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A Population based Analysis of the Effect of Radiofrequency Radiation Emitted from Smart Phones on Dioptric Power of the Eye

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Abstract

Radiofrequency (RF) energy causes various side effects including cataracts and have some undesirable effects on retina and cornea. However it is still uncertain whether the amplitude-modulated RF signals from digital phones exert similar bio effects compared to that of continuous (unpopulated) RF radiation though the increase use of cellular phone generate concern to health. The purpose of the study is to assess the impact of RF radiation emitted by smartphones on dioptric power of the eye. Total 50 healthy male and female adult volunteers were recruited for this study between the age group 18-40 years. The Dioptric value of the subjects was recorded prior to study. After an interval of 30 days, the Dioptric values were recorded again for the assessment. Similarly, Visual acuity, Retinoscopy readings and keratometer reading were recorded. The study suggests that there are certain changes in parameters in the subjects after exposure to RF radiation. We can conclude prolonged use of smartphones in daily life may have a negative effect on the eyes and dioptric values changes with higher exposure to RF.

Keywords: Dioptric power; Radio frequency; Refractive error; Radiation frequency; Smartphone radiation

1. Introduction

Smartphones have become a part of everyone's life in the 21st century. However, the radiation emitted from smartphones causes many health hazards when used excessively, unfortunately, not many of us are aware of this fact [1]. Mobile phones emit Radio wave, microwave radiation, and It has thermal and non-thermal effects, which causes damage to biological tissues. The highly exposed area in our body to mobile phones is eyes compared to

the other parts of the body and therefore the radiation impacts mainly the eyes compared to other organs [1].

It is believed that mobile phones produce RF energy of non-ionizing radiation, which is too low to heat the tissues of the body, and hence is unlikely to have the same impact on human health as those produced by ionizing radiations such as X-rays.The electromagnetic field is categorized into 2 classes and they are, extremely low frequencies (ELF; 3 to 3000Hz), including high-voltage transmission lines and in-house wiring; and the another is radio frequencies (RF; 30 kHz to 300 GHz), which includes cell phones, smart electronics and devices, Wi-Fi, base stations and 5G advancements[1, 2]. The advancement of the mobile phone framework has enormously expanded the degree and extent of RF radiation exposure (RF). Cell phone and base station radiofrequency (RF) radiation can have both thermal and non-thermal effects on the human body.An antagonistic impact on people and animals is to be expected from the short-term and prolong exposure to RF radiation. In 2015 study investigated the potential influence of radiofrequency radiation emitted by mobile phones on human visual function. The research reported statistically significant alterations in visual acuity (Visual acuity, Refraction) [3]. Several research investigations have reported associations between exposure to radiofrequency (RF) radiation and biological effects. Different types of cancers, chromosomal damages and DNA changes are known to be induced through RF radiation exposure [4]. Whereas numerous studies show effects of RF radiation on the human organs, literature related RF radiation effects on eyes with special consideration to dioptric power are scarce. Another study in 2023 found that the eye's temperature increases as it is exposed to waves and the antenna angle relative to the eye is effective in the rate of specific absorption. This study also found that without observing safety points, including maintaining distance, they can cause dangerous bodily complications Therefore, in our study; an effort has been made to know the effects of RF radiation on dioptric power in human eyes [5]. Engaging in cell phone conversations may narrow a driver's peripheral visual field, potentially reducing their awareness of surrounding traffic and increasing the risk of accidents. Cell phone conversations tend to artificially constrict the peripheral awareness as measured by a visual field which recommends that cell phone use while driving can decrease the perceptual visual field, making the driver less aware of the surroundings and more susceptible to accident [6]A study carried out in 2005 found that prolog use of mobile phone may cause blurring of vision, secretion of the eyes, inflammation in the eyes and watering of the eyes.[7]

A study surveyed 229 university students in Kocaeli, Turkey, using a questionnaire in 2008. Chi-square test with Yates correction was performed to analyze six ocular symptoms experienced while using mobile phones. The symptoms studied were blur vision, redness of the eyes, vision disturbance, secretion of the eyes, inflammation in the eyes, and lachrymation of the eyes. The results showed a significant increase in blurring of vision among mobile phone users with possession >2 years compared to those with tenure <2 years. Additionally, women complained more often of inflammation in the eyes than men [8]. Mobile phones use has an impact on the dynamics of tear fluid (TBUT and S1T) and the thickness of the cornea in the eye. This can be attributed to the radiations and/or thermal effects emitted by mobile phones.[9]. Therefore, in our study, an effort has been made to know the effects of RF radiation on dioptric power in human eyes.

