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NON-COMMUNICABLE DISEASES AND COMMON RISK FACTORS IN THE COHORT STUDY OF MOBILE PHONE USE AND HEALTH

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TIIVISTELMÄ

SUSANNA LANKINEN: SUURET KANSANTAUDIT JA NIIDEN RISKITEKIJÄT MATKAPUHELIMEN KÄYTTÄJIEN SEURANTATUTKIMUKSESSA

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Matkapuhelinten ja erityisesti niiden radiotaajuuksisen sähkömagneettisen säteilyn terveyshaittoja on tutkittu laajalti sekä kokeellisesti että väestötasolla. Tutkimuksissa on kuitenkin paljon puutteita ja toistettavaa osoitusta haitallisista terveysvaikutuksista ei ole saatu. Tämän tutkimuksen tavoite oli selvittää laajan matkapuhelimen käyttäjien seurantatutkimuksen kansanterveydellisiä sekoittavia tekijöitä eri puheluaikaryhmissä.

Tutkittavat (8 104) olivat TeliaSoneran ja Elisan yksityisasiakkaita iän ja sukupuolen mukaan ositetusta otannasta seurantatutkimuksen lähtötilanteesta. Heidät jaettiin altistusryhmiin (alle 50%, 50–74%, 75–89% ja yli 90%) operaattoreilta saadun puheajan mukaan ja tiedot aiemmista diagnooseista, lääkityksestä, elintavoista ja sosioekonomisesta asemasta saatiin kyselylomakkeesta.

Korkeimman desiilin puheaikaryhmällä oli selvästi suurentunut riski sepelvaltimotautiin (OR 1.79, CI 1.17–2.75), astmaan (OR 1.70, CI 1.15–2.52), masennukseen (OR 1.43, CI 1.16–1.76) ja verenpainetautiin (OR 1.31, CI 1.09–1.58). Samanlaiset tulokset saatiin myös verenpainelääkkeistä ja masennuslääkkeistä. Syövän, tyypin 2 diabeteksen ja kohonneen kolesterolin vallitsevuus kasvoi puheajan kasvaessa, mutta ei tilastollisesti merkitsevästi. Merkittäviä eroja ei löytynyt keuhkoahtaumataudin vallitsevuudessa. Ylipaino (OR 1.72, CI 1.49–1.99), tupakointi (OR 1.39, CI 1.19–1.63) ja päivittäinen fyysinen aktiivisuus (OR 1.18, CI 1.01–1.39) olivat yleisempiä suuremman puheajan ryhmällä. Alkoholin käytöllä ei ollut yhteyttä puheaikaan. Paljon puhelimessa puhuvat olivat vähemmän koulutettuja (OR 0.73, CI 0.63–0.85), useammin yrittäjiä (OR 3.06, CI 2.13–4.40) ja harvemmin parisuhteessa (OR 0.57, CI 0.48–0.68) kuin vähän puhuvat. Kun altiste painotettiin matkapuhelinverkon (2G/3G) mukaan, erot altistusryhmien välillä sairauksissa, lääkityksissä ja elämäntavoissa kapenivat, mutta erot sosioekonomisessa asemassa olivat samankaltaisia kuin alkuperäisessä analyysissä.

Kansantaudit ja terveyden riskitekijät olivat yleisempiä niillä ryhmillä, joilla oli suurimmat puheajat. Tämän tutkimuksen perusteella tulevissa matkapuhelintutkimuksissa on kiinnitettävä erityistä huomiota sekoittavien tekijöiden tarkasteluun tai ne ovat aiheuttamassa harhaa.

Avainsanat: matkapuhelimen käyttö, poikkileikkaustutkimukset, radioaallot, tartuntatauteihin kuulumattomat taudit, terveyskäyttäytyminen

CONTENTS

1 INTRODUCTION

The possibility that exposure to radiofrequency electromagnetic fields (RF-EMF, 30 kHz–300 GHz) from mobile phones and other wireless devices might increase risk of adverse health outcomes has sustained an interest in both public audience and scientific community. Natural RF-EMF arises mainly from black-body radiation of lightning discharges and terrestrial objects. Modern people are exposed to RF-EMF to a greater extent than ever before, since the most significant sources are man-made: radio and television broadcasting, radars, industrial appliances such as heat-sealers, medical devices such as MRI imaging, Wi-fi devices and mobile phone base stations. However, mobile phones are the most important source of exposure to RF-EMF in everyday life. (1-3) The expansion of mobile technology has been rapid during the last decades. For example, in the EU there were approximately 1370 mobile phone subscriptions per 1000 inhabitants in 2016 (4). According to a forecast, there will be over 9 billion mobile phone subscriptions globally in 2020. (5) Finland has been one of the leading countries in mobile phone use since the 1990s, and in 2018 there were almost 6,9 million mobile subscriptions in the Finnish households alone. (6)

The health effects of RF-EMF have been studied for over two decades, motivated more by a public apprehension rather than any specific hypothesis founded on a biophysically plausible mechanism or epidemiologically proven causality. The main interests of previous studies have been biophysical effects of RF-EMF on risk of tumours, especially intracranial and haematological neoplasms. The results are predominantly negative, and reliable, repeatable evidence of adverse health effects at the exposure levels encountered in the general population have not been reported by several expert groups. (1-3) However, some diverging results and a broad range of methodological problems keep the scientific community from drawing final conclusions. Recently, psychosocial effects of RF-EMF devices has been an emerging field of research, in addition to the research based on the biophysical effects. (7-11)

In 2015 a scientific committee founded by the European Commission (SCENIHR) presented a risk assessment concluding from three independent lines of evidence (*in vitro* studies, *in vivo* animal studies and epidemiological studies) that exposure to RF-EMF below exposure limits defined in guidelines is unlikely to lead to an increase in cancer or other diseases (3).

Nevertheless, the World Health Organization's International Agency for Research on Cancer (IARC) has classified RF-EMF "Possibly carcinogenic to humans" (group 2B). This category is used for agents for which there is "limited evidence" of carcinogenicity in humans and "less than sufficient evidence" of carcinogenicity in experimental animals. IARC concluded that there is limited evidence in both humans and experimental animals for the carcinogenicity of RF-EMF. The epidemiological evidence was rated as mixed, but associations between acoustic neuroma or glioma and mobile phone use were considered more than inadequate. (2)

RF-EMF is non-ionizing radiation i.e. it does not carry enough energy to directly break chemical bonds or ionize molecules. According to the current knowledge, tissue heating is the best-established effect on living organisms from exposure to RF-EMF at levels encountered in everyday environment. In addition, a few non-thermal mechanisms have been suggested, including magnetic field effect on radical pair recombination rates, ferrimagnetic or molecular resonances, effects on ion flux, and oxidative stress. (12,13) However, it has been argued that the tissue heating mechanism would surpass the other possible mechanisms, because the temperature rise needs to be high the other mechanisms to have an effect on the tissues. The public exposures guidelines for RF-EMF are set to avoid excessive heating of tissues by limiting exposures to remain sufficiently low. (1-3) To conclude, no biological mechanism has been identified that could explain adverse health effects.

Most of the *in vitro* and *in vivo* -studies have not found any biological changes as a result of exposure to RF-EMF, and the few positive results have not been repeatable. (1-3) However, a few recent studies have established a statistically significant increase in the incidence of schwannomas of the heart in RF-EMF exposed Sprague-Dawley male rats. It is noteworthy that these findings are somewhat consistent with some epidemiological studies of mobile phone users, with some evidence of a connection of tumours of the same cytological origin, namely vestibular schwannoma also known as acoustic neuroma, and mobile phone use. (14-16) These new results complicate the question of RF-EMF and health further.

Short term provocation studies with double-blind exposure and sham exposure setup have not shown evidence of symptoms or physiological effects triggered by RF-EMF exposure. Some people react to both sham and real exposure, when they think they are under an influence of real exposure, and on the other hand their symptoms are missing when there is a real exposure that they are not aware of. (17,18) This suggests that there is a nocebo mechanism accompanying RF-EMF exposure. Nocebo is a widely known phenomenon in medicine in which a treatment produces nonspecific adverse side effects which are not a direct result of the biological actions of the treatment. Factors suggested to affect nocebo are patient's expectations of adverse effects of the treatment and prior experiences, psychological characteristics of the patient, and situational factors. (19) Furthermore, there is no evidence that people who report being hypersensitive to RF-EMF have unusual physiological reactions from RF-EMF or that they could reliably detect whether they are under the influence of RF-EMF. (17,20,21) The results of the short-term provocation studies do not, however, eliminate the possibility of long-term effects on health of repeated exposure to mobile phones.

