National Collaborating Centre for Environmental Health

Factors that affect RF Exposure from Mobile Phones

AIHA – BC/Yukon Local Section
Annual General Meeting and Conference

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Background

- Widespread cell phone use
- Ongoing epidemiologic studies
  - IARC
  - Epidemiologic research show largely negative associations, though, some studies link brain cancer and cell phones
  - Look mainly at duration of exposure, not intensity
- Need for better understanding of exposure
- Technology of cell phones is changing
Project

- Recall study
- Software Modified Phone survey
- Field Study
- Analysis of FCC Maximum SAR compliance data
Recall Study
Introduction

- Epidemiologic studies often use self-report of cell phone use as a surrogate for RF exposure:
  - Frequency of calls
  - Average length of call or total duration of calls
  - Years using cell phone
- Previous validation studies have evaluated correlation between self-report and billing records or SMP data
  - Limited by short period of recall or small sample size
- Our study examines the accuracy of recall of mobile phone use by comparing questionnaire data and billing records
Study Objectives

● Evaluate correlation of:
  ● Self-reported cell phone use
  vs.
  ● Cell phone billing records

● Practical advantages:
  ● US companies record incoming and outgoing calls
  ● Centralized billing records maintained by company that issues phones to employees
  ● Longer term billing records (3 years) available
Methods

- Volunteers recruited from a professional consulting organization that issued mobile phones to employees
  - Used a company-issued phone for at least 1 year
- Web-based questionnaire
  - Mobile phone use going back three years
  - Respondents reported on:
    - Duration of use
    - Number of calls received or made
    - Frequency of calls on weekdays/weekends
    - Time of day
Methods – Analysis

- Compare average frequencies and durations between self report and billing records
- Calculate agreement between two sources as ratio of billing minutes/self report minutes
- Categorize ratio into groups:
  - Within 75%
  - Within 50-74%
  - Within 25-49%
  - Less than 25%
- Correlation analyses
Results – Study Participation

- 72 participants completed questionnaire
- Of these we obtained billing records for 60 participants
- Primarily male (75%) and over 40 (70%)
### Results – Overall Summaries

<table>
<thead>
<tr>
<th></th>
<th>Number of calls [SD]</th>
<th>Average duration (min) [SD]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Questionnaire</td>
<td>Billing records</td>
</tr>
<tr>
<td>Per call</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Per day</td>
<td>7.4 [5.4]</td>
<td>4.6 [3.1]</td>
</tr>
<tr>
<td>Per weekday</td>
<td>N/A</td>
<td>N/C</td>
</tr>
<tr>
<td>Per weekend day</td>
<td>N/A</td>
<td>N/C</td>
</tr>
</tbody>
</table>
## Reporting Duration: Agreement by Sex

<table>
<thead>
<tr>
<th>Group</th>
<th>Within 25%</th>
<th>25-50%</th>
<th>50-75%</th>
<th>Outside 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%</td>
<td>N (%)</td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>Total</td>
<td>20 (33.3)</td>
<td>10 (16.7)</td>
<td>15 (21)</td>
<td>15 (34)</td>
</tr>
<tr>
<td>Males</td>
<td>15 (33.3)</td>
<td>10 (21.7)</td>
<td>7 (15.2)</td>
<td>13 (28.3)</td>
</tr>
<tr>
<td>Females</td>
<td>5 (33.3)</td>
<td>0 (0)</td>
<td>8 (53.3)</td>
<td>2 (13.3)</td>
</tr>
</tbody>
</table>

*Totals do not add up to 61, because not all participants answered these questions in the questionnaire.*
## Reporting Duration: Agreement by Age

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Within 25%</th>
<th>25-50%</th>
<th>50-75%</th>
<th>Outside 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40 yrs</td>
<td>N (32)</td>
<td>N (0)</td>
<td>N (32)</td>
<td>N (36)</td>
</tr>
<tr>
<td>&gt;40 yrs</td>
<td>7 (34.2)</td>
<td>10 (26.3)</td>
<td>8 (21)</td>
<td>7 (18.4)</td>
</tr>
</tbody>
</table>