2. Methodology

Study design: This is a single randomized single center study, single blind experiment which was conducted Out Patient Department (OPD), Department of Optometry, RIPANS, where students of RIPANS and participants were from different parts of Mizoram. The study was approved by Human ethical Committee, Mizoram University.

Participants: Eligibility criteria of the participants were ≥18 years old. Written consent was obtained from the participant and participants were explained about the study and their role.

Recruitment: The inclusion criteria followed were users of smart phones, between the age group of 18-40 years, visited optometry Out Patient Department (OPD) in our Institute. The exclusion criteria followed were, patients who discontinued treatments in our hospital, who had diagnosed existing ophthalmological diseases, patients with under nutritional status.

Study Outcomes: This study was conducted between May 2021 and December 2021. First, the initial recordings were taken and then follow up measurements were recorded. Between these two recordings (initial and follow-up), the included participants have used smart phones extensively daily basis around 4-5 hours. After applying exclusion inclusion and criteria, 50 patients were recruited for the study. We have recorded initial measurements of Visual Acuity, Retinoscopy, Refraction, Keratometer and. After 2-3 months, follow up study was carried out and the measurements were recorded. The study was intended to find out the negative impact of RF radiation on the patients' eyes especially dioptric power after usage of smart phones.

For the statistical analysis Graph pad prism 7.01 software was used. Data within the Aizawl, Mizoram were analyzed by using a paired t test. 5% significance for the statical analysis was taken between the groups. A number of instruments are being utilized to perform the procedures.

3. Results and Discussion

Visual acuity (Snellen's chart) is the resolving power of the eye. By using this chart, we have estimated the distant vision of the volunteer. Snellen chart kept at a distance of 6 m (Figure 1) can determine distant visual acuity. Autorefractometer (Nidek, ARK-510A) is a computer-based device to know the refractive condition of the eye whether it is myopic, hyperopic or astigmatic with eye dioptric power as well as axis**.**

Figure 1 : Snellen chart

In addition, the radius of corneal curvature and Inter pupillary distance can be observed using an Autorefractometer equiped with He-Ne laser beam **(**Figure 2**).**

