



Cell Phone Use and The Associated Health Risks Among Adults

A Literature Review

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<p>ABSTRACT</p> <p>Background</p> <p>The number of cell phone users has increased dramatically over the past few decades globally, which has raised public concerns about potential risks associated with the exposure to cell phones. Given the dramatic increase in the number of cell phone users, a small negative effect may have huge public health impact. This study aims to explore the health risks associated with cell phone use among adults and to search available precautionary measures to minimize the possible adverse health effects.</p> <p>Research Methodology</p> <p>A literature review was done on the basis of established inclusion and exclusion criteria. Articles for literature review were selected from three different electronic databases: PubMed, Science Direct and Academic Search Elite. In total 17 articles were identified for analysis. Data analysis was done using inductive content analysis technique.</p> <p>Results</p> <p>The review demonstrated that cell phone use might lead to the cellular changes, cancer, psychiatric symptoms, musculoskeletal disorders, infertility and other non-specific symptoms. Studies have suggested several precautionary measures such as lowering call handling time, avoiding call during poor signal strength and when charging, keeping phone away from the body, using landline phone whenever possible, using hand-free devices/ear phone, turning off cell phones while sleeping and so on. Overall evaluations show that the evidence for any association is unconvincing due to methodological limitations.</p> <p>Conclusion</p> <p>Further studies are needed to find clear explanations for the controversies on the health risks associated with cell phone use. In this light of uncertainty, cell phone users can take precautions to minimize the risks associated with cell phones.</p>	
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List of Abbreviations

ITU: International Telecommunication Union

IARC: International Agency for Research on Cancer

RF-EMF: Radiofrequency Electromagnetic Fields

ICNIRP: International Commission on Non-Ionizing Radiation Protection

SAR: Specific Absorption Rate

RF: Radiofrequency

SEER: Surveillance, Epidemiology and End Results

ICNE: International Centre for Nursing Ethics

OR: Odd Ratios

PR: Prevalence Ratios

PSS: Perceived Stress Scale

HIT-6: Headache Impact Test-6

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FOREWORD

I would like to acknowledge all the continuous support provided by my supervisor Gun-Britt Lejonqvist. This thesis would not have been possible without her guidance, motivation and encouragement. I would like to thank for the kind availability whenever and wherever needed.

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1 INTRODUCTION

In the last few decades, communication technologies have changed dramatically, replacing landline devices with portable cell phones or other communication technologies, connecting people more easily. Nowadays, cell phone has become an essential part of modern lifestyles. According to The International Telecommunication Union (2015), the number of cell phone subscribers reached more than 7 billion in 2015 worldwide, representing approximately 97 percent of the world's population. This surge of cell phone users reflects how deeply they are integrated into our day-to-day lives. Therefore, public has become more concerned about the possible health hazards due to cell phone use. Given the billions of cell phone users, even narrow rise in risk might result to the large number of affected people on long-term basis. (National Cancer Institute 2016).

The International Agency for Research on cancer (IARC) has categorized radiofrequency electromagnetic fields produced by cell phones as 'a possible carcinogen for humans', although there is no any clear evidence (Baan et al., 2011). The American Cancer Society (2011) in response to IARC classification states that there could be some risk but the evidence is not strong enough warranting further studies and therefore recommends to limit cell phone exposure by using an ear piece and limiting cell phone use, particularly among children.

Over the past few decades, there have been several epidemiological studies reporting the effect of cell phone use on health risk, predominantly brain tumors due to the proximity of exposure (Inskip et al., 2001; Lönn et al., 2005; Schoemaker et al., 2005; Hoffman 2006; Hardell et al., 2007; Rösli et al., 2007; Hardell et al., 2008; Kan et al., 2008; ; Lahkola et al., 2008; Deltour et al., 2009; Khurana et al., 2009; Frei et al., 2011; Repacholi et al., 2011; Wild 2011; Hardell et al., 2013; Benson et al., 2013; Lagorio & Rösli 2013; Coureau et al., 2014). Interphone study is the largest case-control study in 13 different countries (Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the UK) of cell phone use and brain tumors. Few studies have focused on leukemia (Cooke et al., 2010), lymphoma (Linnet et al., 2006), salivary gland tumors (Hardell et al., 2004) and testicular cancer (Hardell et al., 2007).

Besides, a large number of studies have also investigated the effects of cell phone exposure and self-reported symptoms such as fatigue, confusion, discomfort, sleep quality, anxiety, tension, depression etc. (Eltiti et al., 2007; Soderqvist et al., 2008; Augner & Hacker 2012; Szykowska et al., 2014; Silva et al., 2015). Inconsistent and inconclusive results have been published from the majority of the studies investigating risk associated with cell phone. Till date, the well-established risks associated with cell phone on health risk are traffic accident and interference to medical devices (Sánchez 2006).

2 THEORITICAL BACKGROUND

In this chapter, author has presented a collection of several existing relevant publications about cell phone and the associated health risks. It provides the basis for the current study to understand the widespread public concern towards rising cell phone use. Section 2.1.1 gives a simple understanding on the history of cell phone and its rapid growth worldwide. Section 2.1.2 explains the uses of cell phone generally and in health care settings. Section 2.1.3 explains health concerns over cell phone use and 2.1.4 gives a broader view of possible cell phone risks on human health.

2.1 The evolution of cell phone and its expansion worldwide

Cell phone is not the discovery of modernized age. During the Second World War in the 1930's, the use of wireless communication system started with the adoption of 'Walkie-talkies' which enabled foot soldiers to contact with headquarters (Momani & Noor 2009). In 1956, Eriksson (A Swedish multinational provider of communication technology and services) introduced the first fully automated mobile telephone system for vehicles. In 1960s, Improved mobile telephone services (IMTS) was launched which became the base for first analog cellular systems. In 1971, Finland launched ARP network (Auto-radio puhelin in Finnish or car radio phone in English) which was a great success. (Hanne 2016). John F. Mitchell and Dr. Martin Cooper of Motorola introduced the first hand-held mobile phone in 1973. Before 1973, cellular mobile phone technology was only confined to phones installed in car and other vehicles. (Anjarwalla 2010).

Mobile technologies have evolved in several successive generations. The first generation (1G) was based on analog cellular system which was able to carry voice only mobile services. It appeared in 1950s (Hultén & Dunnewijk 2006). In addition to the voice service of analog phone, the second generation introduced short message service (SMS), i.e. text messages. It also introduced features to download ringtones and games. The world's first commercial GSM network was launched in Finland in 1991 (Bouwman et al., 2008). The third generation (3G) pre-commercial Wideband Code Division Multiple Access (WCDMA) trail network begun in Japan, Tokyo in 2001 and then spread to Europe

and USA in 2002. It made improvements in screen displays and the ability to handle multimedia data, such as graphics and video streaming. (Elliot 2004). After the success of 3G systems, the fourth generation (4G) of mobile telephony were introduced. 4G is better described as MAGIC (mobile multimedia, any-time anywhere, global mobility support, integrated wireless solution, and customized personal service. (Agarwal & Agarwal 2014).

The number of mobile phone users has risen sharply since the early 1990's. With time, new technologies, beautiful designs, new applications such as text messaging, internet access, cameras, calendars, music are continuously evolving making people fond of it. In 2015 there are more than 7 billion mobile cellular subscriptions worldwide, which was less than 1 billion in 2000 (Sanou 2015).