*Totals do not add up to 61, because not all participants answered these questions in the questionnaire.*
Results

- Older males tended to recall use of mobile phones better than younger participants and females.
- Correlations noted in this study similar to previous reports:
  - $R=0.71$ (minutes per day), $p<0.001$
  - $R=0.69$ (calls per day), $p<0.001$
- Monthly level reporting more accurate than daily or weekly.
- Correlations did not differ much from year to year.
Conclusion

- Recall of phone use is fair
- Bill records are needed to obtain accurate duration of exposure information
SMP Study
Study Objectives

- Assess factors potentially influencing RF of GSM phones
  - Geographic location
  - Urbanicity
  - Moving vs. stationary samples
  - Indoors vs. outdoors
  - User characteristics (e.g., hands-free)
  - Environmental factors (e.g., weather)
Methods

- Recruited volunteers
- 3 study areas (SAs):
  - SA1 – New Jersey
  - SA2 – New York City
  - SA3 – San Francisco area
- Survey Components
  - Software-modified phones (SMPs)
  - Log book
  - 5 days of logging phone calls
  - Questionnaire
Analysis

- Included only volunteers: >70% compliance (SMP and log book matched)
- Calculated average energy output per minute (J/min) per call
- Associations assessed within each of 3 SAs and all 3 combined
- Conducted ANOVA and post hoc tests before combining
- Multivariate, step-wise regression analysis
Results

- 2537 calls
- 53 subjects
- Compliance rate
  - NJ (college students): 77.7%
  - NYC (public): 82.8%
  - SF (professionals): 86.8%
- Most calls were within study areas
# Energy Output: Analysis of Behavioral and Situation Variables

<table>
<thead>
<tr>
<th>Predictor</th>
<th>SA1 (J/min)</th>
<th>P-value</th>
<th>SA2 (J/min)</th>
<th>P-value</th>
<th>SA3 (J/min)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside</td>
<td>40.8</td>
<td>0.061</td>
<td>33.9</td>
<td>&lt;0.001</td>
<td>27.1</td>
<td>0.0063</td>
</tr>
<tr>
<td>Outside</td>
<td>35.7</td>
<td></td>
<td>22.6</td>
<td></td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td><strong>Urbanicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>39.7</td>
<td>0.060</td>
<td>NA</td>
<td></td>
<td>23.6</td>
<td>0.694</td>
</tr>
<tr>
<td>Urban</td>
<td>51.9</td>
<td></td>
<td></td>
<td></td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td><strong>Movement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving</td>
<td>34.2</td>
<td>0.001</td>
<td>19.7</td>
<td>0.001</td>
<td>19.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Not moving</td>
<td>42.0</td>
<td></td>
<td>30.6</td>
<td></td>
<td>27.7</td>
<td></td>
</tr>
</tbody>
</table>
Results

Step-wise regression analysis showed

1. SA - strongest predictor of energy output (explaining ~6% of variability)
2. Movement - next best predictor (~4% variability)
3. Location
4. Use of hands-free device
5. Urbanicity

These factors explain ~12% variability.
Factors with unclear effect on energy output

- Weather (limited data)
- Transportation (sparse data; modes not comparable)
- Place (sparse data over many categories)
Discussion

- Movement affects energy output (J/min)
  - Stationary > Moving
  - GSM technology goes to max power at each handover
  - Expect more handovers and higher total energy while moving, particularly driving
  - Observed opposite finding

Cell Phone Technology
Cell Phone Technologies

- 1 G – Analog
- 2 G – GSM, TDMA, CDMA
- 2.75 G – enhanced GSM
- 3 G – UMTS (W-CDMA), mainly CDMA
- 3.5 G – UMTS (HSDPA)
- 3.75 G
- 4 G – Flash OFDM, 3GPP LTE (upgrade UMTS)
1G