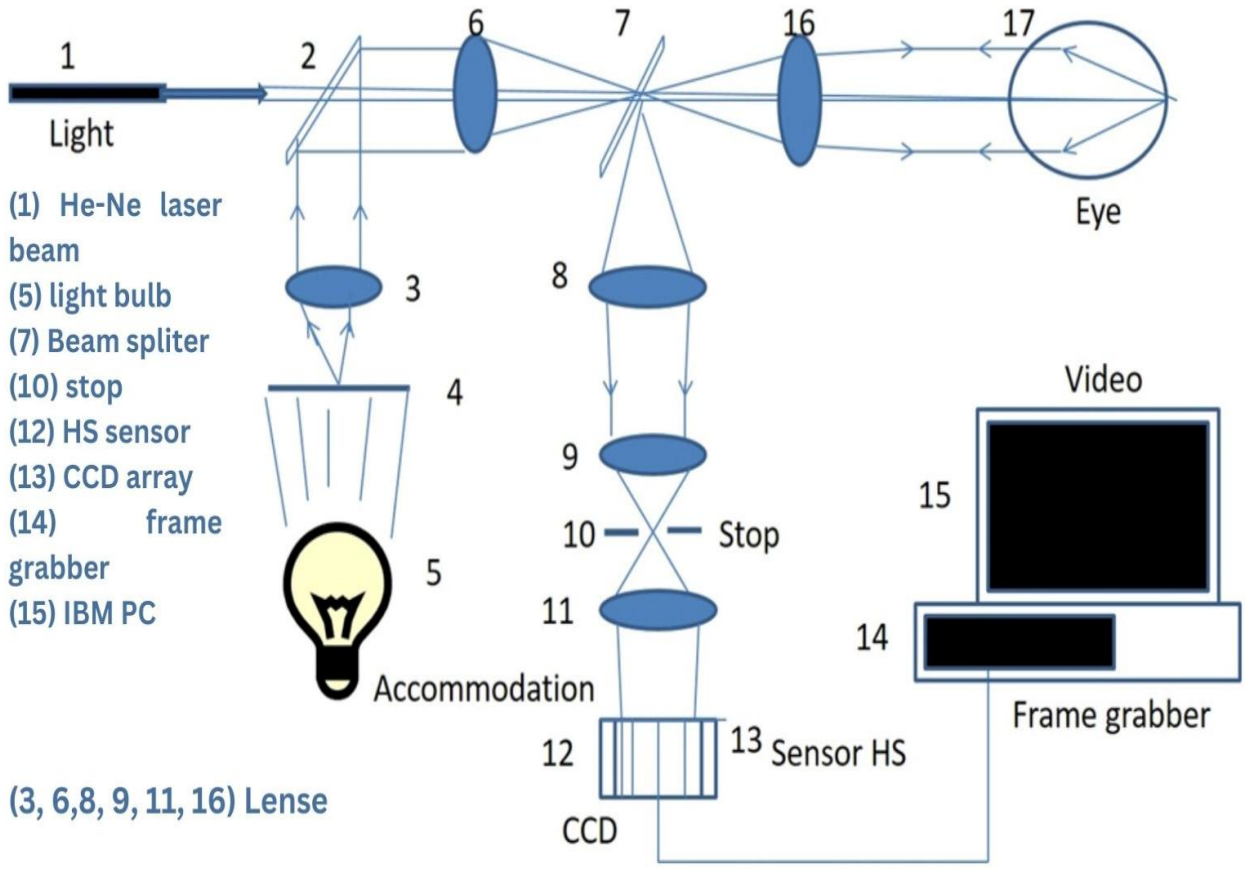

Figure 2 : A schematic diagram of Autorefractometer equiped with He-Ne laser beam

Retinoscope (Heine Beta 200) is an instrument to know the refractive error of the eye whether it is nearsighted, hyperopic or astigmatic with powers as well as axis. Retinoscopy depends on the way that when light is reflected from a mirror into the eye, the bearing wherein the light will traverse the understudy will rely on the refractive condition of the eye (Figure 3).

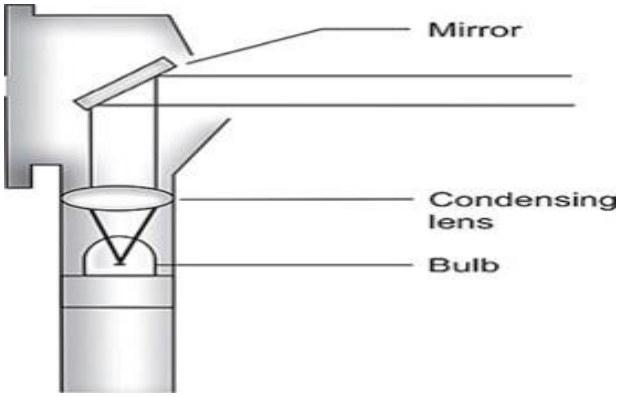

Figure 3 : Streak Retinoscope

A device (Bausch &Lomb) uses the refractive properties of the cornea to measure the radius of curvature and power of different meridians of the cornea. By measuring the size of the image, formed by reflection from the cornea, an object of known size and position, a measurement of the radius can be measured (figure 4).

