Bluetooth's impact on radiation emissions

Michael Nguyen[1], Bobby Sidhu[2]
1. Lead Author, B. Tech Student, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G-3H2
2. Supervisor, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G-3H2

Abstract

Introduction: Cellphone usage has increased leaps and bounds over the past decade. With the growing popularity of cellphones come numerous studies on the effects of mobile radiation on human health. Cellphone radiation has been associated with many health implications such as: sleep deprivation, hearing loss, slower sperm, cancers and tumors to name a few; however, more research is needed to confirm these claims.

Purpose: The purpose of this research is to determine the Bluetooth impact on radiation levels when it is paired with a cellphone. This is a two-fold process: firstly, to determine radiation levels emitted by the pairing of a cellphone and a Bluetooth headset and comparing it to a control group of the cellphone alone and secondly, comparing the radiation emissions of a paired cellphone with the associated paired Bluetooth headset.

Methods: An Extech RF EMF strength meter was used to measure the radiation emission levels ($\mu W/cm^2$) of various phone types by Apple and Samsung when they were unpaired and paired with a LG HBM-220 Bluetooth device. The radiation emissions of the paired Bluetooth were also measured.

Results: There was a statistically significant increase in radiation emissions ($\mu W/cm^2$) observed in a cellphone paired with a Bluetooth when compared to an unpaired cellphone. This was statistically significant as the p-value (0.00026) was less than the 0.05 and 0.01 values and the power was near 100 % (99.8%). When comparing the paired cellphone with the associated paired Bluetooth, the Bluetooth emitted much more radiation than the cellphone. This data was statistically significant as well as the p-value was at 0.00000 and the power at 100%.

Discussion: The findings in this study suggest that Bluetooth headsets increase radiation emissions; however, it is important to note that only one Bluetooth headset model (LG HBM-220) was tested. The results also conflict with Health Canada claims that Bluetooth headsets decrease radiation emissions. More research is needed to confirm the results found in this study. A key limitation of this study was that only Samsung and Apple Inc. brands were tested. Additionally, the equipment used to measure radiation levels (Extech RMF meter) was subject to background radiation sources.

Conclusion: The pairing of a LG HBM-220 Bluetooth to a cellphone increases radiation emissions in both the cellphone and Bluetooth when compared to an unpaired cellphone. These increases in emissions when paired would results in additive effects to one's body.

Key words: Bluetooth, cellphone, EMF radiation, Apple, Samsung

Introduction

The effects of mobile radiation on human health have been the subject of many recent and current studies throughout the world; this is attributed to the growing popularity of cellphones. In 2013, it was reported that approximately half of the world's population use mobile phones and there was an estimated 6.8 billion subscriptions worldwide (mobiThinking, 2013). With the vast amount of growing users, it is imperative to investigate, monitor, research, and understand any potential public health impact that long-term mobile phone usage may cause.

In response to the increasing use of cellphones, the WHO (2011) has recommended Bluetooth hands-free headsets in attempts to lower radiation exposure. However, the British Consumer's Association has reported that radiation could actually be increased significantly when a Bluetooth headset is paired with a mobile phone; it depends on where the phone is positioned around the body (The British Consumer's Association, 2000). This raises the question of whether or not Bluetooth headsets contribute additively to the radiation exposure on humans.

Interest to conduct this study arose as the author spends a significant amount of time on his smartphone. The author wishes to determine the amount of radiation levels emitted through mobile phones and whether or not a Bluetooth headset would decrease radiation levels. This topic was also proposed in a presentation done at British Columbia Institute of Technology by Lorraine MacIntyre of the British Columbia Centre for Disease Control.

Literature Review

Electromagnetic Radiation

Radiofrequency (RF) energy and its association with adverse health outcomes has been a growing concern, especially as cellphone use has been increasing leaps and bounds over the past decade. RF energy produced by mobile phones releases non-ionizing radiation which mobile phone users are exposed to. This energy is not capable of breaking the chemical bonds in the body, however it is important to note that low-levels of RF energy are absorbed into the body (Health Canada, 2011).

The energy that is absorbed through human body tissue is called electromagnetic radiation (EMR). EMR is made up of RF and thermal radiation and it causes dielectric heating once it penetrates through human body tissue. The skin around the ear-skull area is very thin, so EMR is absorbed quite easily and is known to affect the human immune system (Mat et al., 2010). In the study performed by Mat et al. (2010), they found that the specific absorption rate (SAR) was higher in cellphones that operated in higher frequencies (Mat et al. compared cellphone frequencies of 900 MHz and 1800 MHz), as they produced higher levels of EMR.

RF radiation is known to cause biological stress on the body through heating effects. Long-term use of mobile phones has been found to cumulatively increase the blood-brain barrier's permeability. The blood-brain barrier is vital for the protection of the brain from potential harmful substances in the blood, and with the frequent exposure to EMF, the brain's defense mechanism gradually decreases overtime (Nittby et al., 2009).