- Motorola Dynatac 8000X
- Analog
- 850 Hz
2G

- Motorola Timeport L7089
- GSM
- 900, 1800, 1900 MHz
2.75G

- 2.75 G
- Blackberry
- GSM
- 850, 900, 1800, 1900 MHz depending on model
3G

- Nokia 6650
- UMTS (W-CDMA)
- 850, 900, 1800, 1900 MHz
3.5G

- iPhone
- UMTS/HSDPA (850, 1900, 2100 MHz)
- GSM/EDGE (850, 900, 1800, 1900 MHz)
- Wi-Fi (802.11b/g)
- Bluetooth 2.0 + EDR
4G

- To be determined
Field Study
Instrumentation: SYNEHA

- One EASY4 allows data acquisition from probes at high sampling rates; PC-controlled
- IT’IS developed portable phantom system that could take readings from a car or van
Van Photos with SYNEHA and Phantoms
Parameters Evaluated

- Technology
  - GSM (1900 MHz),
  - CDMA, TDMA, and Analog (850 MHz)
- Type of Geographic Region (Proxy for Base station density)
  - Urban (San Francisco)
  - Suburban (Peninsula)
  - Rural
- Cellular traffic
  - Time of Day
- Type of phone
  - Flip/brick
  - Model
## Average Power by Technology (dBm)

<table>
<thead>
<tr>
<th></th>
<th>Analog</th>
<th>CDMA</th>
<th>GSM</th>
<th>TDMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (trips)</td>
<td>22</td>
<td>92</td>
<td>68</td>
<td>26</td>
</tr>
<tr>
<td>Mean</td>
<td>22.34</td>
<td>-0.38</td>
<td>14.11</td>
<td>18.23</td>
</tr>
<tr>
<td>Median</td>
<td>24.10</td>
<td>2.36</td>
<td>15.36</td>
<td>16.10</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>3.02</td>
<td>8.24</td>
<td>5.40</td>
<td>5.37</td>
</tr>
<tr>
<td>Minimum</td>
<td>19.35</td>
<td>-17.26</td>
<td>-12.41</td>
<td>11.22</td>
</tr>
<tr>
<td>Maximum</td>
<td>29.01</td>
<td>13.43</td>
<td>17.66</td>
<td>25.88</td>
</tr>
</tbody>
</table>
Summary: Average Power By Technology and Route

- Analogue
- GSM
- TDMA
- CDMA

Region:
- Rural
- Suburban
- Urban
# ANOVA Results: Unbalanced Design

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Total Sum of Squares</th>
<th>Mean Sum of Squares</th>
<th>F Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>3</td>
<td>738.7</td>
<td>246.2</td>
<td>195.7</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Route</td>
<td>2</td>
<td>126.3</td>
<td>63.1</td>
<td>50.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Technology * Route</td>
<td>6</td>
<td>43.5</td>
<td>7.3</td>
<td>5.8</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
### Summary Results of Average Power (dBm) by GSM Phone Model

<table>
<thead>
<tr>
<th></th>
<th>Motorola V60 (Flip)</th>
<th>Timeport (SMP) (Candybar)</th>
<th>Nokia 5190 (Candybar)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>8</td>
<td>41</td>
<td>8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>24.09</td>
<td>23.84</td>
<td>21.94</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>24.32</td>
<td>24.38</td>
<td>24.22</td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>0.80</td>
<td>1.66</td>
<td>5.35</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>22.26</td>
<td>19.64</td>
<td>9.67</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>24.71</td>
<td>26.31</td>
<td>25.18</td>
</tr>
</tbody>
</table>
Federal Communications Commission Data
FCC Database