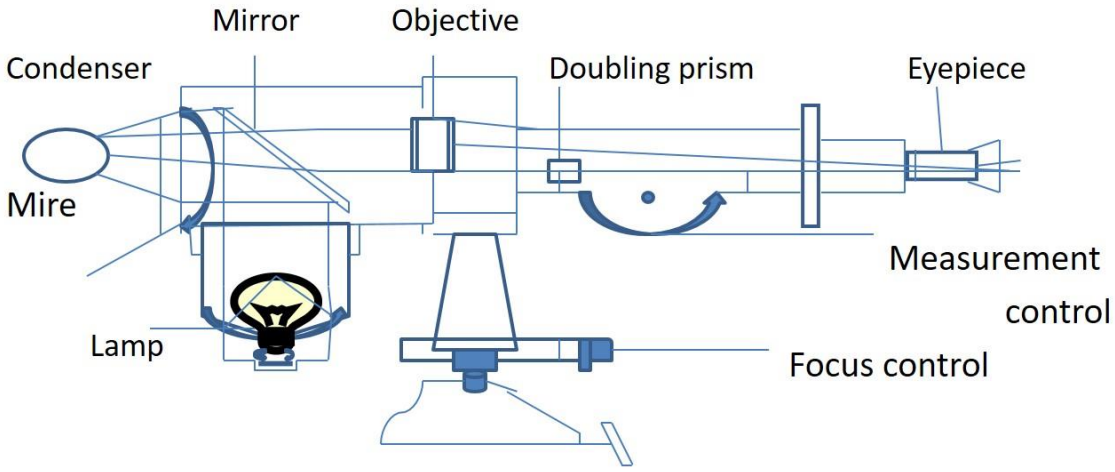

Figure 4 : Schematic diagram of Keratometer

The study has found that the use of smartphones has a significant effect on the eyes due to emission of radiation in the patients who were avid users only. The study recorded the several parameters (visual acuity, retinoscopic findings, refraction findings and keratometer) during each patient's first visit. Again, the follow up study was done where we recorded the same parameters for the same patients.

Visual acuity of OD and OS has been represented in Table 1 and Table 2 respectively. In our study 50 persons underwent a visual acuity test before and 30 days after using a mobile phone. The results suggest that the visual acuity of the participants decreased after using the mobile phones. The mean percentage of visual acuity OD of 6/6 before using the mobile phone was 25.33±1.15%, while the mean percentage of visual acuity after using the mobile phone in OD was 15.33±1.15%. The result suggests that there was a significant decreased in 6/6 visual acuity in OD. Similar results could be observed in visual acuity 6/6(P) and 6/9(P) in OD. However, % of visual acuity is increased in OD were 6/9, 6/12, 6/12(P),6/18, 6/18(P),6/24, 6/36 and 6/60. The increased percentage of visual acuity % may be due to the shifting of visual acuity from lower higher. There are some evidences to suggest that prolonged mobile phone use may have a negative impact on visual acuity [10]. However, the

extent of this impact can vary depending on a number of factors, including the duration and frequency of mobile phone use, as well as the individual's overall eye health. Prolonged exposure to the blue light emitted by mobile phone screens can cause eyestrain, fatigue, and headaches [11]. Additionally, some studies have suggested that the blue light exposure may contribute to the development of age-related macular degeneration and other vision problems over time [12].Similarly, changes in visual acuity were observed in OS among the population under study.

Table 1 Visual Acuity, right Eye (OD) of the subjects

Visual Acuity	**Initial (OD) (%)**	**After (OD) (%)**	**P-value**
6/6	25.33±1.15	15.33±1.15	<0.0004
6/6(P)	20±1.15	16.66±1.15	0.02
6/9	4±1.15	23.33±1.15	<0.0001
6/9(P)	10.66±1.15	6.66±1.15	0.013
6/12	0.66±0.15	13.33±1.15	<0.0001
6/12(P)	2±0.75	2.66±1.15	0.45
6/18	4±1.35	9.33±1.15	<0.0001
6/18(P)	0±0	0.66±1.15	-
6/24	0±0	2±0	-
6/24(P)	2±0	0±0	-
6/36	0±0	4±0	-
6/36(P)	2.66±0	0±0	-
6/60	2±1.3	6±1.75	<0.0001
6/60(P)	2±0	0±0	
	Data are represented as Mean±SD; significance was taken at P≤0.05.		

The study showed a change in dioptric power of participants during the follow up. The distribution of this change for each participant is represented in figure 5. The boxplot diagram figure 6 shows the various parameters like minimum, maximum, standard deviation (SD) a mean of the changes in Dioptric Power in each case (Both the eyes, left eye and right eye). The changes in Dioptric Power after usage of smartphones were found in several participants.