2.2 Cell phone usage

Nowadays, cell phones have been considered as the necessity of life (Aoki & Downes 2003). In fact, cell phones have turned from a technological tool to a social tool (Campbell 2005). In a telephone survey conducted among a nationally representative sample of Americans, the Pew Research Center's Internet and American life Project found that cell phones are very useful for quick information retrieval and an important tool in emergency situations. People use their cell phones for variety of purposes such as text messaging, taking pictures, sending photos or videos, accessing internet, sending or receiving emails, playing video games, playing music, recording video, downloading various application, using social networking site, online banking, video call or video chat, getting directions etc. (Smith 2011). Similar study found that 94% of parents and 93% of teens ages 12-17 agreed with the statement 'I feel safer because I can always use my cell phone to get help'. Moreover, majority of the teens used cell phones as a tool for entertainment when they are bored. (Lenhart et al., 2010). It has been stated that cell phones are the major source of connection with fellow beings and people feel cut off from others with-out it (Davie et al., 2004). A study in New Zealand reported 56% of the students use their mobile phones to talk and send messages to their friends (Netsafe 2005). Another study concluded that mobile phone is 'a must' for college students to keep in contact with their families, to keep them informed regarding their studies, health, to share experiences and emotions with

their parents and to get moral support (Chen & Katz 2009). Majority of the parents want their children to have mobile phone for safety. Geser called it 'remote mothering', where mother can communicate with their children anytime, anywhere and makes them available as per the need of their children. Thus mobile phones have been used to maintain social capital by connecting friends and families, in spite of the fact that mobile phone was originally designed for business and professional purposes. (Geser 2004).

According to Mechael (2009) "Individuals around the worlds are using mobile technologies to access health services and information and that the professionals are formally and informally integrating mobile technologies into public health and clinical activities". Information and communication technology has become widespread in health care with expanding use of wireless devices. Nursing professionals are using their cell phones, laptops, tablets, computers and other communicating devices to interact with healthcare team members, clients and colleagues (Koivunen et al., 2014). With increasing workloads, physicians have started using contemporary methods to deliver health care including telephone consultation (Car & Sheikh 2003). Study has shown to reduce the number of unnecessary emergency room visits significantly with cell phone use, decreasing the physicians work burden (Spencer & Daugird 1988; Peleg et al., 2011). Cellular phone usage has aided in delivering health care to address the critical medical needs of people especially in remote places that lack qualified medical personnel and services (Isabona 2013). Text messaging reminders showed increased attendance at health care appointments compared to no reminders (Car et al., 2008). There is a growing evidence that text messaging, video messaging and voice calling is a potentially powerful tool which can improve health service delivery process and health outcomes in terms of adherence to their medical regimen, hospital appointments, and patient monitoring, mostly in the developed countries (Tamrat & Kachnowski 2012; Free et al., 2013; Fjeldsoe & Miller 2009; Pop-Eleches et al., 2011; Horvath et al., 2012). Email and mobile phone text messages have shown to improve knowledge on sexual health among young people having considerable potential for health promotion (Lim et al., 2012). Yang et al., (2009) has concluded that mobile phone is a useful communicating tool for infectious disease surveillance in areas hit by natural disasters. Researches have provided limited evidence that a series of interactive voice messages can improve post-abortion contraception and daily educational text messages can improve adherence to oral contraceptive use (Smith et al., 2015).

A number of studies have demonstrated that telephone consultations are shorter than face to face visits which saves time for both the physician and the client (Oldham 2002; McKinstry et al., 2009). However, telephone consultation is not as much satisfying for the client and the physician as a face to face consultation although it is convenient, reduces waiting time, travel time, improves cost savings and increases possibility of contact with health care teams especially with the people living in rural areas because of the chances of wrong diagnosis, miscommunication, poor communication, interference with other patients clinic visit and inappropriate prescription. Telephone consultation are offered to the client who has prior face to face consultation and it is always necessary to ensure that the clients understand and follows directions accurately (Gupta 2013).

2.3 Health concerns over cell phone use

Public concerns have been raised about the possibility that exposure to radiofrequency electromagnetic fields (RF-EMF) from cell phones or their base-stations could affect overall health of the people . Cell phones emit RF-EMF when making and receiving calls. They are non-ionizing and do not cause DNA mutations. Exposure to ionizing radiation such as x-rays is known to cause DNA damage, however there are no consistent evidence to demonstrate that non-ionizing radiation increases the risk for any of the cancers. But, they may have some thermal effects in contacts with the human body, raising the temperature in the tissues which is the only established mechanism for biological effect of radiofrequency radiation. If there is an effect of mobile phone use at all, then the mechanism would be tumor promotion or advancement rather than commencement. (Kundi 2009).

The International Commission on Non-Ionizing Radiation Protection (ICNIRP 1998) formulated guidelines to protect people from the possible harmful effects of RF radiation by limiting exposure. The guidelines were revised in 2010 and they provided new guidelines for the frequency range 1Hz to 100 kHz (ICNIRP 2010). The ICNIRP guidelines are based on an analysis of all relevant scientific literature, including both thermal and non-thermal studies.

Specific absorption rate (SAR) values are an important tool in judging the level of exposure to radiofrequency (RF) radiation. SAR is expressed as Watts/kilogram (W/Kg) in either 1 gram or 10 gram of tissue. The SAR distribution appears to decrease very rapidly

with increasing depth, on average to a tenth within the 5cm distance of brain tissue (Cardis et al., 2008). ICNIRP has given recommendations for SAR value limits to such a level that the excess temperature rise is limited to 1 degree Celsius. The SAR level for the general public has been set to 0.08 W/Kg averaged over the whole body, 2W/kg for local exposure to the head and torso, and 4W/kg for local exposure to the limbs. A maximum SAR of 2 W/kg has been set as the highest value for localized exposure from cell phone (ICNIRP 1998). However, the SAR from a cell phone varies with a range from about 0.0001 to 2W/kg. The diversification appears due to the several elements of SAR value such as the output power of the phone, phone model, positioning of the phone, distance between the phone and the exposed tissues and network properties (Auvinen et al., 2006).

Researchers have suggested several ways to reduce SAR such as using hands-free devices to keep radiofrequency sources away from the head, by minimizing exposure by reducing the number and duration of phone calls (Thomee et al., 2011; Saravanan & Scarfi 2014; Silva et al., 2015).

2.4 Cell phone use and human health

Several epidemiological studies have been published reporting the effect of cell phone use on human health. Most studies have focused on tumor risk such as glioma, meningioma, acoustic neuroma, pituitary tumor and few on leukemia, lymphoma, salivary gland tumors, testicular cancer, intra-temporal facial nerve tumor and skin cancer. Majority of the studies have also examined non-specific symptoms such as headache, nausea, sleep disturbances, stress, anxiety, and loss of memory.

There are three large epidemiological studies: Interphone Study, The Danish Study and the Million Women Study, which have examined the possible association between cell phone use and cancer. INTERPHONE study is the largest case-control study, initiated in 2000 in 13 different countries to determine whether the radiofrequency energy emitted by mobile phones increase the risk of brain tumors. The INTERPHONE study, reported a reduced odds ratio for glioma (OR 0.81; 95% CI: 0.70–0.94), meningioma (OR 0.79; 95% CI: 0.68–0.91) and acoustic neuroma (OR 0.85; 95% CI: 0.69–1.04) between ever having been a regular mobile phone user and a never regular user. There were warnings of an

increased risk of glioma in the temporal lobe than any other lobes of the brain at the maximum exposure levels. (The Interphone Study Group 2010).