According to ecological and simulation studies, there has been no increase in brain tumour incidence during the period when the popularity of mobile technology has expanded. In a study of the US population in 1992–2008, brain tumour incidence remained generally unchanged while mobile phone use increased from close to 0 % to almost 100 %. (22) Similar results were observed in studies of the English population from 1998 to 2007, in Sweden during 1980–2012, and in Taiwanese in 2000–2009. (23-25) In a Nordic study of glioma incidence in 1978–2008 and simulation of expected incidence growth, no trend change in glioma incidence was found. Furthermore, the simulation showed inconsistency with the results of case-control studies and stable incidence of gliomas for latency period up to 10–15 years. (26) The latest study of Finnish population from 1990–2016 showed no increasing incidence trend of malignant gliomas, except a slight increase in the age group of 80 and older during 1990–2006. (27) However, the induction time of tumours affected by RF-EMF might exceed 20 years, and in that case, we might not observe increases in those conditions yet. In addition, there could be another environmental factor causing tumours to decrease at the same time mobile phones are increasing the occurrence of cancers and other tumours. The latter being an improbable scenario, it is important to focus on studies with sufficient follow-up time.

In a 2008 cross-sectional study with personal dosimetry exposure assessment, no statistically significant associations between the exposure and chronic or acute symptoms were found. The symptoms studied were headache, neurological symptoms such as tinnitus, numbing in limbs, eyelid twitch, cardiovascular symptoms, sleeping disorders, fatigue and concentration problems. (28)

To date, the largest epidemiological study on intracranial tumours and mobile phones is the Interphone study. It was a case-control study on RF-EMF exposure from mobile phones in 13 countries. (29) A correlation was found between gliomas and acoustic neuromas in the highest decile of mobile phone usage with a cumulative call-time of ≥1640 hours, but otherwise there was no exposure-gradient. (30,31) The exposure assessment was based on a self-reported mobile phone use. In a Korean case-control study with methods based on the Interphone, there was a non-significant increase in glioma risk among ipsilateral users, whose body side for usual mobile phone use matched the location of glioma, and a decrease in contralateral users. (32)

Besides the Interphone study, several other case-control studies have been conducted on mobile phone and health effects, mainly tumours. In a Swedish case-control study long-term mobile phone use did not increase risk of acoustic neuroma, but there was a bias observed when taking into account the whole history of laterality of the subject's mobile phone use. The cases reported changes of their preferred side more often than the controls, and consequently strongly reduced risk estimates for ipsilateral use and increased risk estimates for contralateral use were obtained. (33) Pooled analyses of two other Swedish case-control studies from 1997–2003 and 2007–2009 showed an increased risk for glioma associated with cumulative and ipsilateral use of mobile phones and for meningioma associated with heavy mobile phone use. (34,35) A French case-control study found no association of brain tumours when comparing regular mobile phone users to non-users, but a statistically significant positive association was found for gliomas and meningiomas in the heaviest users of mobile phones. (36) For pituitary tumours, no evidence of increased risk with mobile phone use were found in two separate case-control studies in Finnish and English populations. (37,38) In a Swedish study, no support for an increased risk for parotid gland tumours associated with mobile phone use was found. A case-control study has been conducted as well on leukaemia and mobile phone use, where no association was found. (39) All of these studies based their exposure assessment on interviews or questionnaires.

In a large Danish cohort study of mobile phone subscribers, evidence has been found for a weak connection of migraine and vertigo with mobile phone exposure. No evidence of an increased risk of cancer, or amyotrophic lateral sclerosis was shown, but decreased risks of epilepsy, dementia and Parkinson's disease were found among male subscribers. Results of multiple sclerosis was mixed. Among female subscribers, an increased long-term risk of multiple sclerosis was observed, but the finding was based on very few cases. However, the studies of the Danish cohort had no other information on the amount of mobile phone use than the years of subscription. (40-43) Another large prospective cohort study, the British Million Women Study, reported a relation between acoustic neuroma and the use of mobile phone, but mobile phone use was not associated with incidences of other intracranial tumours. However, with further follow-up data, there was no longer association with acoustic neuroma found. Besides tumours, the Million Women Study examined associations between cardiovascular diseases and mobile phone use. Daily use of a mobile phone was associated with higher risk of angina pectoris and ever use of mobile phone was associated with reduced risk of stroke. (44,45)

The latest meta-analysis by Röösli et al. (46) summarizes the epidemiological evidence of cancer risk and RF-EMF. In short, epidemiological studies do not confirm a connection between increased intracranial tumour risk and mobile phone use, but the evidence is mixed with long latency periods (>15 years) and the rarest subtypes of brain tumours, for which epidemiological studies are difficult to conduct due to extremely low numbers of cases.

The methodological limitations of previous studies on mobile phones and health are numerous. First, previous epidemiological studies, not to mention experimental provocation studies, are not informative on long term effects, regarding cancers with long latency periods. Second, in the epidemiological studies, the measurement of the exposure has not been exact. There must be a possibility for exposure gradient analysis because in the modern world the RF-EMF exposure cannot be on/off. The third problem has to do with the case-control design, which has been used in most of the epidemiological studies. In case-control studies based on self-report, there is the possibility of information bias, when the cases might overreport their mobile phone usage and the controls underreport. Furthermore, the response proportions among control groups have been low, which may lead to selection bias. (47-51) Fourth, case-control studies lack the opportunity to assess a large number of outcomes. RF-EMF studies on diseases have concentrated mainly on intracranial tumours and neurological diseases, and little attention has been given to more common non-communicable diseases (NCD), which include heart disease, cancer, diabetes and chronic lung disease. (52) Although RF-EMF from mobile phones is so called near-field exposure and most of the radiation energy is absorbed in one side of the head during calls, the exposure affects also to the whole body and other organs than brain which can mediate a variety of outcomes. (53) To conclude, a broad prospective cohort study with an extensive follow-up period and a broad variety of outcomes was needed to clarify the evidence of mobile phones and adverse health effects.

There is one additional question concerning mobile phone use and health. If a connection between adverse health effects and mobile phone use exists, does it necessarily arise from the

RF-EMF exposure? There has been an increasing interest in the psychological and behavioural perspective of mobile phone use, especially since smartphones became increasingly common. In this field of research, the adverse health effects of mobile phone use are not so much hypothesised to be caused by RF-EMF as psychosocial stress or tendency to addictive behaviour. The direction of causation is difficult to evaluate. Nevertheless, mobile phone use has been associated with stress, anxiety, adolescent behavioural problems, depression, sleep disorders, alexithymia and "the fear of missing out". (7-11)

Considering the difficulty to evaluate the causal relationships, there is a significant lack of research which studies the question of which kinds of people use mobile more than the average. This is important in evaluating the potential confounding factors of mobile phone and health studies, regardless of the assumed causal mechanism.

The Cohort Study on Mobile Phones and Health (Cosmos) was established to answer the methodological problems of previous studies mentioned. Cosmos is an international prospective study from mobile phone use and diverse adverse health outcomes with over 280,000 participants recruited during 2008–2011 in Sweden, Finland, Denmark, the United Kingdom and the Netherlands. The latest country to join the project was France. Exposure data is collected from operator databases and outcomes are assessed by repeated self-report questionnaires or data through national health registries. The participants, aged 18+ years, will be followed up for 25+ years. Due to the cohort approach, several types of health outcomes can be assessed, from cancer to psychosocial disorders. Findings from the first Finnish and Swedish repeated questionnaires and data have already been published. (54)

In this study, the aim is to report a cross-sectional study of the connection between mobile phone use and NCD and the main risk factors of these diseases. The findings are based on the Finnish Cosmos data. This study does not examine a causal relationship between mobile phone use and adverse health outcomes, but it will provide a background for the future prospective cohort studies and help to control the potential confounding factors, plan the analysis and interpret the results.

2 METHODS

2.1 Study population

The study subjects were identified from the subscriber databases of mobile phone network operators TeliaSonera (currently known as Telia Finland) and Elisa in Finland. Letters of invitation, forms of informed consent and questionnaires were mailed to stratified random samples of mobile phone subscribers. Stratified sampling by age, amount of mobile phone use and gender was employed with the intention to balance exposure-age distributions within the cohort to maximise statistical power. Corporate subscriptions were excluded due to difficulties in obtaining a valid consent for the data. A detailed description of the cohort recruitment has been published previously. (55) In this study, the operator data was obtained from the year of the subject's consent and disease history variables used in the analysis were acquired from the baseline questionnaire. The baseline questionnaire covered information about exposure history, the overall state of health, diseases, medications, alcohol use, smoking, height, weight and socio-demographic factors. The questionnaire was available as both paper and electronic versions.