Table 2 Visual Acuity, left eye (OS) of the subjects

Visual Acuity	**Initial (OS) (%)**	**After (OS) (%)**	**P-value**
6/6	16.66±1.15	7.14±2.31	0.003
6/6(P)	15.33±1.15	5.69±2.31	0.003
6/9	23.33±1.15	14.83±2.31	0.0047
6/9(P)	6.66±1.15	23.45±2.31	<0.0004
6/12	13.33±1.15	13±1.15	0.74
6/12(P)	2.66±1.15	11.33±1.15	0.0008

6/18	10±1.15	12.5±1.15	0.056
6/18(P)	0±0	10.85±1.15	-
6/24	2±0	1±0	-
6/24(P)	0±0	0.4±0	-
6/36	4±0	0.5±0	-
6/36(P)	0±0	3±0	-
6/60	6±0	0±0	-
6/60(P)	0±0	6±0	-
Data are represented as Mean±SD; significance was taken at P≤0.05.			

Table 3 represents the retinoscopic readings of the subjects in both eyes. Retinoscopy is a objective test used to evaluate the refractive error of the eye, which includes the spherical and cylindrical power [13]. The given data suggests that there is a change in the average spherical power of the eye after 30 days of mobile phone exposure. The initial average spherical power of the eye in the OD is -0.51±0.71, which means that the mean spherical power is slightly nearsighted, with a range of ±0.71 diopters (D) around the mean. After 30 days of mobile phone exposure, the average spherical power in the OS increased to -0.80±0.90, indicating a greater degree of nearsightedness compared to the initial measurement. The range also increased to ±0.90 D, suggesting a wider distribution of refractive errors.

Table 3 Retinoscopy readings

	Initial (OD)	**After (OD)**	**P-value**
Spherical	-0.51±0.71	-0.80±0.90	0.07
Cyllinder	-0.39±0.49	-0.38±0.66	0.93
	Initial (OS)	**After (OS)**	
Spherical	-0.57±0.57	-0.86±0.85	0.047
Cyllinder	-0.5±0.28	-0.54±0.27	0.47
Data are represented as Mean±SD; significance was taken at P≤0.05.			

Based on the given data, the average cylindrical powers of the OD of the 50 subjects were -0.39±0.49 before mobile phone exposure, and -0.38±0.66 after 30 days of exposure.The small changes in cylinder powers between the initial and post-exposure measurements are within the range of normal variability and could be due to measurement error or other factors unrelated to mobile phone use.

The results suggest that there was a statistically significant change in the spherical power of the OS after 30 days of mobile phone exposure. The average spherical power of the OS increased from -0.57 ± 0.57 to -0.86 ± 0.85. This means that, on average, the participants had a more nearsighted (myopic) refraction after 30 days of mobile phone exposure.

