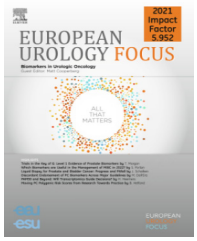
EUROPEAN UROLOGY FOCUS xxx (xxxx) xxx–xxx

available at www.sciencedirect.com
journal homepage: www.europeanurology.com/eufocus



Andrology

# Effect of Radiofrequency Electromagnetic Radiation Emitted by Modern Cellphones on Sperm Motility and Viability: An In Vitro Study

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**Article info**

*Article history:*
Accepted November 2, 2022

***Associate Editor: Christian Gratzke***

*Keywords:*
Cellphones
Radiofrequency electromagnetic radiation
Sperm
Male fertility
Environmental pollutants

**Abstract**

*Background:* Cellphones emit radiofrequency electromagnetic radiation (RF-EMR) for transmission of data for social media communication, web browsing, and music/podcast streaming. Use of Bluetooth ear buds has probably prolonged the time during which cellphones reside in the trouser pockets of men. It has been postulated that RF-EMR increases oxidative stress and induces free radical formation.

*Objective:* To investigate the effect of wireless-spectrum (4G, 5G, and WiFi) RF-EMR emitted by modern smartphones on sperm motility and viability and explore whether these effects can be mitigated using a physical barrier or distance.

*Design, setting, and participants:* Semen samples were obtained from fertile normozoospermic men aged 25–35 yr. A current-generation smartphone in talk mode was used as the RF-EMR source. A WhatsApp voice call was made using either 4G, 5G, or WiFi wireless connectivity. We determined if exposure effects were mitigated by either a cellphone case or greater distance from the semen sample.

*Outcome measurements and statistical analysis:* The semen samples were analyzed according to 2010 World Health Organization laboratory guidelines. Statistical analysis was performed using SPSS v.28.

*Results and limitations:* We observed decreases in sperm motility and viability with WiFi exposure but not with exposure to 4G or 5G RF-EMR. With large variability among smartphones, continued research on exposure effects is needed.

*Conclusions:* Our exploratory study revealed that sperm motility and viability are negatively impacted by smartphones that use the WiFi spectrum for data transmission.

*Patient summary:* We looked at the effect of cellphone use on sperm motility and viability. We found that cellphones using WiFi connectivity for data usage have harmful effects on semen quality in men.



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https://doi.org/10.1016/j.euf.2022.11.004
2405-4569/

Please cite this article as: K.Y. Chu, K. Khodamoradi, R. Blachman-Braun et al., Effect of Radiofrequency Electromagnetic Radiation Emitted by Modern Cellphones on Sperm Motility and Viability: An In Vitro Study, Eur Urol Focus (2022), https://doi.org/10.1016/j.euf.2022.11.004

## 1. Introduction

The use of mobile phones has revolutionized the way in which we communicate and work in the modern world. The use of mobile phones and other wearable wireless technologies has gradually increased over the past several decades. This has led to increased contact with devices that emit radiofrequency electromagnetic radiation (RF-EMR) that is capable of being absorbed by the human body [1]. Cellular technology now allows high-speed data connectivity via RF-EMT on 4G, 5G, or WiFi wireless networks, in contrast to historical connectivity via cellular networks. In addition to local radiation exposure because of direct contact with devices, the advent of 5G and WiFi communication networks has led to the propagation of RF-EMR in public spaces [2]. Bluetooth ear buds and global positioning system (GPS) tracking have also significantly prolonged the time for which cellphones are kept in men's pockets in proximity to male genitourinary structures. The testicles, the site of sperm production, are particularly vulnerable to the RF-EMR emitted and the heat generated by these devices, which have well-known deleterious effects on spermatogenesis. The RF-EMR and elevated temperature may damage sperm structure or function via several mechanisms, including an increase in the production of reactive oxygen species (ROS), which can induce DNA damage [3,4]; histological changes in the testes [5]; apoptosis of sperm cells [6]; changes in the cell cycle [7]; and impairment of spermatogenesis due to an increase in local body temperature [8].