In total 15,477 subjects (9.4% of all invited) gave consent to the study. Complete baseline mobile phone data was obtained for 9,085 participants (6.0%) for whom the operator data was successfully linked on mobile phones they used at the baseline. Exclusion criteria for this study were: 1) lack of informed consent or baseline questionnaire, 2) no mobile phones reported or more than two mobile phones reported, 3) lack of comprehensive call data of any mobile phones reported), 4) missing data on the use of a hands-free device in the questionnaire, and 5) indication of other people using any of the reported mobile phones "often" in the baseline questionnaire. The participants aged 70 or older were excluded as well, leaving 8,104 eligible subjects (5.4%) to the analysis. (Figure 1)

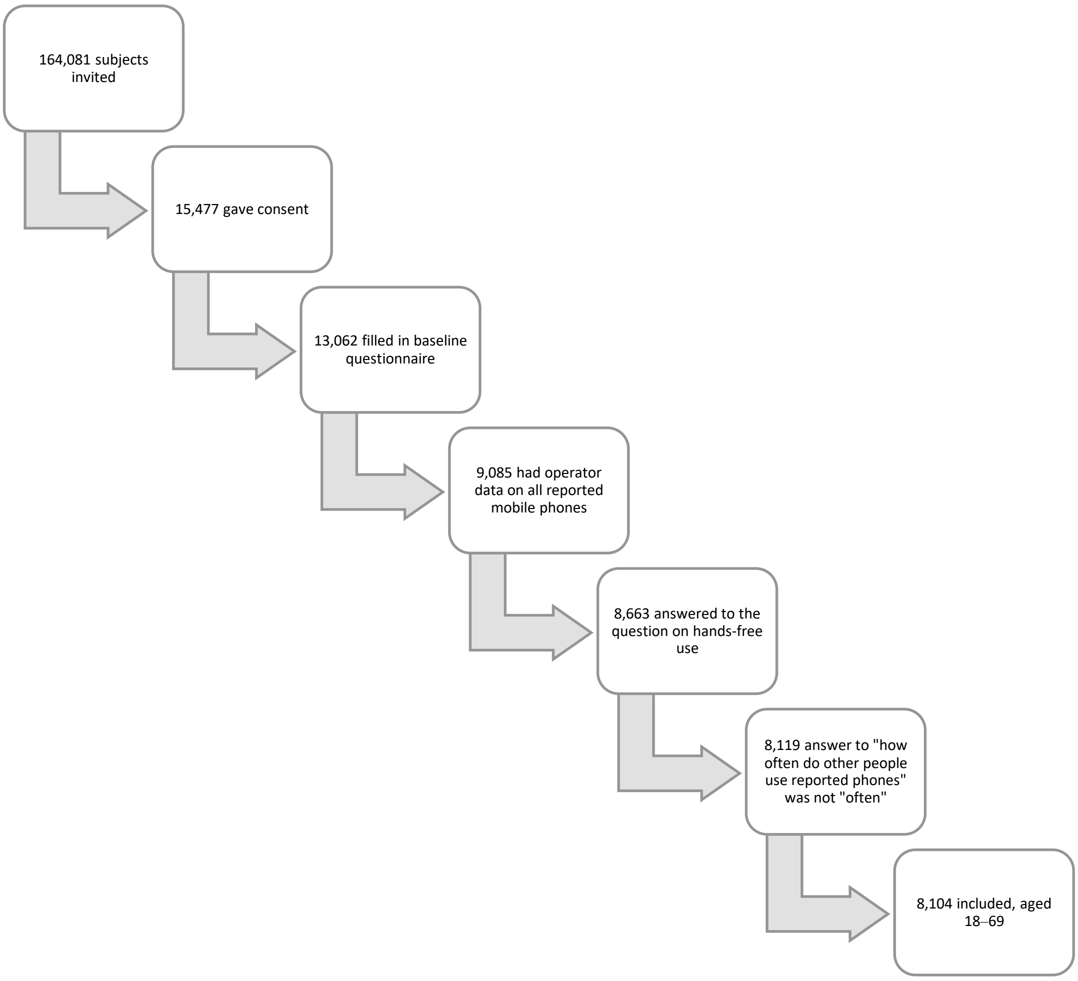

Figure 1 *Flowchart of the study subjects*

2.2 Exposure assessment

The indicators of the exposure to RF-EMF from a mobile phone are the number of calls and the duration of calls (56), and these factors are covered by the operator data used in the analysis. The mobile phone data used in this study included the cumulative call-time from a period of 3 months and the type of the network used (2G/3G/unknown). The main exposure in this study was each individual's mean weekly call-time calculated from the cumulative call-time of individual calls. The exposure groups were categorized by the weekly usage of mobile phone: 0-49%, 50-74%, 75-89%, and 90-100%. Mean weekly use was adjusted for the reported use of a hands-free device. For "Less than half the time", "About half the time", "More than half the time" and "Always/almost always" exposure was reduced to 95%, 90%, 75%, and 50% of the original value, based on data from a study by Goedhart et al. (57) (Table 1)

Table 1 *Adjustment of the operator exposure to the reported use of hands-free devices*

Over the last 3 months, how often have you used a hands-free device when making or receiving calls?	Adjusted exposure
Never/almost never	X
Less than half the time	0.95×X
About half the time	0.90×X
More than half the time	0.75×X
Always/almost always	0.50×X

Additional analyses were conducted for call-time adjusted by the network used and for call-time with the hands-free coefficient removed. In the network analysis, the call-time in 2G (GSM) and unknown networks remained the same, but call-time in 3G (UMTS) network was divided by 150 based on the lower output power of the third generation network. (58)

2.3 Health outcomes

Of the previous diagnoses, asthma, angina pectoris or myocardial infarction (MI), any cancer, chronic obstructive pulmonary disease (COPD), depression, type 2 diabetes (DM2), arterial hypertension (HA), and hypercholesterolemia were included. Medications for hypertension, hypercholesterolemia, diabetes (pills and insulin) as well as depression were included. For these outcome variables, the baseline questionnaire was used. Risk factors taken into account were age, gender, weight, height, alcohol, smoking, physical activity, education, occupation, employment status and relationship status. In addition, summary scores from the SF-12 Health Survey were analysed.

Categorical or continuous variables were derived from the answers to the questionnaire. Diagnoses and medications were treated as binary variables. From the SF-12 Health Survey, physical and mental health composite scores were calculated and these remained as continuous values (59). Alcohol intake was defined as the total number of units per week based on the question “How much of each of the following types of alcohol did you drink in a typical week during the last year?” and was then categorized according to the Finnish risk drinking guidelines into risk users and others, with a cut-point 24 alcohol units per week for men and

16 for women. (60) Smoking was defined as a cumulative consumption (pack-years) assigned from the questionnaire responses and was categorised into non-smokers, <10 packyears, 10-20 pack-years and 20 pack-years or more. Additionally, subjects were grouped into non-smokers, ex-smokers and current smokers. Physical activity included both work-related and leisure-time physical activity. Values were categorized as active (daily leisure-time heavy/lighter physical activity or heavy activity daily at work) and not active (others). Height and current weight from the questionnaire were used to calculate the Body Mass Index and grouped into normal or underweight (<25 kg/m^2), overweight (25–29 kg/m^2), or obese (30+kg/m^2). Age groups were under 30 years, 30–39 years, 40–49 years, 50–59 years, and 60–69 years.

Employment status was defined as currently employed “yes” or “no”. “No” covered everyone who was not active (unemployed, sick leave, retired). Relationship status was defined as having a relationship (married, cohabiting, or other) “yes” or “no”. Educational level was defined in three categories: “basic” (“compulsory school” or “other”), “secondary” (“upper secondary school”, “vocational training”), and “university” (“college”, “university”). The occupation was defined as “labourer”, “clerical”, “managerial”, “entrepreneur”, and “other/outside work”.

For data cleaning, range checks for numerical values (height and weight, cigarettes, alcohol use) were used to exclude implausible values.

2.4 Statistical analysis and ethical permission

Each outcome category was assigned the stratum-specific mean amount of use per week based on operator data. Logistic regression was used for binary outcomes, multinominal or ordinal logistic regression for polytomous outcome variables, and category-specific medians were sought for continuous variables. All analyses were adjusted for age and gender. Odds ratios (OR) were calculated with the participants in the lowest exposure category as the reference and random variation was estimated through 95% confidence intervals (CI). In addition, trend tests were used with the indicator for exposure category as a continuous variable for evaluating an exposure gradient effect. The cut-off $p<0.05$ was considered as a statistically significant result. Dropout analysis was performed for the excluded data to assess possible selection effect. Cross-tabulations and chi-squared tests were used for the dropout analysis. The analyses were conducted with Stata 13.1.

The study protocol of Cosmos was reviewed by The Regional Ethics Committee of Tampere University Hospital, Pirkanmaa Hospital District, with tracking numbers R04179 and R09105.

3 RESULTS

The median age of the participants was 52.5 years, and the median age of the different call-time groups did not vary significantly. Proportions of age categories in the call-time groups are presented in Table 2. In total 4,773 (58.9%) of the participants were women, and the percentage of women ranged from 53.1% to 65.7% across the exposure categories. (Table 2) The median call-time of men was 82 minutes and women 108 minutes.

In the dropout analysis, participants did not differ from the excluded subjects in age, gender, diagnosis, medications, or lifestyle habits. In the excluded group there were more university degrees (62.2% vs 53.7%, p<0.00) and managerial occupations (31.4% vs 20.8%, p<0.00) and less employment (29.1% vs. 42.9%, p<0.00).

The amount of weekly call-time was highly skewed toward low values with a maximum of 2177 minutes and over 98% of participants had call-time under 500 minutes. (Figure 2) Call-time in minutes for different exposure categories is presented in Table 2.