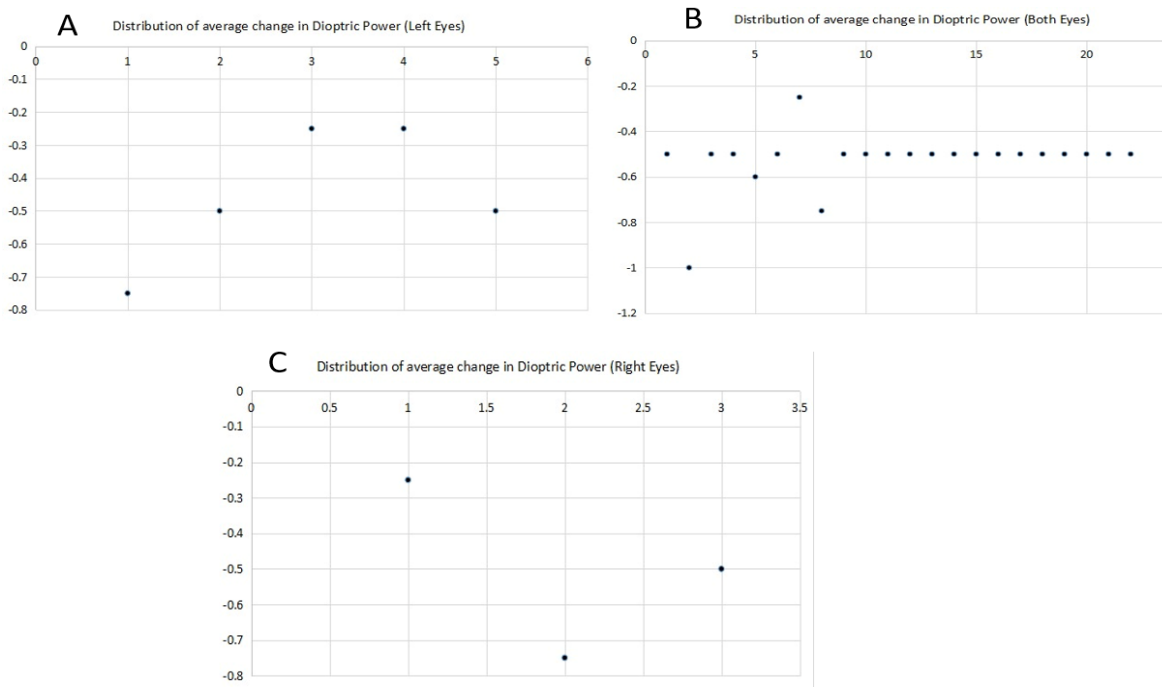

Figure 5 : The piecharts showing the findings of the percentages of patients for each parameter in the follow-up study (a) Distribution of average change in Dioptric Power (Left Eye) (b) Distribution of average change in Dioptric Power (Both Eye) (c) Distribution of average change in Dioptric Power (Right Eye)

However, it is important to note that the magnitude of the change in spherical power was relatively small, with an average increase of only 0.29 diopters. The results of the retinoscopic reading of 50 subjects in average, shows that the average cylinder power of the eye in initial (OS) was -0.5±0.28 and after 30 days of mobile phone exposure, it was -0.54±0.27.This difference of 0.04 diopters in cylinder power between the initial reading and after mobile phone exposure may not be clinically significant, as it falls within the range of measurement error or variability of the technique used. The standard deviation of the readings is relatively low, which suggests that the measurements were consistent.

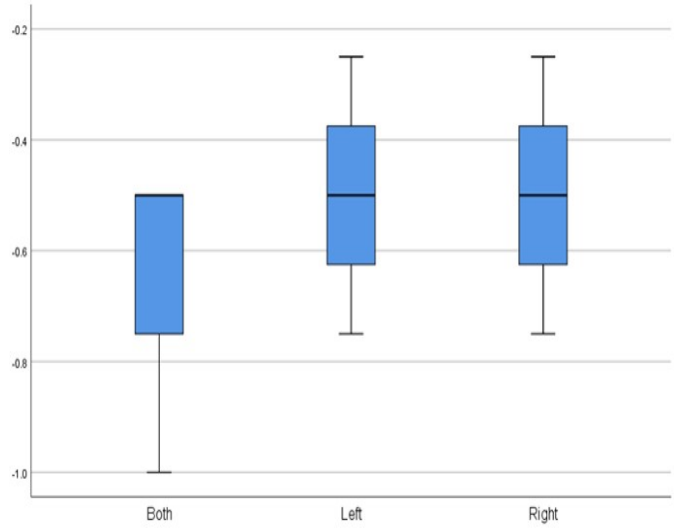

Figure 6 : Distribution of changes of Dioptric power in left, right and both the eyes after usage of smartphone (exposure of radiation)

It is well-established that blue light emitted from electronic devices, such as mobile phones, can have a negative impact on ocular health, including the development of myopia. The increase in the degree of nearsightedness observed in the study is likely due to the prolonged exposure from mobile phones [14].