A large nationwide cohort study (The Danish Study) using a retrospective cohort of Danish mobile phone subscribers investigated cancer risk using billing information for more than 358,000 cell phone subscribers during 1982-1995. During 21 years follow-up, this study found no association between cell phone use and the incidence of glioma, meningioma or acoustic neuroma among both short-term or long-term users. (Johansen et al., 2001; Frei et al., 2011).

In the large prospective study of middle-aged UK women, the Million Women Study, self-reported cell phone use was not associated with an increased risk of glioma, meningioma or non-central nervous system tumors. However, an increased risk (RR 1.88, 95% CI: 1.14–3.11) was found for acoustic neuroma among long-term cell phone users (> 5 years). However, this significantly elevated risk among long-term users remained unjustified. (Benson et al., 2013).

A meta-analysis to evaluate the brain tumor risk among long-term users with 2 cohort studies and 16 case control studies found a consistent pattern of increased risk especially for ipsilateral exposure, acoustic neuroma (ORs 2.4;95% CI 1.15-3.3) and for glioma (ORs 2;95% CI 1.2-3.4). (Hardell et al., 2007).

The Surveillance, Epidemiology and End Results (SEER) program which collects long-term population-based incidence data in the United States indicated that despite of the sharp increase in the number of cell phone users in the U.S between 1987 and 2008, the overall age-adjusted incidence of brain cancer did not increase (Inskip et al., 2010). Similar findings have been noted from the Nordic countries (Deltour et al., 2009; Deltour et al., 2012).

There are large number of studies investigating potential non-cancer effects of cell phone exposure. Most researched areas are the cognitive functions (Thomas et al., 2010; Sauter et al., 2011; Hareuveny et al., 2011), psychiatric symptoms (Silva et al., 2015), sleep quality (Sahin et al., 2013; Exelmans & Van den Bulck 2016; Danker-Hopfe et al., 2016), fertility and sexual function (Agarwal et al., 2008; Yildirim et al., 2015), auditory changes

(Huang et al., 2008; Kwon et al., 2010; Sevi et al., 2014), physiological changes (Parkar et al., 2010), musculoskeletal disorders (Gustafsson et al., 2015), infertility (Merhi 2012), and oral mucosal changes (Gandhi & Singh 2005; Yadav & Sharma 2008; Hintzsche & Stopper 2010) . There are huge discrepancies on the association between cell phone exposure and these health effects.

3 AIMS AND RESEARCH QUESTIONS

The aim of this study is to review the recent literature based on cell phone use and health risks among adults, to explore adverse health effects of using cell phones, to develop awareness regarding health hazards and to summarize available precautionary measures to minimize health risks.

The study aims at answering following two questions:

1. What are the health risks associated with cell phone exposure?
2. How can cell phone users minimize the risks associated with its exposure?

4 RESEARCH METHODOLOGIES

In order to provide latest information and summarize the available health risks associated with mobile phone use, the author decided to choose the literature review as a suitable method. Literature review was conducted on the basis of web based materials. The review was based on scientifically published articles by accredited scholars and researchers. Author has studied all the selected previous literature in a systematic manner. In addition, strict inclusion and exclusion criteria were set to avoid bias in selecting studies.

4.1 Overview of a Literature Review

A literature review is a process of reviewing available literatures related to the topic in order to critically evaluate the previous research. Boswell and Cannon (2014) have defined literature review as an analytical summary of specific research findings related to the particular study subjects. Fink (2010) stated that a literature review is an efficient and explicit method to assess and identify the existing body of completed work by researchers and scholars.

There are different types of literature review. One of them is scoping review which is quite similar to systematic review. The key difference is that scoping review is more flexible than systematic review as there are no restrictions on the materials resourced and scoping review tend to address broader topics. This thesis is based on scoping literature review. According to Colquhoun et al. (2014), “A scoping review or scoping study is a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge”. Arksey and O’Malley (2005) have provided a framework for conducting a scoping review. It includes five different stages which are precisely followed by the author during reviews

- Identifying the research question
- Finding relevant studies
- Selecting studies that are relevant to research question
- Charting information from the relevant studies and

- Collating, summarizing and reporting the results.

4.2 Inclusion and Exclusion Criteria

Author performed literature search on the basis of established inclusion and exclusion criteria. These criteria helped author to select or eliminate articles and to conduct this study effectively. Those articles that met the inclusion criteria were chosen for the study and those not meeting the inclusion criteria were excluded from this study. The following Table 1 shows the inclusion and exclusion criteria in detail.

Table 1. *Inclusion and Exclusion Criteria*

Inclusion Criteria	Exclusion Criteria
Articles published from 1/1/2010 to 10/1/2017	Articles published before 1/1/2010
Articles are completely in English language	Articles are in other languages
Articles with mobile phone exposure and health outcome	Articles related to mobile phone but not health outcome
Original articles	Review articles
Human studies related to mobile phone	Animal studies
Health risks other than unsafe driving and interference with medical devices.	Established risk factors for mobile phone use (unsafe driving and interference with medical devices).
Adult (19+ years)	Children

4.3 Data Collection

Data were collected using Arcada’s “Libguides” program in order to access electronic databases. The author conducted a literature search on the basis of a number of criteria. Review of literature was carried out using National Library of Medicine (Pubmed) <https://www.ncbi.nlm.nih.gov/pubmed/>, Science Direct <http://www.sciencedirect.com/>

and Academic Search Elite (EBSCO) <https://www.ebscohost.com/academic/academic-search-elite> .

In PubMed, search terms were defined as medical subject terms (MeSH) which included “Cell Phone” or “Wireless technology” and “adverse effects” and “prevention” or “precautionary principles”. In advanced search, the MeSH terms were combined. The author obtained 1053 articles. Search was further filtered according to the date of publication (1/1/2010 - 10/1/2017), the language of the article (English), and the age group (Adult 19+ years). Now, the articles count decreased to 211. Author went through the titles and selected 90 articles. Screening was further done on the basis of abstract. Author identified 41 articles, out of which author found 10 full text articles which were included for data analysis. This whole process has been shown in Figure 1 below.