- FCC Requirements:
  - In the US, all cell phones are tested for RF emissions
  - Operated at maximum power output under specified standard test conditions
  - FCC limits – no greater than 1.6 W/kg Specific Absorption Rate (SAR)

- Methods:
  - Examined FCC database of results of compliance testing reports
  - Analyzed data for 2083 phones 1999-2005
800 MHz

Plots of Means and Medians of Power Values at Levels of Five Factors
(Part 22)
Factors
Mean of Power Values
0.45 0.50 0.55 0.60 0.65
CDMA
GSM
TDMA
Extndable
Fixed
Intern
Brick
Cheek
Tilt
Left
Right
Technology Antenna Shape Contact Side

Plots of Means and Medians of Power Values at Levels of Five Factors
(Part 24)

1900 MHz
<table>
<thead>
<tr>
<th>Field Testing (RF level)</th>
<th>FCC Testing (SAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog</td>
<td>Analog (only 800 MHz)</td>
</tr>
<tr>
<td>GSM</td>
<td>CDMA (800 Hz) TDMA (1900 Hz)</td>
</tr>
<tr>
<td>TDMA</td>
<td>CDMA (1900 Hz) TDMA (800 Hz)</td>
</tr>
<tr>
<td>CDMA</td>
<td>GSM</td>
</tr>
</tbody>
</table>
What does this all mean?

- CDMA when forced into highest output power, produces relatively high SAR levels
- GSM at highest output power level, in comparison produces the lowest SAR
- In the real world, CDMA hardly ever reaches this highest output level, whereas GSM goes to max power at each base station handover

Real world is different from the lab!
General Conclusions

- Recall of phone use is ok
- Technology has the biggest impact on RF exposure
- Urbanicity (which is a proxy for base station density) also impacts RF exposure
- Individual behavioural/environmental factors explain a small amount of variation in exposure
Implications for Health?

- Cell phone technology is moving to CDMA-based
- In real-world, CDMA technology produces much lower levels of RF than others
- Expect lower RF output levels than in the past
- Weak evidence that $\geq 10$ years and ipsilateral use associated with increased brain tumours
  - More likely to have used analog phones
- It will be more difficult to find associations with health effects as phone technology improves
Acknowledgements

- **Funding:** Cellular Telecommunications and Internet Association (CTIA)
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- **Exposure Assessment Panel:** Joseph Bowman, Richard Tell, Dimitrios Trichopoulos, Joe Wiart
- **Motorola:** Joe Morrissey
Thank You

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## Technology and Brain Tumours

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog vs. unexposed</td>
<td>1.13 (0.83-1.54)</td>
</tr>
<tr>
<td>Digital vs. unexposed</td>
<td>0.86 (0.68-1.09)</td>
</tr>
<tr>
<td>Analog vs. Digital</td>
<td>1.22 (1.06-1.41)</td>
</tr>
</tbody>
</table>

Kan et al., 2008 – 5 studies cell phone type and brain tumours
Brain tumours

- ≥ 10 years use - OR: 1.25 (95%CI: 1.01-1.54) (Kan et al 2008)
- ≥ 10 years and ipsilateral use (Hardell et al 2008)
  - glioma (OR: 2.0, 95%CI: 1.2-3.4)
  - acoustic neuroma (OR: 2.4, 95%CI: 1.1-5.3)
  - NOT meningioma (OR: 1.7, 95%CI: 0.99-3.1).
Wi-Fi

– Uses OFDM – Orthogonal Frequency Multiplexing
Cordless Phones

- 900 MHz (older)
- 2.4 GHz
- 5.8 GHz
- Base stations closer (cradle)
- On average, much less power output than mobile phones
Blue Tooth

- Replaces RS232 cables
- Exchanges data over short distances from fixed and mobile devices
- Uses radio technology called frequency-hopping spread spectrum
- 2.4 GHz short-range radio frequency
Cell Phone Technologies

- Analog
- CDMA
- TDMA
- GSM