Humans generate their own electromagnetic fields (EMF); this is essential for repairing damaged cells, reproduction, and DNA replication. Weak EMF from cellphones can interact with the weak EMF generated by humans; thus potentially impacting the immune system (Jalil, Taib, Abdullah, & Yunus, 2012). Although not confirmed, there have been associations found with fatigue, headaches, difficulty in concentration, increases in reaction time, increase in resting blood pressure, and alteration in electroencephalogram pattern and disturbance in sleep from the EMF emitted by cellphones (Deepinder, Makker, & Agarwal, 2007).

Since mobile phones are usually held right against the ear, EMF exposure is considerably higher than any other EMF sources in the RF band (Huber et al., 2002). Health Canada (2011) has developed guidelines that provide recommendations to reduce RF exposure. This includes: cutting the time you spend on cellphone calls, using hands-free headsets, and substituting cellphone calls with text messages.

This study will help reveal whether radiation emissions will increase or decrease when a mobile device is paired with a Bluetooth compared to an unpaired cellphone; this information can be further used to determine possible ways to limit EMF exposure.

Health effects

Cancer and tumours

The most significant public concern with exposure to low-level RF is the potential for cancer. Epidemiological studies have been conducted in attempts to determine whether RF exposure contributes to an increased risk of cancer, and there have been some positive associations that linked it to leukemia and brain tumors; however, the results were always inconclusive (Repacholi, 2001). These studies were subjected to serious limitations such as uncontrollable confounding factors, potential biases, and misclassification of exposure or simple chance. Therefore, the positive associations between EMR exposure and increased risk of leukemia and cancer is not yet definitive (Calvente, Fernandez, Villalba, Olea, & Nuñez, 2010).

The International Agency for Research on Cancer (IARC) has labelled RF-EMF as being "possibly carcinogenic" to humans based on an increased risk of glioma, a malignant type of brain cancer that is associated with cellphone use. Being "possibly carcinogenic" is defined as:

> "*… limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals* (IARC, 2011)*."*

Health Canada (2011) has supported these claims as stating that scientific evidence has been inconclusive and more research is needed.

Findings that claim that there is no increased risk of brain tumors from cellphone use have been the subject of much debate. A comparison between two studies, the Interphone study and a self-funded Swedish study yielded different results. The Interphone study found no increased risk of brain tumors from cellphone use, while the Swedish study found significant evidence of increased risk of brain tumors from cellphone and cordless phone use. When analyzing the data between the two studies, the Interphone study was subject to eleven identified flaws:

> *"(1) selection bias, (2) insufficient latency time, (3) definition of 'regular' cellphone user, (4) exclusion of young adults and children, (5) brain tumor risk from exclusion of brain tumor types, (6) exposure to other transmitting sources are excluded, (7) exclusion of brain tumor types, (8) tumors outside the cell phone radiation plume are treated as exposed, (9) exclusion of brain tumor cases because of death or illness, (10) recall accuracy of cellphone use, and (11) funding bias* (Morgan, 2009)*,"*

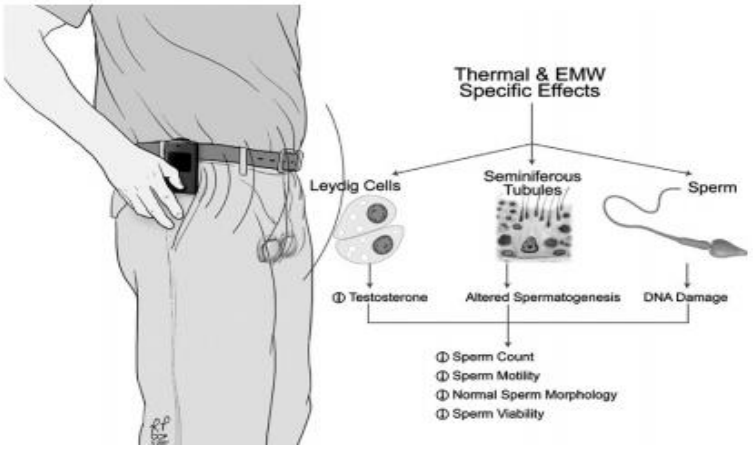
while the Swedish studies only had three flaws (8, 9, and 10) (Morgan, 2009).

Although the link between mobile phone use and cancer has been inconclusive thus far, there have been numerous associations found through multiple studies. The author wishes that this study will provide mobile phone users with information on how they can limit radiation emitted through mobile phones.

Male fertility

Studies have shown that prolonged use of mobile phones may contribute negatively to spermatozoa motility. Associations have been found between decreased sperm concentration and men who keep their cellphones around their waist area (Figure 1). However, these past studies did not take into consideration significant factors such as life style issues, occupation, and did not take into account other RF exposures. (Deepinder et al., 2007). Similar to the research between cancers and cellphone use, research with cellphone use and male fertility has also yielded inconclusive results.

Figure 1: Possible pathways for the mechanism of damage caused to spermatozoa by EMF emitted from cell phones.



(Deepinder et al., 2007)

Conversely, Falzone, Huyser, Becker, Leszczynski, & Franken, (2011) conducted a study that analyzed the effect of RF-EMF on the competency of sperm and found that there was an impact on sperm morphometry (the quantitative analysis of form). In their experiment, highly motile spermatozoa were subjected to a 900 MHz cellphone radiation for an hour and observed at various times after exposure. The results found that there was a significant reduction in the sperm head area in the test group when compared to the control group. Although the clinical significance of this finding is unknown, it is an indication that there could be a significant effect of radiation emitted by cell phones on sperm.