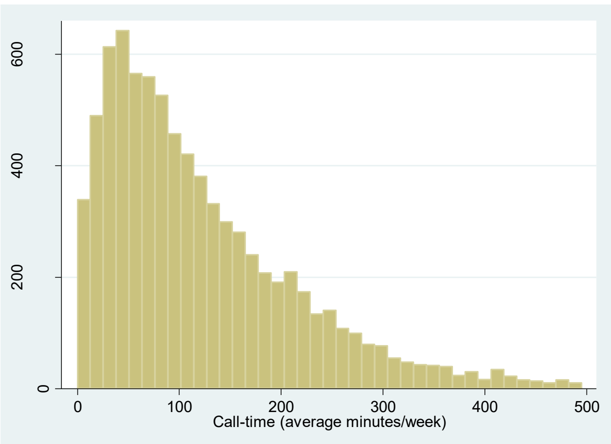

Figure 2 *Distribution of weekly mean call-time (min) among participants with <500 min/week (7994 participants, 98.6%)*

Table 2 *Call-time minutes, age and gender in exposure categories*

Call-time category	Minutes (mean)	Age (years, median)	Age categories (%)					Females (%)
			18–30	30–39	40–49	50–59	60–69	
Lowest 49%	≤97.5	52.2	16.0	15.3	14.8	20.3	33.7	53.1
50–74th percentile	97.5–174	52.6	11.7	17.3	14.9	22.1	34.1	65.7
75–89th percentile	174–264.1	53.2	9.9	16.0	17.5	20.6	36.1	64.4
90–100th percentile	>264.1	52.2	10.5	14.4	19.6	24.5	31.0	62.4

Previously diagnosed angina pectoris, asthma, cancer, depression, DM2, hypertension, and hypercholesterolemia were more common among the participants in the highest call-time categories. (Table 3) In addition, overweight, daily physical activity and current smoking were more frequent among heavy mobile phone users. Compared with the group with the lowest 50% weekly call-time the participants with higher amount of call-time were more often entrepreneurs, less often employed, less educated and less often in a relationship. (Table 4)

The 10% of participants with the largest amount of call-time had an increased adjusted OR of previous diagnosis of angina pectoris or MI (OR 1.79, CI 1.17–2.75), asthma (OR 1.70, CI 1.15–2.52), depression (OR 1.43, CI 1.16–1.76) and depression medication (OR 1.68, CI 1.30–2.17), as well as arterial hypertension (OR 1.31, CI 1.09–1.58) and HA medication (OR 1.29, CI 1.06–1.57). For asthma, also the 50–74th percentile and the 75–89th percentile had increased OR (OR 1.48, CI 1.09–2.00; OR 1.85, CI 1.33–2.58) and there was an increase of OR across the call-time categories (p trend 0.00). In addition, angina pectoris or MI (p trend 0.01), depression (p trend 0.00), and depression medication (p trend 0.00), showed gradient by call-time. No statistically significant results were obtained for cancer, COPD, DM2, hypercholesterolemia, or medication for DM2 or hypercholesterolemia, but for all of these diseases, excluding COPD, OR was increased in the 90–100th percentile group. (Table 5)

Overweight increased across call-time categories with OR from 1 to 1.72 (p trend 0.00). Similarly, OR of current/ex smoking increased from 1 to 1.39 (p trend 0.00). For smoking categorised as packyears, the 50–74th percentile and 90–100th percentile groups had statistically significantly increased OR of higher amount of packyears (OR 1.16, CI 1.03–1.31; OR 1.31, CI 1.11–1.55, p trend 0.00). The 75–89th percentile and 90–100th percentile groups had increased OR of physical activity (OR 1.20, CI 1.05–1.38; 1.18, CI 1.01–1.39, p trend 0.01). For risk drinking, there was no statistically significant difference between groups. (Table 6)

In the analysis of socio-demographic factors, several associations were found between call-time groups compared with the lowest 50% weekly call-time. Employment decreased across call-time categories with OR from 0.85 to 0.60 (p trend 0.00) and, on the contrary, being an entrepreneur increased strongly by the amount of mobile phone use with OR from 1.83 to 3.06 (p trend 0.00). The 10 % of the participants with the largest amount of weekly call-time had lower level of education (secondary education OR 0.77, CI 0.61–0.97 and university OR 0.65, CI 0.52–0.79) and were less often in a relationship (OR 0.57, CI 0.48–0.68). In addition, the findings were similar in the 75–89th percentile group. University education and relationship status showed statistically significant gradient by call-time. (Table 6) No considerable differences were observed in SF-12 composite scores between exposure groups. (Figure 3 and 4)

In the analysis of call-time by network type (2G/3G), results with asthma and socio-demographic factors remained largely similar. For angina pectoris, depression, hypertension and medications for these conditions, OR was increased in the highest call-time category, but there were no statistically significant differences between call-time groups, in contrast to the original analysis. For physical activity, the 75–89th percentile and 90–100th percentile groups had increased OR (OR 1.28, CI 1.12–1.47; 1.32, CI 1.13–1.55, p trend 0.00), thus stronger trend across the categories was observed compared to the main analysis. For smoking the network analysis showed no substantial differences between groups. Overweight was more common among the 10% of the participants with the largest amount of weekly call-time (OR 1.46, CI 1.26–1.68). The 50–74th percentile group had a decreased OR of previous cancer (OR 0.77, CI 0.61–0.98) compared with the group with the lowest 50% call-time. (Table 7 and 8)

***Table 3** Prevalence for diagnoses and medications by amount of mobile phone use*

	Prevalence, % (N)					Participants[1], N
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	Total	
Angina pectoris/MI	2.8 (111)	3.2 (64)	3.2 (38)	3.8 (30)	3.1 (243)	7,930
Asthma	2.5 (102)	3.8 (77)	4.7 (57)	4.3 (35)	3.4 (271)	8,047
Cancer	5.5 (220)	6.3 (127)	6.3 (76)	7.0 (56)	6.0 (479)	8,045
COPD	1.1 (42)	1.4 (27)	1.3 (16)	0.9 (7)	1.2 (92)	8,004
Depression	12.4 (498)	14.9 (299)	14.6 (176)	17.8 (142)	13.9 (1,115)	8,012
Medication for depression	6.7 (267)	7.7 (155)	8.1 (97)	11.2 (89)	7.6 (608)	8,004
DM2	5.8 (233)	5.1 (102)	6.3 (76)	6.8 (54)	5.8 (465)	8,018
Medication for DM2	5.8 (231)	4.7 (94)	6.2 (74)	6.8 (54)	5.7 (453)	7,964
Hypercholesterolemia	20.3 (810)	20.5 (409)	20.7 (247)	23.0 (183)	20.7 (1,649)	7,985
Medication for hypercholesterolemia	15.0 (600)	14.3 (286)	15.6 (187)	16.7 (133)	15.1 (1,206)	7,995
Arterial hypertension	24.5 (985)	25.0 (502)	24.8 (299)	29.1 (232)	25.1 (2,018)	8,032
Medication for HA	21.0 (842)	21.3 (427)	21.5 (258)	24.5 (196)	21.5 (1,723)	8,022

1: Not all eligible participants answered to all outcomes

***Table 4** Prevalence for risk factors of public health and socio-demographic factors by amount of mobile phone use*

	Prevalence, % (N)					
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	Total	Participants[1], N
Alcohol use[2]	4.6 (127)	3.8 (52)	4.8 (37)	4.7 (23)	4.4 (239)	5,389
BMI <25 kg/m[2]	46.8 (1,887)	45.5 (916)	41.4 (501)	34.3 (275)	44.4 (3,579)	8,063
BMI 25–29 kg/m[2]	37.0 (1,493)	35.1 (707)	37.2 (450)	39.7 (318)	36.8 (2,968)	8,063
BMI≥30 kg/m[2]	16.3 (656)	19.5 (392)	21.4 (259)	26.1 (209)	18.8 (1,516)	8,063
Physical activity[3]	35.6 (1,381)	34.4 (662)	38.4 (441)	38.7 (295)	36.0 (2,779)	7,711
Non-smoker	51.1 (1,694)	48.0 (806)	48.6 (487)	43.9 (289)	49.2 (3,276)	6,653
Smoking: < 10 packyears	19.2 (592)	24.3 (379)	19.6 (176)	23.5 (141)	21.0 (1,288)	6,140
10–20 packyears	9.3 (287)	7.6 (119)	10.6 (95)	12.3 (74)	9.4 (575)	6,140
>20 packyears	13.1 (405)	12.5 (194)	12.3 (111)	12.8 (77)	12.8 (787)	6,140
Ex-smoker	32.5 (1,078)	36.3 (609)	33.4 (335)	36.0 (237)	34.0 (2,259)	6,653
Current smoker	16.4 (542)	15.7 (263)	18.1 (181)	20.1 (132)	16.8 (1,118)	6,653
Education: Basic	17.1 (690)	18.3 (369)	19.9 (241)	22.1 (178)	18.3 (1,478)	8,076
Secondary	28.7 (1,158)	25.8 (522)	29.0 (352)	28.7 (231)	28.0 (2,263)	8,076
University	54.2 (2,188)	55.9 (1,131)	51.1 (620)	49.2 (396)	53.7 (4,335)	8,076
Employed	59.2 (2,380)	56.9 (1,143)	53.0 (637)	53.0 (422)	57.1 (4,582)	8,027
Occupation: Labourer	38.5 (1,546)	37.5 (750)	38.6 (461)	37.7 (300)	38.2 (3,057)	8,005
Clerical	19.6 (787)	19.3 (386)	15.9 (190)	15.45 (123)	18.6 (1,486)	8,005
Managerial	21.9 (880)	20.5 (409)	19.6 (234)	17.5 (139)	20.8 (1,662)	8,005
Entrepreneur	10.2 (408)	14.8 (296)	18.7 (223)	22.7 (181)	13.8 (1,108)	8,005
Relationship	81.0 (3,269)	80.2 (1,620)	73.3 (891)	70.6 (571)	78.6 (6,351)	8,081