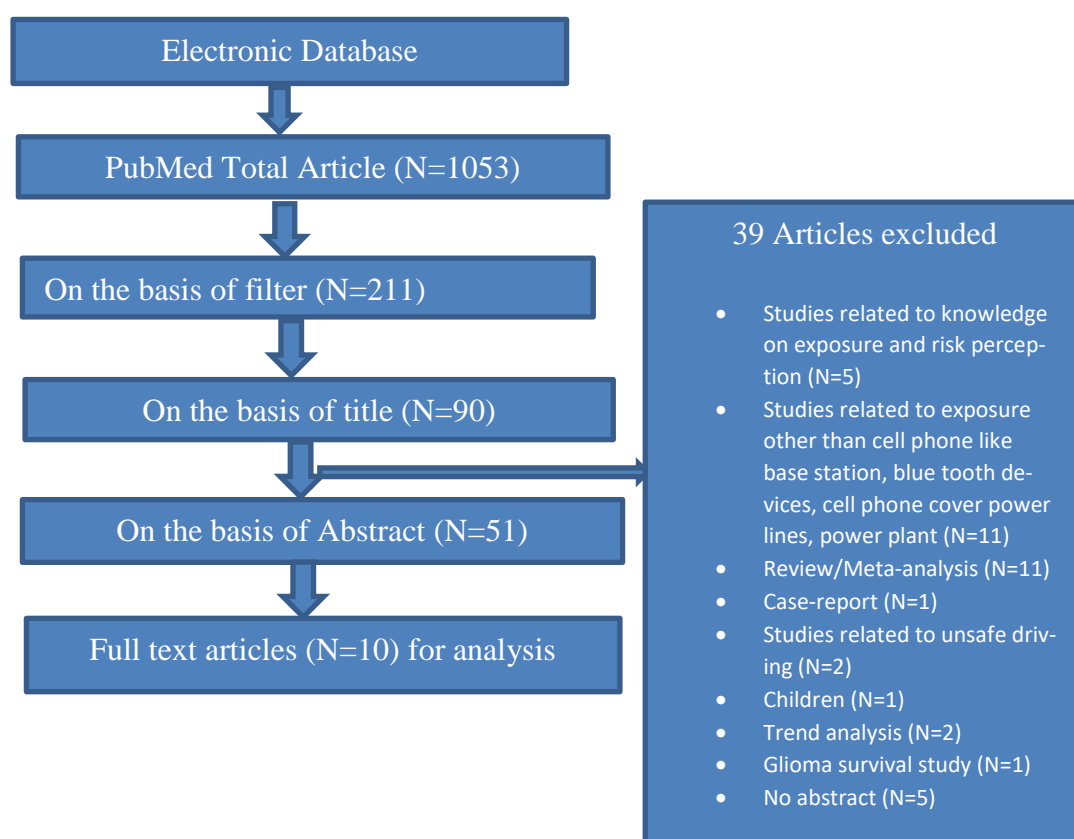


Figure 1. PRISMA flow diagram for data collection from PubMed

In another database; Science Direct, the keywords used were ‘cell phone’ or ‘mobile phone’ or ‘mobile phone technology’ in combination with ‘adverse health effects’ and “prevention”. It produced 6603 articles. After applying filter, 1193 articles were obtained. On the basis of title, 12 articles were selected. The author went through the abstract and identified 7 articles out of which 3 full text articles were selected for analysis. Figure 2 shows the article search process from Science Direct clearly.

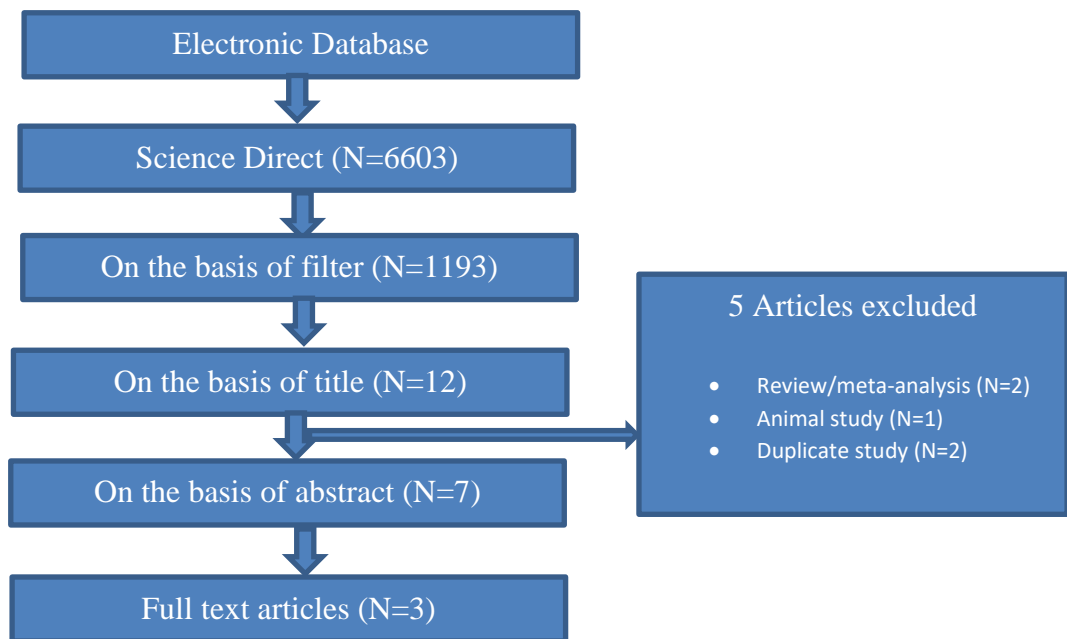


Figure 2. PRISMA flow diagram for data collection from Science Direct

Additional search was done in Academic Search Elite (EBSCO). The Boolean/phrase “cell phone” AND “health effects” AND “prevention” were used. The database produced 202 articles. After filtering with date, 116 articles were obtained. On the basis of title, 19 articles were selected. Author screened abstract and found 4 full text articles meeting inclusion criteria.

Figure 3 shows the article search process from EBSCO.

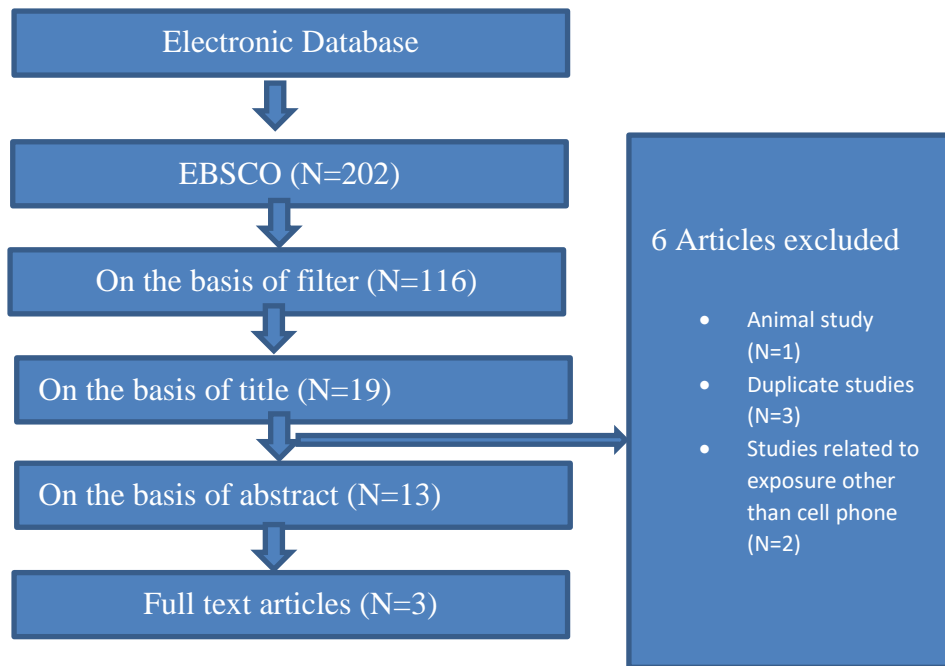


Figure 3. PRISMA flow diagram for data collection from EBSCO

Contents of the total 17 research articles that were retrieved for the literature review are summarized in Appendix 1 (See Appendix 1 for detailed information). The contents of the research articles are divided into different categories which include author, year, title, study design, study aim, and main findings.