Many men, including the author of this study, place their mobile devices in their pant pocket without knowing that the radiation emitted can have an impact on their sperm. A popular placement of a cellphone while speaking on a Bluetooth headset is also in a pant pocket. The results of this research will provide the public with information on whether or not radiation levels are increased when paired with a Bluetooth.

Bluetooth Hands-free Headsets

Health Canada (2011) has recommended the use of Bluetooth headsets in order to decrease exposure to electromagnetic radiation of the auditory system. There are claims that the EMF absorption rate of the Bluetooth headsets is far below that of mobile phones as Bluetooth is believed to emit less radiation.

A Bluetooth device operates in a bandwidth between 2.400 to 2.485 GHz and like mobile phones, emits non-ionizing EMR (Bluetooth, 2013). Unlike mobile phones is that the radiation levels emitted by Bluetooth headsets do not affect normal hearing, while mobile phones have been shown to reduce hearing effectiveness over time (Oktay & Dasdag, 2006). Oktay & Dasdag (2006) found that the more time spent on a cellphone would result in more exposure to EMF, which caused a higher degree in hearing loss in their subjects. On the other hand, the study by Balachandran et al. (2012) found that emissions of EMF from Bluetooth headsets did not decrease or impact hearing thresholds in their subjects as levels of electromagnetic radiation were much lower than cellphone emissions.

Emissions of thermal radiation was also proven to be much lower with Bluetooth headsets than cellphones as described in Mat et al.'s (2010) study. Cellphone and Bluetooth headset emissions of thermal radiation were analyzed and compared using a thermal imaging camera; this camera captured the local temperature around the ear-skull region. The results found that thermal radiation from the cellphone operating at 900 MHz reached 38.3˚C after 35 minutes of operation and thermal radiation emissions from the Bluetooth headset was 35.3˚C. This shows that using Bluetooth headsets reduces thermal radiation exposure in the ear-skull area as heat is distributed around the head.

The results of this study can be used to either confirm or challenge the findings mentioned above in regards to Bluetooth use.

Legislation

The use of cellphones is prohibited while driving in British Columbia according to the Motor Vehicle Act (Province of British Columbia, 2013). This law was passed as there was a sudden increase in car accidents due to distracted driving by talking on a cellphone. Studies have shown that a person is up to five times more likely to be involved in a car accident while talking on a phone while driving (Canadian Automobile Association, 2013). With this latest law, drivers have been looking to Bluetooth hands-free headsets to avoid fines. As mentioned earlier, placing a cellphone in a pocket is a popular placement while speaking off of a Bluetooth device. The author hopes that this study will provide a valuable tool to educate the public on whether or not the radiation emissions are higher when a cellphone is paired with a Bluetooth device.

Role of an Environmental Health Officer (EHO)

One of an EHO's main duties is to educate the public on how to protect themselves from hazards that may cause injury or illness. As the use of cellphones has been associated with many health implications, this study can serve as a resource on ways to minimize cellphone radiation exposure.

The health promotion field has been a blossoming field as of late for EHOs. This field can serve as a platform for EHOs to educate the public on any potential health risks that may stem from cellphone use. The author hopes that his study will provide current and future EHOs with relevant information to utilize as health promotional material to educate the public.

Purpose

In Canada and many parts throughout the world, Bluetooth headsets are growing in popularity due to cellphone bans while driving, and the evolution of new technology. Although there is research that show Bluetooth headsets emitting lower levels of radiation than cellphones, there have been doubts raised on whether or not the pairing of a Bluetooth headset and a cellphone would contribute to additively to the radiation exposure in humans. The purpose of this research is to determine the Bluetooth impact on radiation levels when it is paired with a cellphone. This is a two-fold process: firstly, to determine radiation levels emitted by the pairing of a cellphone and a Bluetooth headset and comparing it to a control group of the cellphone alone and secondly, comparing the radiation emissions of a paired cellphone with the associated paired Bluetooth headset.

Materials and Methods

Materials Used

i. Extech RF EMF strength meter model: 480846
ii. LG HBM-220 Bluetooth hands-free headset
iii. Measuring tape
iv. Cellphones: the following are mobile devices that were tested:

	Make	Model
1	Apple	iPhone 3GS
2	Apple	iPhone 4
3	Apple	iPhone 4S
4	Apple	iPhone 5
5	Apple	iPhone 5S
6	Samsung	Galaxy S3
7	Samsung	Galaxy S4
9	Samsung	Galaxy S4 Mini
8	Samsung	Note 2
9	Samsung	Note 3

v. NCSS – Statistical Analysis Tool Pack: software used to analyze results of the readings (Hintz, 2013).
vi. Microsoft Excel

Methodology

Location

This study was conducted at British Columbia Institute of Technology (BCIT) on 3700 Willington Avenue, Burnaby. The experiment was carried out in the courtyard on a table between the SW1 building and SE2 building. A background radiofrequency test was measured at 0.001 $\mu W/cm^2$.