1: Not all eligible participants answered to all outcomes
2: Risk drinking (yes/no) according to Finnish guidelines
3: Daily light/heavy physical activity at work/leisure

Table 5 *Odds ratio, confidence intervals, p trend and prevalence for diagnoses and medications by amount of mobile phone use*

	OR[1] (95% CI)				
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	P trend
Angina pectoris/MI	1 (reference)	1.35 (0.98–1.86)	1.31 (0.89–1.93)	**1.79 (1.17–2.75)**	**0.01**
Asthma	1 (reference)	**1.48 (1.09–2.00)**	**1.85 (1.33–2.58)**	**1.70 (1.15–2.52)**	**0.00**
Cancer	1 (reference)	1.09 (0.86–1.37)	1.06 (0.80–1.40)	1.23 (0.90–1.86)	0.23
COPD	1 (reference)	1.32 (0.81–2.16)	1.26 (0.70–2.26)	0.86 (0.38–1.94)	0.82
Depression	1 (reference)	1.14 (0.97–1.33)	1.13 (0.93–1.36)	**1.43 (1.16–1.76)**	**0.00**
Medication for depression	1 (reference)	1.11 (0.90–1.36)	1.18 (0.92–1.50)	**1.68 (1.30–2.17)**	**0.00**
DM2	1 (reference)	0.90 (0.70–1.14)	1.11 (0.84–1.46)	1.29 (0.94–1.77)	0.14
Medication for DM2	1 (reference)	0.83 (0.64–1.07)	1.10 (0.83–1.44)	1.29 (0.94–1.77)	0.17
Hypercholesterolemia	1 (reference)	1.01 (0.87–1.16)	0.99 (0.83–1.17)	1.21 (1.00–1.47)	0.18
Medication for hypercholesterolemia	1 (reference)	0.96 (0.82–1.13)	1.03 (0.85–1.25)	1.24 (0.99–1.55)	0.13
Arterial hypertension	1 (reference)	1.02 (0.89–1.17)	0.97 (0.82–1.14)	**1.31 (1.09–1.58)**	0.05
Medication for HA	1 (reference)	1.02 (0.88–1.18)	0.99 (0.83–1.17)	**1.29 (1.06–1.57)**	0.07

1: Adjusted for gender, age group
In bold: statistically significant results

Table 6 *Odds ratio, confidence intervals, p trend and prevalence for risk factors of public health and socio-demographic factors by amount of mobile phone use*

	OR[1] (95% CI)				
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	P trend
Alcohol use[2]	1 (reference)	0.91 (0.65–1.27)	1.13 (0.77–1.65)	1.09 (0.69–1.73)	0.60
Overweight/Obese	1 (reference)	**1.13 (1.02–1.25)**	**1.28 (1.13–1.45)**	**1.72 (1.49–1.99)**	**0.00**
Physical activity[3]	1 (reference)	1.01 (0.90–1.14)	**1.20 (1.05–1.38)**	**1.18 (1.01–1.39)**	**0.01**
Smoking					
>10 packyears	1 (reference)	**1.16 (1.03–1.31)**	1.10 (0.95–1.27)	**1.31 (1.11–1.55)**	**0.00**
Ex/Current smoker	1 (reference)	**1.17 (1.05–1.31)**	**1.21 (1.05–1.38)**	**1.39 (1.19–1.63)**	**0.00**
Education: Secondary/University	1 (reference)	0.97 (0.87–1.07)	**0.82 (0.72–0.92)**	**0.73 (0.63–0.85)**	**0.00**
Employed	1 (reference)	**0.85 (0.73–0.98)**	**0.71 (0.60–0.84)**	**0.60 (0.49–0.73)**	**0.00**
Occupation[4]					
Labourer	1 (reference)	1.10 (0.88–1.37)	1.14 (0.87–1.50)	1.23 (0.88–1.71)	0.13
Clerical	1 (reference)	1.02 (0.80–1.29)	0.83 (0.61–1.12)	0.90 (0.62–1.30)	0.30
Managerial	1 (reference)	1.08 (0.85–1.37)	1.02 (0.76–1.37)	1.05 (0.73–1.50)	0.74
Entrepreneur	1 (reference)	**1.83 (1.42–2.37)**	**2.28 (1.68–3.10)**	**3.06 (2.13–4.40)**	**0.00**
Relationship	1 (reference)	0.99 (0.86–1.13)	**0.66 (0.57–0.77)**	**0.57 (0.48–0.68)**	**0.00**

1: Adjusted for gender, age group
2: Risk drinking (yes/no) according to Finnish guidelines
3: Daily light/heavy physical activity at work/leisure
4: Other/Outside work as a base outcome
In bold: statistically significant results

***Table** 7 Odds ratio, confidence intervals, p trend and prevalence for diagnoses and medications by amount of network adjusted mobile phone use*

	OR[1] (95% CI)				
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	P trend
Angina pectoris/MI	1 (reference)	1.09 (0.79–1.51)	1.24 (0.85–1.81)	1.39 (0.90–2.13)	0.09
Asthma	1 (reference)	1.29 (0.95–1.75)	**1.63 (1.16–2.28)**	**1.73 (1.18–2.53)**	**0.00**
Cancer	1 (reference)	**0.77 (0.61–0.98)**	0.86 (0.66–1.14)	0.94 (0.69–1.29)	0.36
COPD	1 (reference)	1.32 (0.81–2.16)	1.26 (0.70–2.26)	0.86 (0.38–1.94)	0.82
Depression	1 (reference)	0.88 (0.74–1.03)	1.10 (0.91–1.32)	1.17 (0.95–1.45)	0.14
Medication for depression	1 (reference)	1.01 (0.82–1.24)	1.00 (0.78–1.28)	1.23 (0.93–1.61)	0.27
DM2	1 (reference)	0.90 (0.71–1.15)	0.87 (0.65–1.16)	1.33 (0.98–1.80)	0.37
Medication for DM2	1 (reference)	0.83 (0.64–1.06)	0.83 (0.61–1.11)	1.31 (0.97–1.76)	0.55
Hypercholesterolemia	1 (reference)	1.01 (0.87–1.16)	0.89 (0.75–1.06)	1.05 (0.86–1.27)	0.79
Medication for hypercholesterolemia	1 (reference)	0.99 (0.85–1.17)	0.85 (0.70–1.03)	1.17 (0.94–1.44)	0.84
Arterial hypertension	1 (reference)	0.95 (0.83–1.09)	0.92 (0.78–1.07)	1.06 (0.89–1.28)	0.94
Medication for HA	1 (reference)	0.88 (0.77–1.02)	0.85 (0.71–1.01)	1.03 (0.85–1.25)	0.07

1: Adjusted for gender, age group
In bold: statistically significant results

Table 8 *Odds ratio, confidence intervals, p trend and prevalence for risk factors of public health and socio-demographic factors by amount of network adjusted mobile phone use*

	OR[1] (95% CI)				P trend
	Lowest 49%	50–74th percentile	75–89th percentile	90-100th percentile	
Alcohol use[2]	1 (reference)	0.86 (0.63–1.19)	0.91 (0.61–1.36)	0.76 (0.46–1.26)	0.26
Overweight/Obese	1 (reference)	0.98 (0.88–1.08)	0.99 (0.87–1.12)	**1.46 (1.26–1.68)**	**0.00**
Physical activity[3]	1 (reference)	1.08 (0.96–1.21)	**1.28 (1.12–1.47)**	**1.32 (1.13–1.55)**	**0.00**
Smoking					
>10 packyears	1 (reference)	0.93 (0.83–1.05)	0.92 (0.80–1.07)	1.11 (0.94–1.31)	0.81
Ex/Current smoker	1 (reference)	0.94 (0.84–1.05)	1.02 (0.89–1.17)	1.13 (0.96–1.32)	0.26
Education: Secondary/University	1 (reference)	**0.88 (0.79–0.98)**	**0.79 (0.70–0.90)**	**0.67 (0.58–0.78)**	**0.00**
Employed	1 (reference)	0.93 (0.80–1.07)	**0.81 (0.69–0.97)**	**0.62 (0.51–0.75)**	**0.00**
Occupation[4]					
Labourer	1 (reference)	1.09 (0.88–1.35)	1.17 (0.89–1.53)	1.17 (0.84–1.62)	0.19
Clerical	1 (reference)	0.93 (0.73–1.18)	0.96 (0.72–1.30)	0.84 (0.58–1.20)	0.38
Managerial	1 (reference)	0.90 (0.72–1.14)	0.79 (0.58–1.07)	0.91 (0.63–1.30)	0.20
Entrepreneur	1 (reference)	**1.45 (1.13–1.87)**	**1.91 (1.40–2.60)**	**2.24 (1.56–3.22)**	**0.00**
Relationship	1 (reference)	1.08 (0.94–1.23)	**0.83 (0.70–0.96)**	**0.61 (0.51–0.73)**	**0.00**

