise Induced Hearing Impairment*, International Committee for Standardization, Geneva, Switzerland, 1990.

[16] European Union, "Directive 2003/10/EC of European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). 17th individual Directive within meaning of Article 16(1) of Directive 89/391/EEC)," Official Journal of the European Communities. No L42/38, 2003.

[17] G. Berg, J. Schüz, F. Samkange-Zeeb, and M. Blettner, "Assessment of radiofrequency exposure from cellular telephone daily use in an epidemiological study: German Validation study of the international case-control study of cancers of the brain—INTERPHONE-study," *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 15, no. 3, pp. 217–224, 2005.

[18] A. J. Swerdlow, M. Feychting, A. C. Green, L. Kheifets, and D. A. Savitz, "International commission for non-ionizing radiation protection standing committee on epidemiology. Mobile phones, Brain tumors, and the interphone study: where are we now?" *Environ Health Perspect*, vol. 119, no. 12, pp. 1534–1538, 2011.

[19] I. Inyang, G. Benke, R. Mckenzie, and M. Abramson, "Comparison of measuring instruments for radiofrequency radiation from mobile telephones in epidemiological studies: implications for exposure assessment," *Journal of Exposure Science and Environmental Epidemiology*, vol. 18, no. 2, pp. 134–141, 2008.

[20] M. A. Kelsh, M. Shum, A. R. Sheppard et al., "Measured radiofrequency exposure during various mobile-phone use scenarios," *Journal of Exposure Science and Environmental Epidemiology*, vol. 21, no. 4, pp. 343–354, 2011.

[21] L. Hillert, A. Ahlbom, D. Neasham et al., "Call-related factors influencing output power from mobile phones," *Journal of Exposure Science and Environmental Epidemiology*, vol. 16, no. 6, pp. 507–514, 2006.

[22] M. Vrijheid, B. K. Armstrong, D. Bédard et al., "Recall bias in the assessment of exposure to mobile phones," *Journal of Exposure Science and Environmental Epidemiology*, vol. 19, no. 4, pp. 369–381, 2009.

[23] U.S. Government Accountability Office, Telecommunications: Exposure and Testing Requirements for Mobile Phones Should be Reassessed, http://www.gao.gov/assets/600/592902.pdf, 2012.

[24] M. R. Usikalu and M. L. Akinyemi, "Monitoring of radiofrequency radiation from selected mobile phones," *Journal of Applied Sciences Research*, vol. 3, no. 12, pp. 1701–1704, 2007.

[25] E. A. Masterson, S. Tak, C. L. Themann et al., "Prevalence of hearing loss in the United States by industry," *American Journal of Industrial Medicine*. In press.

[26] P. Velayutham, J. W. Tan, R. Raman, G. Gopala-Krishnan, K. H. Ng, and S. Singh, "Investigation of high frequency hearing loss among mobile phone users," in *Proceedings of the International EMF Conference*, Kuala Lumpur, Malaysia, 2007.

[27] N. S. Seixas, R. Neitzel, B. Stover et al., "10-Year prospective study on noise exposure and hearing damage among construction workers," *Occupational and Environmental Medicine*, vol. 69, pp. 643–650, 2012.