Part I: EMF Measurement of the handheld device during a call without the Bluetooth hands-free device turned on:

The Extech EMF meter was set to an average $\mu W/cm^2$ unit to measure the radiation emissions from the sample cellphone. The sample phone was placed on a table along with a Bluetooth device turned off and placed one meter away *(see figure 2a)*. The sample phone was then dialed at a distance of 15 meters away. As the sample phone answered the call, a reading was taken by placing the EMF reader directly underneath the phone while ensuring the sensory portion touched the bottom of the cellphone. This process was repeated three times for each phone type mentioned in the Materials section for a total of n=30.

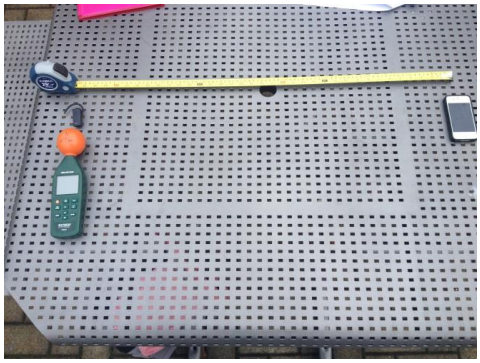
Part II: EMF Measurement of the Bluetooth Hands-Free device during a call:

The second part of the study follows a similar methodology as the first part. The only difference is that the Bluetooth headset is now turned on and paired with the sample cellphone. There were two readings that were taken; one was the EMF emissions of the Bluetooth headset, and the second was the EMF emissions of the sample cellphone while paired with the Bluetooth headset *(see figure 2b)*.

Figure 2

a. (left) Measuring the EMF radiation emissions of a cellphone

b. (right) Measuring the EMF radiation emissions of a Bluetooth hands-free headset.



Methods

The methods of this research were carried out in a courtyard with minimal interference from other radiation sources such as Wi-Fi, cellphone towers, or power lines (Herle, 2012). The readings were taken on cloudy days eliminating much of the radiation emitted by the sun. This will enable the Extech EMF strength meter to provide more accurate readings of the radiation emitted from cellphones and Bluetooth devices as there will be less interference from other radiation sources (Extech User Guide, 2012). Also, the same area in the courtyard was utilized for all readings in order to keep the data consistent.

To also increase consistency, readings for a cellphone without Bluetooth pairing were taken with the Bluetooth device turned off placed one meter away from the cellphone. This reduced variations in environment between part I and II mentioned in the methodology section. Refer to *Appendix C – Placement of cellphone, Bluetooth, and EMF Reader in experiment* for a visual demonstration of the set-up.

Reliability and Validity of Measures

The validity of an instrument depends on its ability to measure what it is supposed to be measuring, while the reliability of an instrument is dependent on whether or not a variable can yield the same results on multiple measurements (Heacock, Crozier, & Sidhu, 2012). In order for an instrument to be valid and reliable, there must be a pilot study conducted utilizing the instrument, the experiment must be done in a consistent environment and a consistent manner, the user must be trained on utilizing the equipment, and the instrument must be calibrated; this experiment has met these requirements.

Calibration of Instrument

The Extech EMF meter (model 480846) was factory calibrated prior to shipment. Annual factory calibration has been recommended, however Extech does not include any calibration certificates; instead, the National Institute of Standards Technology (NIST) would perform the calibrations. This can be done by contacting Extech's return department for return information and authorization number (Extech Instruments, 2013).

The author of this study was notified by BCIT's Environmental Health Lab Technician that the Extech EMF meter that he is using does not require a calibration as the device was recently purchased (F. Shaw, personal communication, November 13, 2013).

Inclusion and Exclusion Criteria

Table 1: Inclusions & Exclusions

Inclusion	Exclusion
➢ Smartphones (Apple and Samsung as mentioned in the Materials and Methods section) ➢ Cellphones with Bluetooth capability ➢ Internet-abled phones	➢ Non-internet-abled phones ➢ Phones pre-2008

Ethical Considerations

Ethical considerations are not applicable to this study, because it is neither a survey nor a human based study (H. Heacock, personal communication, November 5, 2013).

Pilot Studies

On November 15, 2013 a pilot study was conducted in which procedures within the methodology section mentioned earlier was followed for sampling a variety of cellphones 30 times; this ensures that the study is reliable and valid. The pilot study was conducted at BCIT in the courtyard between SW1 and SE1 buildings on a table; it allowed the author to determine an optimal condition and place for minimal EMF interference.

Statistical Analysis

The following statistical analysis was done using NCSS.

Hypothesis

Hypothesis 1:

Ho: The radiation emission ($\mu W/cm^2$) from an unpaired phone is greater than or equal to the radiation emission of a cellphone paired with Bluetooth.

- $Ho \geq Ha$

Ha. The radiation emission ($\mu W/cm^2$) from an unpaired phone is less than the radiation emission of a cellphone paired with Bluetooth.

- $Ho < Ha$

Hypothesis 2:

Ho: There is no difference in the radiation emissions ($\mu W/cm^2$) from a paired Bluetooth to the paired cellphone.

- $Ho = Ha$

Ha: There is a difference in the radiation emissions ($\mu W/cm^2$) from a paired Bluetooth to the paired cellphone.