4.4 Data analysis

Data analysis has been done with a goal to organize and manage data and discover useful information. Author has used content analysis to analyze data and gather a meaningful evidence. Several definitions of content analysis are available. According to Hsieh & Shannon (2005), content analysis is a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns. Krippendorff (2013), defined content analysis as:

“A scientific tool that provides new insights, increases researcher’s understanding of particular phenomena, or informs practical actions. Further, it has been taken as a research technique for making replicable and valid inferences from texts to the context of its use.”

Content analysis may be used either with quantitative data or qualitative data. There are two different approaches; inductive and deductive. Inductive content analysis includes open coding, creating categories and abstraction. Open coding means writing heading and texts to describe all aspects of contents. After open coding, categories are created and lists of category are grouped under higher order headings reducing the number of categories by collapsing the similar categories under same broader heading. Abstraction formulates a general description of the research topic through generating categories which continues as far as possible. A deductive approach is used if the aim is to test an earlier theory in a different situation or to compare categories at different time periods. Both the inductive and deductive approaches consist of three phases: preparation, organizing and reporting. The preparatory phase consists of collecting suitable data for analysis and selecting the unit of analysis which can be a word or a theme. The second phase is different in inductive and deductive approach. In inductive approach, organization phase includes open coding, creating categories and abstraction whereas in deductive approach, the organization phase includes categorization matrix development. In the last phase, results are reported by the content of the categories using either inductive or deductive approach. (Elo & Kyngäs 2008).

Author has used inductive content analysis in this study. Data were gathered from selected research articles. Previous assumptions and theories had nothing to do with the outcomes. Preparatory phase began by selecting appropriate key words guided by the aim and research question of the study. After the selection of key words, searches were made in

three different databases. Articles were filtered on the basis of inclusion and exclusion criteria.

Then data were organized by using open coding process. Each article was provided with a particular number as [1], [2], [3],.... [16], [17]. The given number represented articles when referencing in the text. The next steps were clustering and abstraction to reduce the collected data in to different categories. To achieve these categories and not to miss any important information, the articles were read several times. All the information about health risks and precautionary measures were identified and listed. Higher categories were formed for similar contents. Similar outcomes were put on the same heading to reduce the number of categories. Following figure illustrates the process of creating main category:

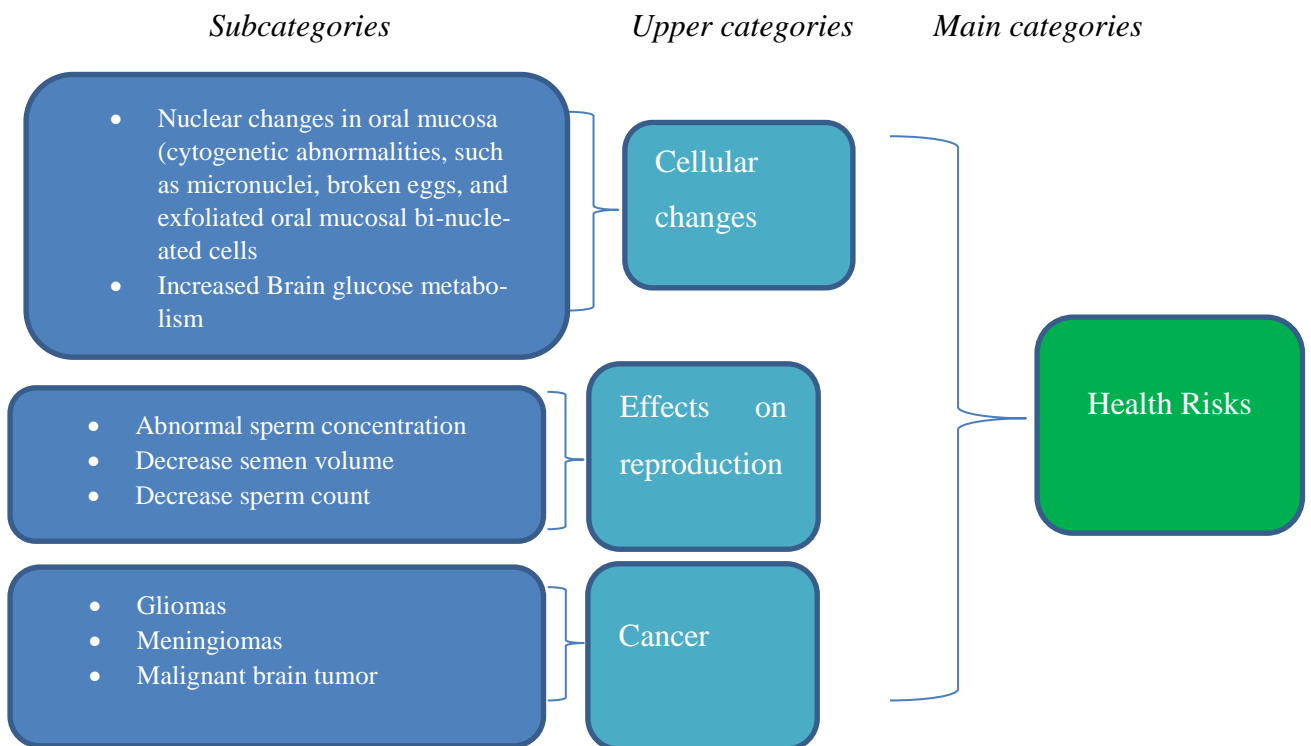




Figure 4. Illustrating the data analysis process

Author has followed the checklist to improve the trustworthiness of a content analysis during all phases (Elo et al., 2014) (See Appendix 2).

4.5 Ethical considerations

The International Centre for Nursing Ethics (ICNE 2003) has given five broad principles for the ethical conduct of International nursing research: respect for persons, beneficence, justice, respect for community and contextual caring. This thesis is based on the literature review. It means author did not have any direct connections with the study participants, which ensures no harm to the study participant during this study. Most of the articles used for this thesis reported having ethical approval by a committee and participant consent. Author has taken into account those articles which has taken ethical considerations. Author has shown respect to the articles and the author of the articles by quoting, referencing accurately. In the referencing section, all the author that were involved in the publication of the article were acknowledged by providing their names. The aim of this study is to explore the health risks associated with cell phone use and communicate the results to minimize growing public concern. Thus, the principle of beneficence is maintained. To avoid plagiarism, author has worked hard to describe things in her own words. Moreover, the author had no conflict of interest in production of this thesis.

4.6 Validity and reliability

Patton (2001) states that validity and reliability are two factors that the qualitative researcher should be aware of while designing, analyzing, interpreting and judging the quality of study.

Validity of the study was ensured as all the articles included in the content analysis correctly answered research question. The reliability of this study was ensured by utilizing up-to-date and recent studies published between 2010 and 2017. This was achieved by limiting the date of publication. In addition, author has used only scientifically published reliable articles from different scientific databases according to the established inclusion and exclusion criteria. Once the articles were selected, author read thoroughly to identify the relevance in terms of contents and findings.

5 RESULTS

In this chapter the findings of this study is presented. It describes the results from literature review.

5.1 Selection of studies

In total, 17 full text articles (10 from PubMed, 4 from EBSCO and 3 from Science Direct) were identified for the study. Thereof, 8 were cohort studies, 4 were experimental, 2 were case-control and 3 were cross-sectional study. The majority of the studies examined non-specific symptoms. All of the 17 articles answer the first research question ‘What are the health risks associated with cell phone exposure?’ But, second research question ‘How can cell phone users minimize the risks associated with its exposure?’ are not addressed by all of the publications. However, most of the articles have mentioned to follow the precautions to minimize risks but have not discussed those measures in detail.