1: Adjusted for gender, age group
2: Risk drinking (yes/no) according to Finnish guidelines
3: Daily light/heavy physical activity at work/leisure
4: Other/Outside work as a base outcome
In bold: statistically significant results

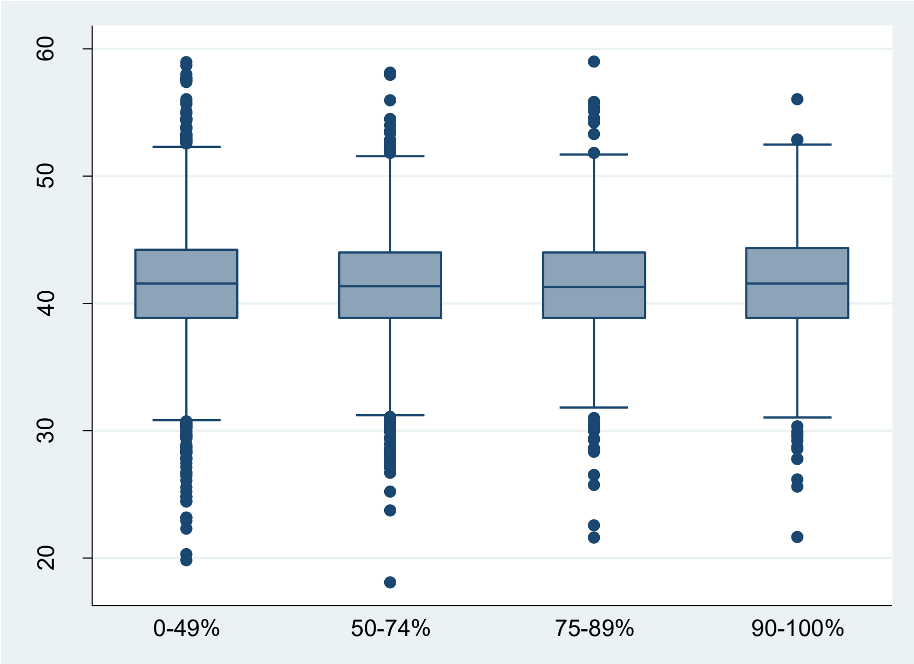

Figure 3 *SF-12 Physical Health Composite Score and call-time categories*

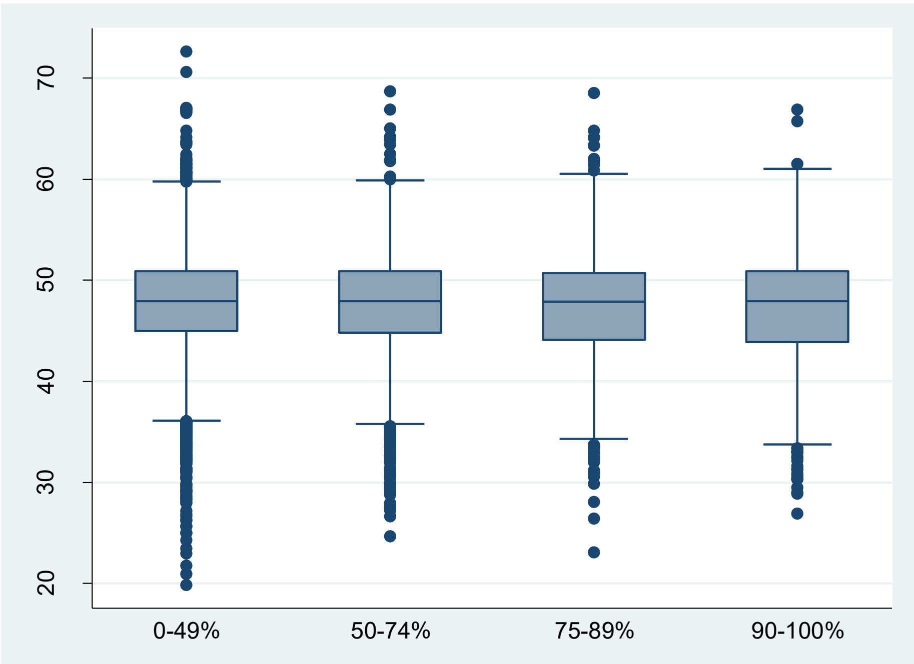

Figure 4 *SF-12 Mental Health Composite Scores and call-time categories*

Additional analysis with the hands-free coefficient removed from the exposure assessment showed no considerable changes in the results. 93.5% of the participants had the hands-free coefficient 1 or 0.95.

4 DISCUSSION

4.1 Main results

The results show several differences in health-related characteristics in relation to the amount of call-time in the Finnish Cosmos study. The participants in the highest decile of weekly call-time had higher prevalence of angina pectoris, asthma, depression and arterial hypertension at the baseline. Similar findings for medications for depression and arterial hypertension supported these results. Prevalence of overweight, smoking and daily physical activity increased with call-time. High amount of call-time was more common among participants with lower education and employment and with those who were entrepreneurs and single.

Most of the associations with the diseases and medications were not observed when the exposure variable was adjusted for the network used. Thus, the findings ignoring network type had more to do with the call-time itself than the network used. Associations with asthma, socio-demographic factors and physical activity were similar in the network analysis than in the original analysis. In addition, prior history of cancer was not associated with call-time adjusted for network.

In the additional analysis with the hands-free coefficient removed, the results remained similar compared to the original analysis. This was expected because the adjusted exposure was closely correlated with the original exposure.

4.2 Strengths and weaknesses

The main advantages of this study are the large sample size and the objective exposure assessment. A large sample of participants increased statistical power and precision of the analysis. Selection bias was minimized, because all participants passed the same recruitment process. A dropout analysis did not show major differences in outcomes between those included in those excluded, except in education and employment. The participation proportion was low among the invited, which may cause unrepresentativeness of the Finnish population. Furthermore, employer-owned subscriptions were excluded from the study population, which may explain the high proportions of unemployed, retirees and entrepreneurs in the study. Nevertheless, the study analyses were based on internal comparisons among participants. This approach eliminates any potential selection bias caused by the exclusions and non-participation.

The major factors affecting the rate of RF-EMF exposure from mobile phones are call-time, the power of a device and the distance from a device. Call-time and network used was obtained from the operators, which eliminated the recall bias. In addition, it was possible to analyse the exposure gradient with such an exact exposure assessment. However, information of hands-free use and other people using the phone was self-reported and cannot be regarded as objective. Hands-free devices decrease the exposure to the head due to the distance. Network affects to the power needed to connect to a base station. Not all the relevant factors affecting the exposure were considered in this study. The power of a device is determined by the properties of the device, such as the model of the mobile phone, and the power needed the connect to a base station. The weaker the connection, the more power is needed. In addition to the type of network, location affects to connection to the base station. At present, adaptive power control (APC) monitors signal quality and may reduce the emitted power of a mobile phone so that the lowest power required for maintaining a proper connection is used. (1-3,56)

An exposure-based cross-sectional study design made it possible to analyse several risk factors and diseases. The major NCD and health risks are potential confounding factors in epidemiological studies, including studies of mobile phone use. The global burden of diseases is shifting from infectious diseases towards NCD (61), which include cardiovascular diseases, type 2 diabetes, chronic respiratory conditions and cancers. Four major risk factors are linked to these diseases: smoking, physical inactivity, alcohol drinking and unhealthy diets. Most of these risk factors were considered. Depression is also one of the leading causes of a disability pension in Finland (62) and is linked to decreased overall health. (63) Socio-demographic factors still affect the prevalence of NCD and lifestyle choices. (64) This study evaluated many of these risk factors.

In this study, it was possible to access most of the important risk factors of public health. Nevertheless, one major risk factor for NCD was not considered, the diet. The most commonly used method for evaluating diet, food frequency questionnaire, is prone to bias and misclassification, and its use is questionable (65). Uncertainty of self-reported data associates also with assessment of physical activity and BMI (66). Other methods, such as activity trackers or measuring weight with a scale, would be resource-intensive, and more importantly, they would lower the participation rate. The amount of call-time correlated with prevalence of smoking and overweight, suggesting that amount of call-time is associated with an unhealthy lifestyle. The direction of causation is unknown, people in poor health may also need to use mobile phones more often. Level of physical activity may be overestimated among the participants, whereas weight is probably underestimated. However, this should not affect the comparisons between-groups within the study, as long as the estimation errors are similar across the groups.