- $Ho \neq Ha$

Numerical Data and Descriptive Statistics

The measurements collected by the Extech EMF strength meter yielded continuous numeric data. The unit for EMF field measured was measured in $\mu W/cm^2$. The 30 samples taken for *Readings of the cellphone unpaired (CUP)* had a mean of 0.0246, median of 0.025, mode of 0.025, and standard deviation of 0.004839. The 30 samples taken for *Readings of cellphone paired (CPP)* had a mean of 0.02836 $\mu W/cm^2$, median of 0.0295, mode of 0.03, and standard deviation of 0.005898. More variation was observed in CUP compared to CPP as can be seen by the differences in the standard deviations. CPP had slightly higher mean and median values than CUP which indicated that CPP emitted slightly higher radiation than CUP.

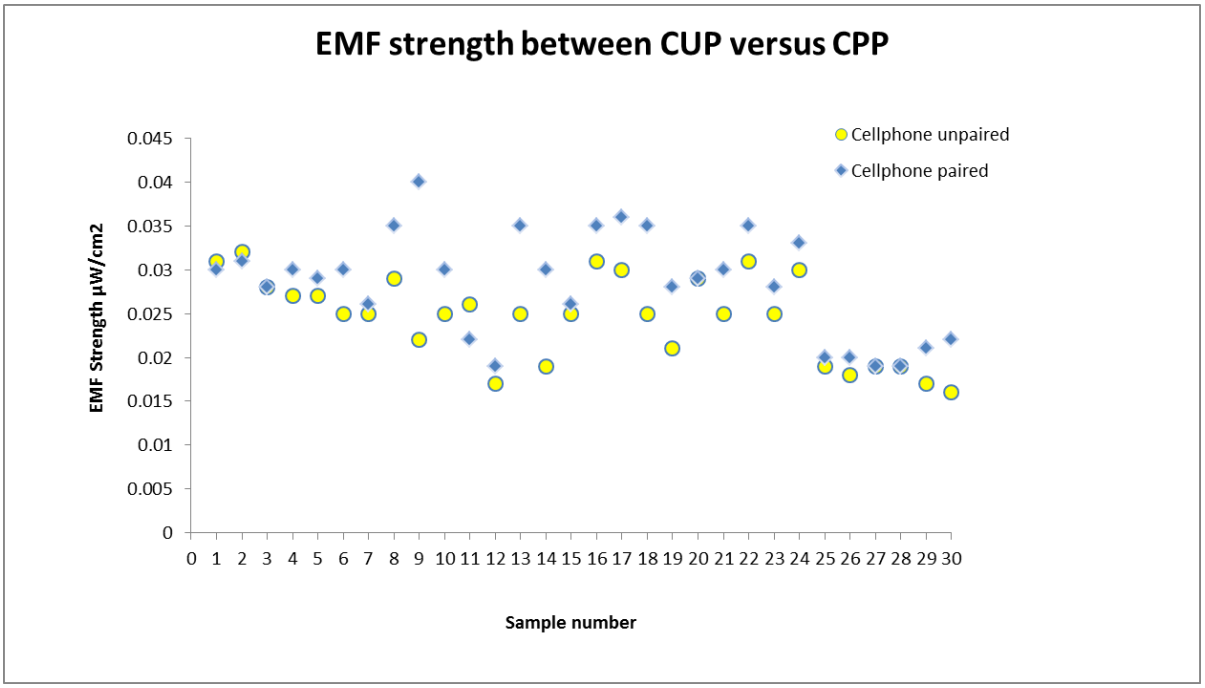
The 30 samples from *Readings of Bluetooth paired* (BTP) had a mean of 0.0600, median of 0.0595, mode of 0.066, and standard deviation of 0.00713. BTP tended to have more variation than CPP as evident in the differences between standard deviations between the two groups. BTP showed a higher mean and median EMF strength which is indicative of higher radiation emissions than CPP.