The results of the study are presented on the basis of categories identified. Content analysis process resulted five major themes for the first research question. They were cellular changes, effects on reproduction, cancer, psychiatric symptoms and subjective symptoms.

5.2 Health risks from cell phone exposure

5.2.1 Cellular changes

Among 17 unit of analyses, two [2, 12] reported the effect of cell phone use on cellular level. The study [2], evaluated the effect of acute cell phone exposure on brain glucose metabolism. It provided evidence that the human brain is sensitive to the effects of acute cell phone exposure. Increased brain glucose metabolism in areas next to the antenna on a prolonged use of 50 mins or more was found. However, the increase in the activity was small (approximately 10%), and its clinical significance is not known. The exact mechanism underlying these effects are still under investigation.

Another study [12], evaluated the effects of exposure in epithelial cells of the oral mucosa. Cells were obtained from anatomical sites with the highest incidence of oral cancer: lower lip, border of the tongue, and floor of the mouth. A slightly increase in the number of micro-nucleated cells in the lower lip and in bi-nucleated cells on the floor of the mouth was observed in individuals who used their phones more than 60 minutes/week. An increased number of broken eggs in the tongue of individuals owning a cell phone for longer years were also noted.

5.2.2 Effects on reproduction

These recent publications [13] [15], investigated the effects of cell phone use on semen parameters. The study [13], included 106 male patients who underwent a first-time semen analysis as a part of infertility workup. They completed a detailed questionnaire regarding cell phone usage. Data regarding the use of hand free devices and ear phones were also collected. Semen quality was assessed using WHO 2010 criteria (volume ≥ 1.5 ml, concentration $\geq 15 \times 10^6$ /ml, progressive motility $\geq 32\%$ and $\geq 4\%$ of normal morphology). Talking on a cell phone for more than one hour per day or while it is being charged was associated with an elevated rate of abnormal sperm concentration. The study also found that participants who constantly carry the device at a distance less than 50cm from the groin were found to have a higher rate of abnormal sperm concentration.

Another similar study [15], screened 794 men for the cell phone information. Semen samples were collected and analyzed according to the WHO 2010 criteria as in the previous study. The study revealed that, the sperm concentration decreased by an average of 6.32% [95% confidence interval (CI), -11.94 to -0.34] per unit increase in the daily duration of talking. Similarly, the total sperm count and semen volume declined with increasing cell phone use.

5.2.3 Cancer

Exposure effects on cancer were investigated in four studies [4] [6] [7] [8]. Out of those four studies, three [6] [7] [8], are about brain tumor and one [4] about skin cancer. One study [6], have evaluated the risk among long-term mobile users (>10 years). Exposure assessment was based on self-reported questionnaire. The study found slightly increased risk of brain tumors among cell phone users (OR 1.7, 95% CI: 1.01-2.7). In contrast, the large prospective study [7], showed no association between cell phone use and glioma (>10 years: RR= 0.78, 95% CI: 0.55–1.10), meningioma (>10 years, RR= 1.10, 95% CI: 0.66–1.84). However, an increased risk of acoustic neuroma (RR= 2.46, 95% CI: 1.07–5.64), among long term users were found with risk increasing with increasing duration of exposure. Another multicenter case-control study [8], did not find any association with brain tumors and mobile phone use (OR=1.24, 95% CI: 0.86- 1.77 for gliomas, OR=0.90, 95% CI: 0.61-1.34 for meningiomas). However, the positive association was statistically significant in the heaviest users (OR=2.89, 95% CI: 1.41-5.93 for gliomas; OR=2.57, 95% CI: 1.02-6.44 for meningiomas). Apart from brain tumor, one study [4] has examined the risk of skin cancer among cell phone users. In this nation wide cohort study based on objective exposure data and outcome data from high-quality prospective registers, no overall increased risk for skin cancer was found.

5.2.4 Effect on musculoskeletal system

Two studies [14] [16] investigated the effect of cell phone use on musculoskeletal system. More specifically, [14] studied the effect of various cell phone functions such as texting, talking, listening to music on postural stability. Postural stability was assessed according

to Biodex Balance System SD. The study has shown that postural stability was significantly worse during texting as compared to talking and listening music increasing individual risks for fall and musculoskeletal injuries.

Another study [16] examined whether text messaging increases musculoskeletal disorders in the neck and upper extremities. Information about perceived symptoms were collected by asking if the subjects have pain in the upper part of the back/neck, in the shoulder/arms/wrists/hands or numbness/tingling in the hand/fingers. The study found that there were associations between text messaging and reported skeletal pain. Among men pain in the back and neck, shoulder and upper extremities, numbness/tingling in hands and fingers were significantly associated with higher texting (OR= 2.3, 95% CI: 1.60-3.27), (OR= 2.1, 95% CI: 1.43-2.98), (OR= 1.9, 95% CI: 1.10-3.22) respectively. Similar association was seen among women.

5.2.5 Other non-specific symptoms

Out of 17 studies, 7 studies have evaluated the effect of cell phone exposure on non-specific symptoms. Of all; symptoms of depression, sleep disturbances, stress and headache were most often investigated. The study [11] found that those having more than one mobile phone device was associated with depressive symptoms. For screening symptoms of depression, the Center for Epidemiological Studies Depression Scale (CES-D) was used. In addition, using two or more chips (OR=1.49, 95% CI: 1.07-2.08) and never turning the cell phone off while asleep (OR=2.08, 95% CI: 1.31-3.31) were associated with anxiety. Using the mobile phone with weak signal coverage (OR= 2.74, 95% CI: 0.81-9.30) was associated with diagnosis of anxiety and irritability. Another similar study [3] in a prospective cohort of young adults revealed that frequent mobile phone use was associated with stress (for men, prevalence ratios (PRs) =1.9, 95% CI: 1.42-2.54; for women, PRs=1.2, 95% CI: 1.07-1.45), sleep disturbances (for men, PRs =1.7, 95% CI: 1.40-2.19; for women, PRs=1.4, 95% CI: 1.21-1.56), and symptoms of depression (for men, PRs =1.3, 95% CI: 1.02-1.58; for women, PRs=1.06, 95% CI: 1.06-1.34). In this study, stress was defined as a situation when a person feels tense, restless, nervous, or anxious or is unable to sleep at night because his/her mind is troubled all the time. Sleep disturbances meant insomnia, fragmented sleep and premature awakening. Symptoms of

depression was obtained by two items: little interest/pleasure in doing things and feeling down/depressed/hopeless.

Another study [1] aimed to investigate the association between cell phone exposure and non-specific symptoms and tinnitus. Regarding near field exposure, self-reported mobile use as well as mobile phone operator data were collected for 1375 randomly selected participants. The researchers did not observe any association between cell phone use, tinnitus and non-specific symptoms.

Prospective cohort study [5] with 955 study participants investigated whether sleep quality is affected by cell phone use. Sleep quality and daytime sleepiness was assessed by means of standardized questionnaires. Mobile phone data were obtained from mobile phone operators. There was no any consistent increase in self-reported daytime sleepiness or sleep disturbances even if exposure at baseline was high.

Study with 26 adults and 26 teenagers [9] were simultaneously investigated by measuring changes in heart rate, respiration rate, HRV, eight subjective symptoms (throbbing, itching, warmth, fatigue, headache, dizziness, nausea, and palpitation) in exposure sessions to verify its effects on adults. The study reported no evidence of physiological changes or any of the eight subjective symptoms.