Table 4 represents the keratometry readings**.** Keratometry readings are used to measure the curvature of the cornea, which is the clear, outermost layer of the eye**.** From the given data, we can see that the average K1 reading of 50 subjects in the OD eye initially was 7**.**7 ± 0**.**20, and after 30 days of mobile phone exposure, the K1 reading was 7**.**71 ± 0**.**21**.** The difference between these two measurements is very small, and it is within the range of measurement error**.** Therefore, it is not likely that mobile phone exposure has caused a significant change in the corneal curvature of these subjects**.** However, it is important to note that this study only considers the K1 readings in the OD eye, and it is possible that mobile phone exposure could have had an effect on other aspects of the eye's physiology**.** Additionally, this study only looks at short-term exposure to mobile phones, and it is possible that long-term exposure could have more significant effects**.** In the given scenario, the K2 reading of 50 subjects in average in the right eye **(**OD**)** before and after 30 days of mobile phone exposure are provided**.** The mean K2 reading before exposure is 7**.**6±0**.**18, while the mean K2 reading after exposure is 7**.**6±0**.**21**.** Here, the value 7**.**6 is the mean K2 reading, and the values 0**.**18 and 0**.**21 are the standard deviations of the measurements**.** Since the mean K2 reading is the same before and after exposure, it suggests that there is no significant change in the curvature of the cornea due to mobile phone exposure**.** The study evaluated the changes in the K1 readings of 50 subjects after 30 days of mobile phone exposure in the left eye **(**OS**).** The average K1 reading in OS initially was 7**.**71 ± 0**.**20, and after 30 days of mobile phone exposure, it was 7**.**69 ± 0**.**19**.**The difference between the two means is very small, only 0**.**02, and the standard deviation of each measurement is also small, 0**.**20 and 0**.**19, respectively**.** This indicates that there was not a significant change in the K1 readings after 30 days of mobile phone exposure in the left eye**.**

Table 4 Keratometer readings

Keratometer (OD)			
	Initial (OD)(mm)	After (OD)	P- Value
K1 (mm)	7.7±0.20	7.71±.21	0.809
K2(mm)	7.6±0.18	7.6±0.21	>0.999
Retinoscopy readings (OS)			
	Initial	After	
K1 (mm)	7.71±0.20	7.69±0.19	0.90
K2(mm)	7.60±0.16	7.58±0.16	0.88

Data are represented as Mean±SD; significance was taken at P≤0.05.

RF radiation exposure may have benign or adverse biological impacts due to the heating of cells and tissues. Thermal damage from both confines and entire body heating

varies. The central nervous system, testis and lens of the eye seem to be especially delicate, because of a restricted ability to disperse heat eyes are more susceptible to heat-induced damage [15, 16]. Thermal effects from microwave radiation have been reported to cause cataract and have adverse effects for the cornea, retina and other ocular systems, but effects of non-thermal radiations are not well understood [17]. Investigations on non-thermal impacts of RF radiation from cell phones are moderate, and analysis has suggested further investigation of consequences for the eye lens and lens epithelial cells [18, 19]. Electromagnetic fields from microwave radiation adversely affect the eyes. One review warned that high recurrence microwave electromagnetic radiation from cell phones and other present-day gadgets has potential harmful effects on eye tissues, however, its impact on the lens epithelium is still unidentified [4,17]. Many researchers demonstrated that the lens of the eye is highly sensitive to heat, and damage can occur even from a solitary intense exposure. Consequently, there is a possible system for RF to prompt cataract incidence [20]. Epidemiological exploration has been limited, particularly to exposure evaluation. Exposure of electromagnetic radiation from smartphones is on rise as there is the advent of new generation devices and signals, due to which the hazard is also more than before in terms of damage to the environment and human body, especially when the legal emission values are not maintained [21]. In our study, after exposure of mobile phone for 30 days the average population % shows changes in visual acuity in both eyes. There were significant changes in average retinoscopic reading in the population indicates that the harmful effects in eyes. However, there was no significant change in keratometry reading which indicates thew there was no such harmful effects on curvature of the cornea.

4. Conclusion

Smartphone usage by almost all ages has increased substantially. Due to demands of increased speed and efficiency, the strength of RF signals has been on the rise, hence, more effects on eyes health. Current study has shown that avid users of smartphones have experienced more occurrences of ophthalmologic abnormalities. The study has evaluated the findings of visual acuity, refraction, retinoscopy and keratometer. All these parameters have been shown to deviate except keratometry readings during the follow-up study. The study contained 50 participants and this does not represent the entire population. Therefore, we suggest that a large-scale future study with advance technology is required to get more data to compare the results and make more awareness among the population about the impact of RF on eyes. The study also concludes that there are significant effects on the ophthalmologic parameters such as dioptric power after usage of smartphones. Hence it is essential to choose a good quality smartphone with legally compliant SAR value. Therefore, this study brought forward an essential finding which needs to be addressed by the smartphone manufacturers and the governments.

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Conflict of Interest: The authors declare there is no conflict of interest.

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