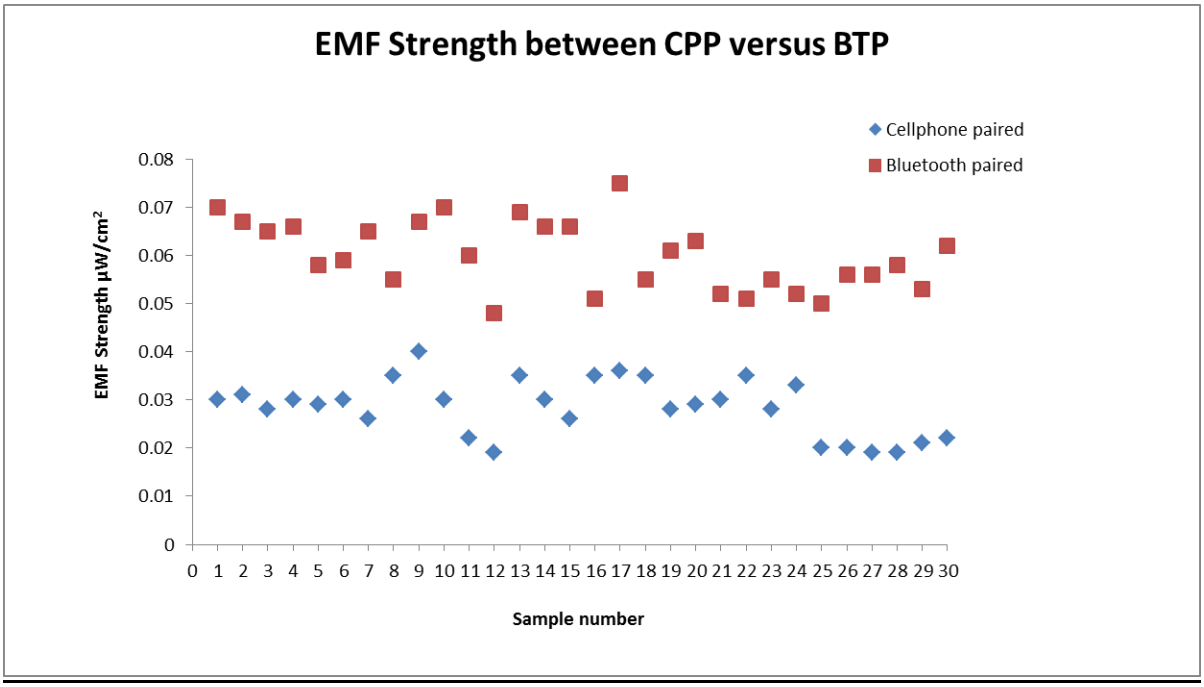
Below are three groups of data (CUP, CPP, and BTP) analyzed separately for descriptive statistics using Microsoft Excel.

Table 2: Descriptive Statistics

Readings of the cellphone unpaired (CUP)		*Readings of the cellphone paired (CPP)*		*Readings of the Bluetooth paired (BTP)*	
Mean	0.0246	Mean	0.02836	Mean	0.060033
Standard Error	0.0008	Standard Error	0.00107	Standard Error	0.001302
Median	0.025	Median	0.0295	Median	0.0595
Mode	0.025	Mode	0.03	Mode	0.066
Standard Deviation	0.00483	Standard Deviation	0.00589	Standard Deviation	0.00713
Range	0.016	Range	0.021	Range	0.027
Minimum	0.016	Minimum	0.019	Minimum	0.048
Maximum	0.032	Maximum	0.04	Maximum	0.075
Sum	0.738	Sum	0.851	Sum	1.801
Count	30	Count	30	Count	30

Figure 3: EMF Strength Plot Results





Inferential statistics (Paired T-Test)

One-tail paired T-Test

A one-tailed paired T-Test was used for the first part of this study as it took into account that the two values (an unpaired cellphone and a cellphone paired with a Bluetooth) go together. It was also to observe if one mean was higher or lower (Ho: $\mu_1 \geq \mu_2$; Ha: $\mu_1 < \mu_2$) than the other (Heacock et al., 2012). Prior to the study, there was an assumption that CPP would emit more radiation than CUP. The test of assumptions showed that the data was not normally distributed; therefore the non-parametric results were taken into account. The values were obtained utilizing NCSS.

The p-value = 0.000026 ($p < 0.05$), therefore the Ho was rejected and it can be concluded that the radiation emission from an unpaired phone (CUP) was less than the radiation emission of a cellphone paired with Bluetooth (CPP). CPP was found to emit slightly higher levels of radiation than CUP.

Power was found to be 0.998 (99.8%) and 0.984 (98.4%) at both the 5% and 1% levels respectively; as this value exceeds 80%, there is a strong probability of correctly rejecting the null hypothesis. This shows that an increase in EMF emission in CPP compared to CUP was evident. The possibility of an alpha error was extremely minimal, because the p-value (0.000026) was less than both the 0.05 value and the more stringent standard of 0.01.

Two-tailed paired T-Test

A two-tailed paired T-Test was used for the second part of this study as it took into account that the two values (a Bluetooth and it's paired cellphone) go together and were used to see if the two means were different from each other (Heacock et al., 2012). Prior to the study, there was no knowledge of which direction the difference was moving. The test of assumptions show that the data was normally distributed, therefore the parametric results will be taken into account.

The p-value = 0.00000 ($p < 0.05$), therefore the Ho is rejected and it can be concluded that there was a significant difference between EMF radiation emissions in from a paired Bluetooth (BTP) and it's paired cellphone (CPP). Radiation levels were found to be significantly higher in BTP.

Power was found to be 100% at both the 5% and 1% levels; as this value exceeds 80%, there is a strong probability of correctly rejecting

the null hypothesis. This shows that a difference in EMF between BTP and CPP were detected. The possibility of an alpha error was extremely minimal, because the p-value was less than both the 0.05 value and the more stringent standard of 0.01.

Discussion

According to this study, the results have revealed that radiation levels were found to increase when a cellphone is paired with a Bluetooth versus an unpaired cellphone. Additionally, it was found that the Bluetooth headset emitted significantly higher levels of radiation than the paired phone. This study has shown that there are in fact additive effects and increased levels of radiation when using a Bluetooth in conjunction with a cellphone.