In contrast, another study [10] assessing the subjective symptoms has shown that the mobile phone users may experience subjective symptoms, depending on the intensity of mobile use. The participants reported headache, memory loss and warmth behind ear if they use mobile phone longer than 30 min/day. Most symptoms disappeared within 2 hours after call, but 26% of the subjects reported continuous headache, persisting for longer than 6 hours since the end of a call.

Another study [17] analyzed the associations between mobile phone call frequency and duration with non-specific symptoms. Exposure assessment was based on face-to-face interview. Health effects were measured by Headache Impact Test-6 (HIT6), Psychosocial Well-being Index-Short Form, Beck Depression Inventory, Korean-Instrumental Activities of Daily Living, Perceived Stress Scale (PSS), Pittsburgh Sleep Quality Index,

and 12-item Short Form Health Survey where a higher score represented greater health effect. This study showed that there was a significant positive correlation between the average duration of phone call and the severity of headaches, but was not significantly associated with stress, sleep, cognitive function, or depression.

5.3 Precautionary measures to minimize risk

Out of 17 articles included in data analysis, only five [3] [11] [13] [15] [16] articles have mentioned the precautionary approach to reduce risk associated with cell phone exposure. Article [3] stated that it is very important to provide information and advice among adults to set limits for own and others' accessibility of mobile phone. Article [11] suggested to reduce the time per day spent on mobile phone calls, avoid using the mobile phone with weak signal coverage, refrain from keeping the mobile phone close to the body, use ear-phones or pop phones, avoid mobile phone use by children, use the hardwire landline phone whenever possible, avoid residing or working within 200m of mobile phone base stations. Article [13] recommended to avoid talking while the phone is being charged, to reduce the total time of conversations, to turn off devices while charging or, if not possible, to keep the device at least 50 cm from the groin during daily activities and while sleeping. Users are advised to carry the device a distance from the groin, for example in the shirt pocket, and to talk using earphones or to use a speaker whenever possible. Article [15] advised to avoid extensive use of cell phone. And article [16], focused to spread information about the risks, ergonomic recommendations about good technique of mobile use through school health, primary care, and occupational health service.

6 DISCUSSION

The aim of this study was to explore the health risks associated with cell phone exposure. The review demonstrates that cell phone use might lead to the cellular changes, cancer, psychiatric symptoms, musculoskeletal disorders, infertility and other non-specific symptoms. Another aim was to identify preventive measures to minimize the risk. Studies have suggested several precautionary measures to reduce the possible risk such as reducing calling time, avoiding call during weak signal coverage, keeping phone away from the body, using landline phone whenever possible, avoiding phone calls when charging, using hand-free devices/ear phone, turning off devices while sleeping, spreading health risk information through various ways and to consider ergonomic principles while texting.

The literature on the effect of cell phone on oral mucosa has been contradictory. Gandhi & Singh (2005); Yadav & Sharma (2008) found a positive correlation between the numbers of micronuclei and increasing exposure to cell phone radiation, on the other hand Hintzsche & Stopper (2010) did not find any association, however, this study reports a slight increase of broken eggs with greater exposure. As per the knowledge of the author, [2], is the first investigation about brain glucose metabolism, hence any conclusion can't be derived from this single study. A number of recent reports [13] [15] have suggested a possible link between cell phone use and infertility. Meanwhile, review studies about cell phone impact on reproductive physiology indicate highly diverse and inconsistent outcome (Merhi 2012). Addressing growing public concern, large number of studies have investigated the effect of cell phone exposure on brain tumor, as cell phones are held very close to the head and neck. The INTERPHONE study (Wild 2011) indicates no overall increase in the glioma and meningioma, which is consistent to the finding in this review for two selected studies [7] [8], however uncertainty remained for long term users. A large number studies have attempted to assess the non-specific symptoms as a consequence of cell phone exposure [1] [3] [5] [9] [10] [17]. The reported association did not show a consistent pattern. Two studies [14] [16], have focused on mobile phone use rather than exposure to electromagnetic radiation and found that cell phone use increases pain in the back, neck, shoulder, hand and fingers with higher number of texting. Exposure assessment in the majority of the studies was based on self-reported questionnaire except very

few depending on the mobile operator data. Hence, the possibility of recall bias is higher while collecting data from study participants.

The articles included in this study use variety of methodological approach, few are case-control, some are cross-sectional, some are experimental and majority are cohort studies. In research methodology, cohort studies are always expected to provide robust results. In this sense, the findings from this review are logical. Another strength of the study is the selection of scientific literatures on the basis of strict inclusion and exclusion criteria. The author herself conducted literature search, extracted data and created themes. The findings were reported without bias.

Not to ignore, this study has several limitations. This study reviewed those articles published between 2010 and 2017, older articles were excluded regardless of their significance to this study. Articles chosen were limited to English texts, articles that could be accessed freely were only included in the study. Relevant and valuable articles could have been left out because of these reasons. Author has selected just 17 articles which can't represent studies about health risks and cell phone use, and the findings could not be generalized. Selection of search keyword might be another limitation. Despite those limitations, this study has successfully answered the research questions.

7 CONCLUSION

In conclusion, this review indicate a positive association between cell phone exposure and brain activity, reproduction, musculoskeletal disorders but the findings are inconsistent for brain tumors and non-specific symptoms. The review indicates that cell phone exposure does not cause skin cancer. The absence of evidence of harm does not necessarily be interpreted as no harm, because this review included just 17 articles and it is not possible to reach to conclusion with such limited numbers of articles. Given the inconsistency in findings, additional studies are required to clarify the association. Prospective studies would be of benefit to clarify it. Overall evaluations show that the evidence for any association is unconvincing, therefore prevention seems the best approach.

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9 APPENDICES

Appendix 1. List of selected articles

S/No	Author Year and Title	Study Design	Study Aim	Main findings
[1]	(Frei et al., 2011) <i>'Cohort study on the effects of everyday life radiofrequency electromagnetic field exposure on non-specific symptoms and tinnitus'</i>	Cohort study	To investigate the association between RF-EMF exposure and non-specific symptoms and tinnitus	The researchers did not observe any association between cell phone use, tinnitus and non-specific symptoms.
[2]	(Volkow et al., 2011) <i>'Effects of cell phone radiofrequency signal exposure on brain glucose metabolism'</i>	Experimental	To evaluate if acute cell phone exposure affects brain glucose metabolism, a marker of brain activity	Increased brain glucose metabolism in areas next to the antenna on a prolonged use of 50 mins or more was found. However, the increase in the activity was small (approximately 10%)
[3]	(Thomee et al., 2011) <i>'Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults- a prospective cohort'</i>	Prospective Cohort Study	To investigate whether there are associations between psychosocial aspects of mobile phone use and mental health symptoms in a prospective cohort of young adults	Frequent mobile phone use was associated with stress (for men, prevalence ratios (PRs)=1.9, 95% CI: 1.42-2.54; for women, PRs=1.2, 95% CI: 1.07-1.45), sleep disturbances (for men, PRs =1.7, 95% CI: 1.40-2.19; for women, PRs=1.4, 95% CI: 1.21-1.56), and symptoms of depression (for men, PRs =1.3, 95% CI: 1.02-1.58; for women, PRs=1.06, 95% CI: 1.06-1.34).
[4]	(Poulsen et al., 2012)	Cohort Study	To examine the association between skin cancer and mobile phone use	No overall increased risk for skin cancer was found