In addition, the diagnoses and medications could have been checked from national health care registries or from the medicine reimbursement statistics of the Social Insurance Institution of Finland, which would have made the study more accurate. However, many of NCD are diagnosed in the primary healthcare system, from which the registries are not complete. Also, the information from the medicine reimbursement statistics is not without problems, as a given medication can have several indications, i.e. be used for different diseases. The prevalences of the diseases and lifestyle factors were for the most part comparable to the statistics of the Finnish Institute for Health and Welfare (67). Risk drinking, asthma and COPD had lower prevalence in the study population than in the general Finnish population. The prevalences of risk factors and diseases seemed to vary with age and gender in this study consistently with population studies, for example, angina pectoris was more common among older participants and men.

One thing that is not considered in this study, is the changes over time in the amount of mobile phone use. This would affect the results if the changes were dissimilar across the categories. In the earlier Cosmos publication, the consistency of the amount of the weekly call-time was quite high when comparing the baseline data to the 4-year follow-up (54).

The cross-sectional method is appropriate when studying confounding factors. The method restrains from inferring anything about the causality. However, causal relationships of the variables are not important, when considering the profiles of the mobile phone users at the baseline as the aim was to evaluate the underlying differences within the study population, not assess the effect of the exposure of interest.

4.3 Consistency with other studies

In the previous Cosmos publication, the association between headache and mobile phone use largely disappeared after adjustment for confounders. (54) This reinforces the results of this study.

Few studies have been conducted with mobile phone use and NCD and common risk factors. Previous studies have suggested that mobile phone use is related to lower physical activity, higher BMI, as well as more common smoking and alcohol use, but these studies have mainly covered adolescents. (68-70) In this study, the highest 25 per cent of the participants with the largest amount of weekly call-time had increased physical activity. The discordant findings might be due to the nature of confounding: the common risk factors and diseases might affect the mobile phone use and the outcomes in some studies, but the confounding factors are not necessarily generalizable.

The findings on depression and angina pectoris were similar to previous studies. (7,44) No previous epidemiological studies were found in the literature on asthma and hypertension in relation to mobile phone use.

Mobile phones have been associated with intracranial neoplasms in some studies. (46) Here, the association between call-time and prior history of cancer was not strong. Previous studies have been focusing on studying the potential causal relationships between mobile phone use and tumours, whereas here the focus was on diagnoses preceding the exposure. Additionally, there are no known risk factors for brain tumours, with the exception of ionizing radiation, allergies and genetic factors. (71-73) Lifestyle factors studied here do not explain the previous findings on intracranial tumours and mobile phone use.

4.4 Conclusion

Participants with larger amount of call-time had increased prevalence of NCD and major NCD risk factors. This may indicate a need for adjustment for other risk factors, or if not controlled for, source of bias in future mobile phone studies, especially Cosmos studies with the same data.

In the future studies, a focus should be on the long-term effects of mobile phone use with a cohort design. Adverse health effects of RF-EMF exposure still require careful consideration.

REFERENCES

(1) AGNIR. Health Effects from Radiofrequency Electromagnetic Fields. Report of the independent Advisory Group on Non-ionising Radiation. Didcot (UK): Health Protection Agency; 2012.

(2) IARC. IARC monographs on the evaluation of carcinogenic risks to humans v. 102. Non-ionizing radiation, Part II: Radiofrequency electromagnetic fields. Lyon (FR): International Agency for Research on Cancer; 2012.

(3) SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks). Potential health effects of exposure to electromagnetic fields (EMF). Luxembourg: European Commission; 2015.

(4) Eurostat. Enlargement countries - information and communication technology statistics. 2019; Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Enlargement_countries_-_information_and_communication_technology_statistics. Accessed 16.9., 2019.

(5) Ericsson. Ericsson Mobility Report: On the Pulse of the Networked Society . 2015; Available at: https://www.ericsson.com/assets/local/mobility-report/documents/2015/ericsson-mobility-june-2015.pdf.

(6) Finnish Transport and Communications Agency. Mobile subscriptions . 2018; Available at: https://www.traficom.fi/en/statistics/mobile-subscriptions. Accessed 16.9., 2019.

(7) Thomee S, Harenstam A, Hagberg M. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults--a prospective cohort study. BMC Public Health 2011 Jan 31;11:66.

(8) Roser K, Schoeni A, Foerster M, Roosli M. Problematic mobile phone use of Swiss adolescents: is it linked with mental health or behaviour?. Int J Public Health 2016 Apr;61(3):307-315.

(9) Wolniewicz CA, Tiamiyu MF, Weeks JW, Elhai JD. Problematic smartphone use and relations with negative affect, fear of missing out, and fear of negative and positive evaluation. Psychiatry Res 2018;262:618-623.

(10) Vahedi Z, Saiphoo A. The association between smartphone use, stress, and anxiety: A meta-analytic review. Stress Health 2018 Aug;34(3):347-358.

(11) Gao T, Li J, Zhang H, Gao J, Kong Y, Hu Y, et al. The influence of alexithymia on mobile phone addiction: The role of depression, anxiety and stress. J Affect Disord 2018 01 01;225:761-766.

(12) Sheppard AR, Swicord ML, Balzano Q. QUANTITATIVE EVALUATIONS OF MECHANISMS OF RADIOFREQUENCY INTERACTIONS WITH BIOLOGICAL MOLECULES AND PROCESSES. Health Phys 2008 October;95(4):365-396.

(13) Dasdag S, Akdag MZ. The link between radiofrequencies emitted from wireless technologies and oxidative stress. J Chem Neuroanat 2016;75(Pt B):85-93.

(14) Wyde ME, Cesta MF, Blystone CR, Bucher JR, Elmore SA, Foster PM, et al. Report of Partial Findings from the National Toxicology Program Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD rats (Whole Body Exposures), Draft 5-19-2016. US National Toxicology Program (NTP) 2016.

(15) Falcioni L, Bua L, Tibaldi E, Lauriola M, De Angelis L, Gnudi F, et al. Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8GHz GSM base station environmental emission. Environ Res 2018 Aug;165:496-503.

(16) Bua L, Tibaldi E, Falcioni L, Lauriola M, De Angelis L, Gnudi F, et al. Results of lifespan exposure to continuous and intermittent extremely low frequency electromagnetic fields (ELFEMF) administered alone to Sprague Dawley rats. Environ Res 2018 Jul;164:271-279.

(17) Rubin GJ, Hillert L, Nieto-Hernandez R, van Rongen E, Oftedal G. Do people with idiopathic environmental intolerance attributed to electromagnetic fields display physiological effects when exposed to electromagnetic fields? A systematic review of provocation studies. Bioelectromagnetics 2011 Dec;32(8):593-609.

(18) Rubin GJ, Nieto-Hernandez R, Wessely S. Idiopathic environmental intolerance attributed to electromagnetic fields (formerly 'electromagnetic hypersensitivity'): An updated systematic review of provocation studies. Bioelectromagnetics 2010 Jan;31(1):1-11.

(19) Barsky AJ, Saintfort R, Rogers MP, Borus JF. Nonspecific medication side effects and the nocebo phenomenon. JAMA 2002 Feb 06;287(5):622-627.

(20) Roosli M. Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: a systematic review. Environ Res 2008 Jun;107(2):277-287.

(21) van Moorselaar I, Slottje P, Heller P, van Strien R, Kromhout H, Murbach M, et al. Effects of personalised exposure on self-rated electromagnetic hypersensitivity and sensibility - A double-blind randomised controlled trial. Environ Int 2017;99:255-262.

(22) Little MP, Rajaraman P, Curtis RE, Devesa SS, Inskip PD, Check DP, et al. Mobile phone use and glioma risk: comparison of epidemiological study results with incidence trends in the United States. BMJ 2012 Mar 08;344:e1147.

(23) de Vocht F, Burstyn I, Cherrie JW. Time trends (1998-2007) in brain cancer incidence rates in relation to mobile phone use in England. Bioelectromagnetics 2011 Jul;32(5):334-339.

(24) Nilsson J, Jaras J, Henriksson R, Holgersson G, Bergstrom S, Estenberg J, et al. No Evidence for Increased Brain Tumour Incidence in the Swedish National Cancer Register Between Years 1980-2012. Anticancer Res 2019 Feb;39(2):791-796.

(25) Hsu M, Syed-Abdul S, Scholl J, Jian W, Lee P, Iqbal U, et al. The incidence rate and mortality of malignant brain tumors after 10 years of intensive cell phone use in Taiwan. Eur J Cancer Prev 2013 Nov;22(6):596-598.

(26) Deltour I, Auvinen A, Feychting M, Johansen C, Klaeboe L, Sankila R, et al. Mobile phone use and incidence of glioma in the Nordic countries 1979-2008: consistency check. Epidemiology 2012 Mar;23(2):301-307.

(27) Natukka T, Raitanen J, Haapasalo H, Auvinen A. Incidence trends of adult malignant brain tumors in Finland, 1990-2016. Acta Oncol 2019 Jul;58(7):990-996.

(28) Thomas S, Kuhnlein A, Heinrich S, Praml G, Nowak D, von Kries R, et al. Personal exposure to mobile phone frequencies and well-being in adults: a cross-sectional study based on dosimetry. Bioelectromagnetics 2008 Sep;29(6):463-470.