Relation to Previous Studies

The results of this study are not consistent with previous research claims that Bluetooth headsets decrease radiation exposure. Interestingly, Health Canada (2011) recommends the use of Bluetooth headsets with the belief that radiation emissions are lower. Although there is a contradiction between this study and the recommendations Health Canada made, it is important to take into consideration possible errors and limitations that may have implicated the results of this study. As will be discussed in the *Limitations* section, only the LG HBM-220 Bluetooth headset was tested which leaves the possibility that other Bluetooth headsets may have yielded different results. However in saying this, the results of this study did clearly show that a Bluetooth headset is capable of emitting higher radiation levels than a cellphone alone. A suggestion for more research on different Bluetooth's will be made in the *Suggestions for Future Research* section.

As previous research has indicated, cellphone radiation has been associated with many health implications including, cancer and tumours, sleep pattern disturbances, reproduction disturbances, fatigue, and headaches (Deepinder et al., 2007; IARC, 2011). With this in mind, the results of this research show that caution must be considered to limit radiation exposure as a Bluetooth headset was tested to emit higher radiation levels than a cellphone alone.

Impact on Public Health

Bluetooth usage has become increasingly popular especially after the BC government implemented a cellphone ban while driving (Province of British Columbia, 2013). Many drivers are unaware that their Bluetooth headsets may potentially increase the radiation levels in both their phones and their headsets.

Through the author's study, a cellphone was found to emit more radiation when paired with the Bluetooth. A popular placement of a cellphone while talking on a Bluetooth headset is in a pant pocket. Recall earlier that cellphone radiation placed around the waist area caused for implications in sperm motility, physiology, and concentrations (Deepinder et al., 2007). With the increasing popularity of Bluetooth headsets, it is important to limit radiation exposure by having the cellphone placed away from the body when paired to a Bluetooth headset.

With cellphone and Bluetooth technology evolving at a significant pace, it is relevant to explore how this interaction affects public health; especially as cellphone-use has become a staple in daily living. Never before have humans been so closely exposed to radiation; thus there is an imminent need to explore this subject matter and include it in policy planning for public health. Although this research suggests a recommendation to limit exposure to cellphone and Bluetooth-use, the reality is that the cellphone-use has been increasing substantially with no signs of slowing down. Therefore, the information from this research along with future research may serve as a resource for cellphone and Bluetooth makers to develop technology that minimizes radiation emissions.

Limitations

The following table details the limitations of this research:

Table 3: Limitations and their explanation

Limitation	Explanation
An older model Bluetooth was used	The LG HBM-220 Bluetooth headset was first released in 2010 and since then there have been advances in technology.
Limited to only Samsung and Apple phones	There are many more types of phones on the market such as HTC, Motorola, Nokia, Sony, and LG.
Background radiation was present	Although all efforts of finding a location with minimal radiation were made, there were still possible interferences from other radiation sources that could not be controlled such as the sun, body heat, Wi-Fi signals, and power lines.
Time	This research study was performed under a time restriction; otherwise the author would have been able to test more cellphone and Bluetooth types.
Accessibility	The author was limited in using an Extech Radiation meter as this was the only equipment available at BCIT for this study. There is much more expensive equipment that can limit background radiation.
Errors	During the pilot project, the author made an error when measuring radiation levels at various distances as he did not touch the top of the Extech EMF reader to the cellphone as he did with other studies, therefore these results could not be used for this study.

Recommendations

Findings in this study suggest that caution should be taken when utilizing Bluetooth headsets. Although the findings cannot be confirmed, an association was found to indicate that not all Bluetooth headsets are capable of decreasing radiation emissions regardless of what Health Canada (2011) claims.

EHOs and Health Canada can collaborate and push for more research as only one Bluetooth headset model was tested for this research. Further studies are required to test various brands and models of Bluetooth to confirm whether or not a trend can be found which shows that Bluetooth headsets contribute to radiation emissions rather than limit them. Once more research has been conducted, EHOs can educate the public of any findings that may affect their health; this can be done in the health promotion field. Health Canada may also wish to update their website with information regarding Bluetooth once more research is completed.

Suggestions for Future Research

The following are suggestions for future studies in relation to the experiments presented in this paper:

i. Use different brands and models of cellphones
ii. Use different brands and models of Bluetooth headsets
iii. Test radiation of built-in Bluetooth in vehicles.
iv. Test radiation levels of Bluetooth and their paired cellphones at various distances.
v. Compare radiation levels between different models of phones
vi. Compare radiation levels between different models of Bluetooth headsets

Conclusion

The findings in this study show that a Bluetooth headset emits higher radiation levels than the paired cellphone and also causes the cellphone to emit higher levels than it normally would had it been unpaired. This suggests that

that there are additive effects in radiation exposure when utilizing a Bluetooth headset; however there is a caveat with these findings. It is important to note that only one Bluetooth headset was used throughout the entire experiment and future studies would be needed to confirm whether or not the higher levels of radiation was due to the specific Bluetooth tested (LG HBM-220).

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Competing Interest

The authors declare that they have no competing interests.

References

Aron, E., Aron, A., & Coups, E. (2006). *Statistics for psychology* (4rth ed., pp. 132–133). Upper Saddle River; New Jersey: Pearson Prentic Hall.