	<i>'Mobile phone use and the risk of skin cancer: A Nationwide Cohort Study in Denmark'</i>			
[5]	(Mohler et al., 2012) <i>'Exposure to radiofrequency electromagnetic fields and sleep quality: A Prospective Cohort Study'</i>	Prospective Cohort Study	To investigate whether sleep quality is affected by mobile phone use or by other RF-EMF sources in the everyday environment	There was no any consistent increase in self-reported daytime sleepiness or sleep disturbances even if exposure at baseline was high.
[6]	(Hardell et al., 2013) <i>'Case-control study of the association between malignant brain tumors diagnosed between 2007 and 2009 and mobile and cordless phone use'</i>	Case-control Study	To explore the relationship between especially long-term (>10 years) use of wireless phones and the development of malignant brain tumours.	The study found slightly increased risk of brain tumors among cell phone users (OR 1.7, 95% CI: 1.01-2.7).
[7]	(Benson et al., 2013) <i>'Mobile phone use and risk of brain neoplasms and other cancers: prospective study'</i>	Prospective Cohort study	To examine the association between mobile phone use and incidence of intracranial central nervous system tumours	The study no association between cell phone use and glioma (>10 years: RR= 0.78, 95% CI: 0.55–1.10), meningioma (>10 years, RR= 1.10, 95% CI: 0.66–1.84). However, an increased risk of acoustic neuroma (RR= 2.46, 95% CI: 1.07– 5.64), among long term users were found with risk increasing with increasing duration of exposure
[8]	(Coureau et al., 2014) <i>'Mobile phone use and brain tumours in the CERENAT case-control study'</i>		To analyse the association between mobile phone exposure and primary central nervous system tumours (gliomas and meningiomas) in adults.	No association with brain tumors and mobile phone use (OR=1.24, 95% CI: 0.86- 1.77 for gliomas, OR=0.90, 95% CI: 0.61-1.34 for meningiomas) was

				found. However, the positive association was statistically significant in the heaviest users (OR=2.89, 95% CI: 1.41-5.93 for gliomas; OR=2.57, 95% CI: 1.02-6.44 for meningiomas).
[9]	(Choi et al., 2014) <i>'Effects of short-term radiation emitted by WCDMA mobile phones on teenagers and adults'</i>	Experimental	To test whether RF-EMFs affected heart rate, respiration rate, and HRV, or gave rise to subjective symptoms in adults and teenagers	The study reported no evidence of physiological changes or any of the eight subjective symptoms (throbbing, itching, warmth, fatigue, headache, dizziness, nausea, and palpitation).
[10]	(Szyjkowska et al., 2014) <i>'The risk of subjective symptoms in mobile phone users in Poland-an epidemiological study'</i>	Cross-sectionoanl	To assess the type and incidence of subjective symptoms related to the use of mobile phones in Polish users	The participants reported headache, memory loss and warmth behind ear if they use mobile phone longer than 30 min/day. Most symptoms disappeared within 2 hours after call, but 26% of the subjects reported continuous headache, persisting for longer than 6 hours since the end of a call.
[11]	(Silva et al., 2015) <i>'Exposure to non-ionizing electromagnetic radiation from mobile telephony and the association with psychiatric symptoms'</i>	Cross-sectional study	To investigate the association between exposure to non-ionizing electromagnetic radiation from mobile phone base stations and psychiatric symptoms	Those having more than one mobile phone device was associated with depressive symptoms, using two or more chips (OR=1.49, 95% CI: 1.07-2.08) and never turning the cell phone off while asleep (OR=2.08, 95% CI: 1.31-3.31) were associated with

				anxiety. Using the mobile phone with weak signal coverage (OR= 2.74, 95% CI: 0.81-9.30) was associated with diagnosis of anxiety and irritability.
[12]	(Daroit et al., 2015) <i>'Cell phone radiation effects on cytogenetic abnormalities of oral mucosa cells'</i>	Experimental	To evaluate the effects of exposure to cell phone electromagnetic radiation on the frequency of micronuclei, broken egg cells, binucleated cells and karyorrhexis in epithelial cells of oral mucosa	A slightly increase in the number of micro-nucleated cells in the lower lip and in bi-nucleated cells on the floor of the mouth was observed in individuals who used their phones more than 60 minutes per week. An increased number of broken eggs in the tongue of individuals owning a cell phone for longer years were also noted.
[13]	(Zilberlicht et al., 2015) <i>Habits of cell phone usage and sperm quality-does it warrant attention?</i>	Experimental	To investigate an association between characteristics of cell phone usage and semen quality	Talking on a cell phone for more than one hour per day or while it is being charged was associated with an elevated rate of abnormal sperm concentration. The study also found that participants who constantly carry the device at a distance less than 50cm from the groin were found to have a higher rate of abnormal sperm concentration.
[14]	(Rebold et al., 2016) <i>'The impact of different cell phone functions and their effects on postural stability'</i>	Experimental	To assess the effects of different cell phone functions on postural stability	The study has shown that postural stability was significantly worse during texting as compared to talking and listening music

				increasing individual risks for fall and musculoskeletal injuries.
[15]	(Zhang et al., 2016) <i>'Effects of cell phone use on semen parameters: Results from the MARHCS cohort study in Chongqing, China'</i>	Cohort study	To investigate effects of cell phone use on semen parameters in a general population	The study revealed that, the sperm concentration decreased by an average of 6.32% [95% confidence interval (CI), -11.94 to -0.34] per unit increase in the daily during of talking. Similarly, the total sperm count and semen volume declined with increasing cell phone use.
[16]	(Gustafsson et al., 2016) <i>'Texting on mobile phones and musculoskeletal disorders in young adults: A five year cohort study'</i>	Cohort Study	To examine whether texting on a mobile phone is a risk factor for musculoskeletal disorders in the neck and upper extremities in a population of young adults.	The study found that there were associations between text messaging and reported skeletal pain. Among men pain in the back and neck, shoulder and upper extremities, numbness/tingling in hands and fingers were significantly associated with higher texting (OR= 2.3, 95% CI: 1.60-3.27), (OR= 2.1, 95% CI: 1.43-2.98), (OR= 1.9, 95% CI: 1.10-3.22) respectively. Similar association was seen among women.
[17]	(Chao et al., 2016) <i>'A cross-sectional study of the association between mobile phone use and symptoms of ill health'</i>	Cross-sectional study	To analyze the associations between mobile phone call frequency and duration with non-specific symptoms	This study showed that there was a significant positive correlation between the average duration of phone call and the severity

				of headaches, but was not significantly associated with stress, sleep, cognitive function, or depression.
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Appendix 2. Checklist for Researchers Attempting to Improve the Trustworthiness of a Content Analysis

Phases of the content analysis	Questions asked by the author
Preparation phase	<ul style="list-style-type: none"> • How do I collect the most suitable data for my content analysis? • Is this method the best available to answer the target research question? • What is the unit of analysis? • Is the unit of analysis too narrow or too broad?
Organization phase	<ul style="list-style-type: none"> • How should the concepts or categories be created? • Is there still too many concepts? • Is there any overlap between categories?
Reporting phase	<ul style="list-style-type: none"> • Are the results reported systematically and logically? • Is the content and structure of concepts presented in a clear and understandable way? • How well do the categories cover the data? • Are there similarities within and differences between categories? • Is scientific language used to convey the results?

(Adopted from Elo et al., 2014)