(29) Cardis E, Richardson L, Deltour I, Armstrong B, Feychting M, Johansen C, et al. The INTERPHONE study: design, epidemiological methods, and description of the study population. Eur J Epidemiol 2007;22(9):647-664.

(30) INTERPHONE Study Group. Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Cancer epidemiol 2011 Oct;35(5):453-464.

(31) INTERPHONE Study Group. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int J Epidemiol 2010 Jun;39(3):675-694.

(32) Yoon S, Choi J, Lee E, An H, Choi HD, Kim N. Mobile phone use and risk of glioma: a case-control study in Korea for 2002-2007. Environ Health Toxicol 2015;30:e2015015.

(33) Pettersson D, Mathiesen T, Prochazka M, Bergenheim T, Florentzson R, Harder H, et al. Long-term mobile phone use and acoustic neuroma risk. Epidemiology 2014 Mar;25(2):233-241.

(34) Hardell L, Carlberg M. Mobile phone and cordless phone use and the risk for glioma - Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology 2015 Mar;22(1):1-13.

(35) Carlberg M, Hardell L. Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. Oncol Rep 2015 Jun;33(6):3093-3098.

(36) Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, et al. Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med 2014 Jul;71(7):514-522.

(37) Shrestha M, Raitanen J, Salminen T, Lahkola A, Auvinen A. Pituitary tumor risk in relation to mobile phone use: A case-control study. Acta Oncol 2015;54(8):1159-1165.

(38) Schoemaker MJ, Swerdlow AJ. Risk of pituitary tumors in cellular phone users: a case-control study. Epidemiology 2009 May;20(3):348-354.

(39) Cooke R, Laing S, Swerdlow AJ. A case–control study of risk of leukaemia in relation to mobile phone use. British Journal of Cancer 2010 November;103(11):1729.

(40) Schuz J, Waldemar G, Olsen JH, Johansen C. Risks for central nervous system diseases among mobile phone subscribers: a Danish retrospective cohort study. PLoS ONE 2009;4(2):e4389.

(41) Harbo Poulsen A, Stenager E, Johansen C, Bentzen J, Friis S, Schuz J. Mobile phones and multiple sclerosis--a nationwide cohort study in Denmark. PLoS ONE 2012;7(4):e34453.

(42) Schuz J, Jacobsen R, Olsen JH, Boice JDJ, McLaughlin JK, Johansen C. Cellular telephone use and cancer risk: update of a nationwide Danish cohort. J Natl Cancer Inst 2006 Dec 06;98(23):1707-1713.

(43) Ahlbom A, Feychting M, Cardis E, Elliott P. Re: Cellular telephone use and cancer risk: update of a nationwide Danish cohort study. J Natl Cancer Inst 2007;99(8):655-6.

(44) Benson VS, Pirie K, Schuz J, Reeves GK, Beral V, Green J, et al. Mobile phone use and risk of brain neoplasms and other cancers: prospective study. Int J Epidemiol 2013 Jun;42(3):792-802.

(45) Benson VS, Pirie K, Schüz J, Reeves GK, Beral V, Green J. Authors' response to: The case of acoustic neuroma: comment on mobile phone use and risk of brain neoplasms and other cancers. Int J Epidemiol 2014 /02/01;43(1):275-275.

(46) Roosli M, Lagorio S, Schoemaker MJ, Schuz J, Feychting M. Brain and Salivary Gland Tumors and Mobile Phone Use: Evaluating the Evidence from Various Epidemiological Study Designs. Annu Rev Public Health 2019.

(47) Vrijheid M, Cardis E, Armstrong BK, Auvinen A, Berg G, Blaasaas KG, et al. Validation of short term recall of mobile phone use for the Interphone study. Occup Environ Med 2006 Apr;63(4):237-243.

(48) Vrijheid M, Armstrong BK, Bedard D, Brown J, Deltour I, Iavarone I, et al. Recall bias in the assessment of exposure to mobile phones. J Expo Sci Environ Epidemiol 2009 May;19(4):369-381.

(49) Lahkola A, Salminen T, Auvinen A. Selection bias due to differential participation in a case-control study of mobile phone use and brain tumors. Ann Epidemiol 2005 May;15(5):321-325.

(50) Aydin D, Feychting M, Schuz J, Andersen TV, Poulsen AH, Prochazka M, et al. Impact of random and systematic recall errors and selection bias in case--control studies on mobile

phone use and brain tumors in adolescents (CEFALO study). Bioelectromagnetics 2011 Jul;32(5):396-407.

(51) Heinavaara S, Tokola K, Kurttio P, Auvinen A. Validation of exposure assessment and assessment of recruitment methods for a prospective cohort study of mobile phone users (COSMOS) in Finland: a pilot study. Environ Health 2011 Mar 08;10:14.

(52) World Health Organization. Noncommunicable diseases and their risk factors. Available at: https://www.who.int/ncds/introduction/en/.

(53) Lauer O, Frei P, Gosselin M, Joseph W, Roosli M, Frohlich J. Combining near- and far-field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: a reference case. Bioelectromagnetics 2013 Jul;34(5):366-374.

(54) Auvinen A, Feychting M, Ahlbom A, Hillert L, Elliott P, Schüz J, et al. Headache, tinnitus and hearing loss in the international Cohort Study of Mobile Phone Use and Health (COSMOS) in Sweden and Finland. Int J Epidemiol 2019.

(55) Schuz J, Elliott P, Auvinen A, Kromhout H, Poulsen AH, Johansen C, et al. An international prospective cohort study of mobile phone users and health (Cosmos): design considerations and enrolment. Cancer epidemiol 2011 Feb;35(1):37-43.

(56) Hillert L, Ahlbom A, Neasham D, Feychting M, Järup L, Navin R, et al. Call-related factors influencing output power from mobile phones. Journal of Exposure Science and Environmental Epidemiology 2006;16(6):507-514.

(57) Goedhart G, Kromhout H, Wiart J, Vermeulen R. Validating self-reported mobile phone use in adults using a newly developed smartphone application. Occup Environ Med 2015 Nov;72(11):812-818.

(58) Persson T, Törnevik C, Larsson L, Lovén J. Output power distributions of terminals in a 3G mobile communication network. Bioelectromagnetics 2012;33(4):320-325.

(59) Ware JJ, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. Med Care 1996 Mar;34(3):220-233.

(60) Working group set up by the Finnish Medical Society Duodecim and the Finnish Society of Addiction Medicine. Treatment of alcohol abuse. Current Care Guidelines.
. 2015; Available at: https://www.kaypahoito.fi/hoi50028. Accessed 18.9., 2019.

(61) Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories. Lancet 2018;392(10159):2052-2090.

(62) Finnish Centre for Pensions. Depression leads increasingly more often to disability. 2019; Available at: https://www.etk.fi/en/tiedote/depression-leads-increasingly-more-often-to-disability/.

(63) Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. Lancet 2007 Sep 08;370(9590):851-858.

(64) Bono F, Matranga D. Socioeconomic inequality in non-communicable diseases in Europe between 2004 and 2015: evidence from the SHARE survey. Eur J Public Health 2019 02 01;29(1):105-110.

(65) Bennett DA, Landry D, Little J, Minelli C. Systematic review of statistical approaches to quantify, or correct for, measurement error in a continuous exposure in nutritional epidemiology. BMC Med Res Methodol 2017 Sep 19;17(1):146.

(66) Welk GJ, Beyler NK, Kim Y, Matthews CE. Calibration of Self-Report Measures of Physical Activity and Sedentary Behavior. Med Sci Sports Exerc 2017;49(7):1473-1481.

(67) Finnish institute for health and welfare. Morbidity
. 2018; Available at: https://thl.fi/en/web/thlfi-en/statistics/statistics-by-topic/morbidity.

(68) Lajunen H, Keski-Rahkonen A, Pulkkinen L, Rose RJ, Rissanen A, Kaprio J. Are computer and cell phone use associated with body mass index and overweight? A population study among twin adolescents. BMC Public Health 2007 Feb 26;7:24.

(69) Lepp A, Barkley JE, Sanders GJ, Rebold M, Gates P. The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. Int j behav nutr phys act 2013 Jun 21;10:79.

(70) Koivusilta L, Lintonen T, Rimpela AR. Intensity of mobile phone use and health compromising behaviours--how is information and communication technology connected to health-related lifestyle in adolescence?. J Adolesc 2005 Feb;28(1):35-47.

(71) Aherne NJ, Murphy BM. Radiation-Induced Gliomas. Crit Rev Oncog 2018;23(1-2):113-118.

(72) Bondy ML, Scheurer ME, Malmer B, Barnholtz-Sloan JS, Davis FG, Il'yasova D, et al. Brain tumor epidemiology: consensus from the Brain Tumor Epidemiology Consortium. Cancer 2008 Oct 01,;113(7 Suppl):1953-1968.

(73) Turner MC, Krewski D, Armstrong BK, Chetrit A, Giles GG, Hours M, et al. Allergy and brain tumors in the INTERPHONE study: pooled results from Australia, Canada, France, Israel, and New Zealand. Cancer Causes Control 2013 /05/01;24(5):949-960.