Bluetooth. (2013). Basics | Bluetooth technology website. Retrieved October 20, 2013, from http://www.bluetooth.com/Pages/Basics.aspx

Calvente, I., Fernandez, M. F., Villalba, J., Olea, N., & Nuñez, M. I. (2010). Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: a systematic review. *The Science of the Total Environment*, *408*(16), 3062–9. doi:10.1016/j.scitotenv.2010.03.039

Canadian Automobile Association. (2013). CAA distracted driving. Retrieved January 24, 2014, from http://distracteddriving.caa.ca/education/crash-odds.php

Cheng, R. (2014). Apple, Samsung own two-thirds of US smartphone market. *CNET*. Retrieved March 13, 2014, from http://news.cnet.com/8301-1035_3-57617334-94/apple-samsung-own-two-thirds-of-us-smartphone-market/

Deepinder, F., Makker, K., & Agarwal, A. (2007). Cell phones and male infertility: dissecting the relationship. *Reproductive BioMedicine Online*, *15*(3), 266–270. doi:10.1016/S1472-6483(10)60338-0

Extech Instruments. (2013). Extech Instruments - FAQs. Retrieved from http://www.extech.com/instruments/faq.asp

Extech User Guide. (2012). User's guide: Extech RF EMF Strength Meter Model 480846. Retrieved from http://www.extech.com/instruments/resources/manuals/480846_UM.pdf

Falzone, N., Huyser, C., Becker, P., Leszczynski, D., & Franken, D. R. (2011). The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. *International Journal of Andrology*, *34*(1), 20–6. doi:10.1111/j.1365-2605.2010.01054.x

Heacock, H., Crozier, V., & Sidhu, B. (2012). *Research Methods ENVH 8400 Lecture Notes* (pp. 34–35). Burnaby, BC.

Health Canada. (2004, July 26). Consumer Radiation. Retrieved from http://www.hc-

sc.gc.ca/ewh-semt/radiation/cons/index-eng.php

Health Canada. (2011, November 3). It's your health - safety of cell phones and cell phone towers. Retrieved October 19, 2013, from http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/prod/cell-eng.php

Herle, K. (2012). *ENVH 3600 - environmental assessment lab 6: nonionizing radiation* (pp. 8–9). British Columbia Institute of Technology, Burnaby, BC.

Hintz, J. (2013). NCSS 9. Kaysville, Utah: NCSS LLC. Retrieved from www.ncss.com

Huber, R., Treyer, V., Borbély, a a, Schuderer, J., Gottselig, J. M., Landolt, H.-P., … Achermann, P. (2002). Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. *Journal of Sleep Research*, *11*(4), 289–95. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12464096

IARC. (2011). IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. *World Health Organization*. Retrieved from http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

Jalil, S. Z., Taib, M. N., Abdullah, H., & Yunus, M. (2012). Frequency radiation characteristic around the human body. *IJSST*, *12*(1), 34–39.

Leeper, E. (2001). *Silencing the fields: a practical guide to reducing AC magnetic fields* (p. 340). New York, NY: Symmetry Books. Retrieved from http://silencingthefields.com/emf-meters.html

Mat, D. A. A., Kho, F., Joseph, A., Kipli, K., Sahrani, S., Lias, K., & Marzuki, A. S. W. (2010). Electromagnetic radiation from mobile phone near ear-skull region. *International Conference on Computer and Communication Engineering (ICCCE'10)*, (May), 1–5. doi:10.1109/ICCCE.2010.5556752

mobiThinking. (2013). Global mobile statistics 2013 Part A: Mobile subscribers; handset market share; mobile operators. *mobiThinking*. Retrieved March 13, 2014, from http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/a

Morgan, L. L. (2009). Estimating the risk of brain tumors from cellphone use: Published case-control studies. *Pathophysiology : The Official Journal of the International Society for Pathophysiology / ISP*, *16*(2-3), 137–47. doi:10.1016/j.pathophys.2009.01.009

Nittby, H., Brun, A., Eberhardt, J., Malmgren, L., Persson, B. R. R., & Salford, L. G. (2009). Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology : The Official Journal of the International Society for Pathophysiology / ISP*, *16*(2-3), 103–12. doi:10.1016/j.pathophys.2009.01.001

Oktay, M. F., & Dasdag, S. (2006). Effects of intensive and moderate cellular phone use on hearing function. *Electromagnetic Biology and Medicine*, *25*(1), 13–21. doi:10.1080/15368370600572938

Province of British Columbia. (2013). Motor Vehicle Act. Retrieved January 24, 2014, from http://www.bclaws.ca/EPLibraries/bclaws_new/document/LOC/freeside/-- M --/46_Motor Vehicle Act RSBC 1996 c. 318/00_Act/96318_06.xml

Repacholi, M. H. (2001). Health risks from the use of mobile phones. *Toxicology Letters*, *120*(1-3), 323–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11323191

The British Consumer's Association. (2000). CNN.com - Technology - U.K. consumer group: Hands-free phone kits boost radiation exposure - November 2, 2000. *CNN*. Retrieved October 19, 2013, from http://edition.cnn.com/2000/TECH/computing/11/02/london.phone/