Agarwal et al [9] found that ejaculated sperm exposed to RF-EMR showed decreases in sperm motility and viability. The most recent study on this topic, published in 2015, showed concordant results of negative impacts on sperm motility [4]. Two systematic analyses have been performed. One found reductions in sperm motility, viability, and concentration across in vitro and in vivo studies, while the other only found deleterious effects on mature sperm in vitro [10,11]. We hypothesized that all types of RF-EMR cause deleterious effects, although mitigation is possible by increasing distance from the device emitting radiation and the use of a protective cover. We sought to understand the effects of RF-EMR emitted by contemporary cellphones on sperm motility and viability.

## 2. Patients and methods

The study protocol was approved by the institutional review board of the University of Miami Miller School of Medicine (reference 20130891). This experimental observational study was performed in two parts. In both experiments, we recruited patients aged between 25 and 35 yr who were fertile and normoozspermic at the time of vasectomy. Potential subjects with a prespecified list of previous exposures that are known to impact semen parameters (Table 1) were excluded from the study. Semen samples were collected by participants via masturbation after an abstinence period of at least 2 d. After specimen collection, initial macroscopic (color, liquefaction, viscosity, pH) and microscopic (concentration, total motility, progressive motility, total motile sperm count, and viability) semen parameters were meticulously analyzed according to the 2010 World Health Organization laboratory manual. All semen analyses were performed by the same laboratory technicians for the duration of the study. For all experiments, a current-generation Apple iPhone with the most recent software was used. A map of cellphone towers close to the experimental laboratory is shown in Figure 1. At all times, RF-EMR exposure was validated using a calibrated detection meter (Trifield TF2; AlphaLab Inc, Salt Lake City, UT, USA). During each exposure, other data applications were deactivated.

In the first experiment, we investigated the impact of exposure to 4G, 5G, and WiFi data transmission on semen parameters. We recruited nine men for this experiment. After standard semen analysis, an equivalent proportion of total seminal volume was added to each of five 24-well plates. One plate was not exposed to cellphone-generated radiation and was left under ambient room conditions. Each of the other plates was exposed to 4G cellphone data use, 5G cellphone data use, WiFi calling (WhatsApp voice call), or cellular network calling for 6 h.

In the second experiment, we investigated the impact of distance from the radiation source on semen parameters, for which we recruited 18 new men. After standard semen analysis, an equivalent proportion of total seminal volume was added to each of four 24-well plates. One plate was not exposed to cellphone-generated radiation and was left under ambient room conditions as the control. Each of the other three plates was exposed to WiFi calling (WhatsApp voice call) for 6 h, with variation in the degree of exposure: direct exposure involved placing the smartphone directly on top of the plate; barrier coverage involved placing the smartphone into a hard-shell plastic case; and distance separation involved placing the phone without a case 4 inches above the plate.

### 2.1. Outcomes

The primary endpoint of this study was the effect of continuous RF-EMR exposure on sperm parameters, including total motility, progressive motility, and viability. The secondary endpoint was evaluation of methods for mitigating the effects of RF-EMR on sperm quality.

### 2.2. Statistical analyses

Statistical analysis was performed using SPSS v.28. Continuous variables are reported as the median and interquartile range. In accordance with the non-normal data distribution, a nonparametric statistical test was used to compare median values (Mann-Whitney U test).

## 3. Results

### 3.1. Control versus 4G/5G

We found no negative impact of 4G/5G exposure on sperm motility or viability in comparison to the control ($n$ = 9; Table 2).

**Table 1 – List of exclusion criteria**

| |
|---|
| History of tobacco use |
| History of exogenous hormone use (testosterone replacement therapy) |
| Alcohol consumption |
| Varicocele(s) |
| Orchitis |
| Hypertension |
| Diabetes mellitus |
| Recent febrile illness |
| Prior genitourinary surgery |

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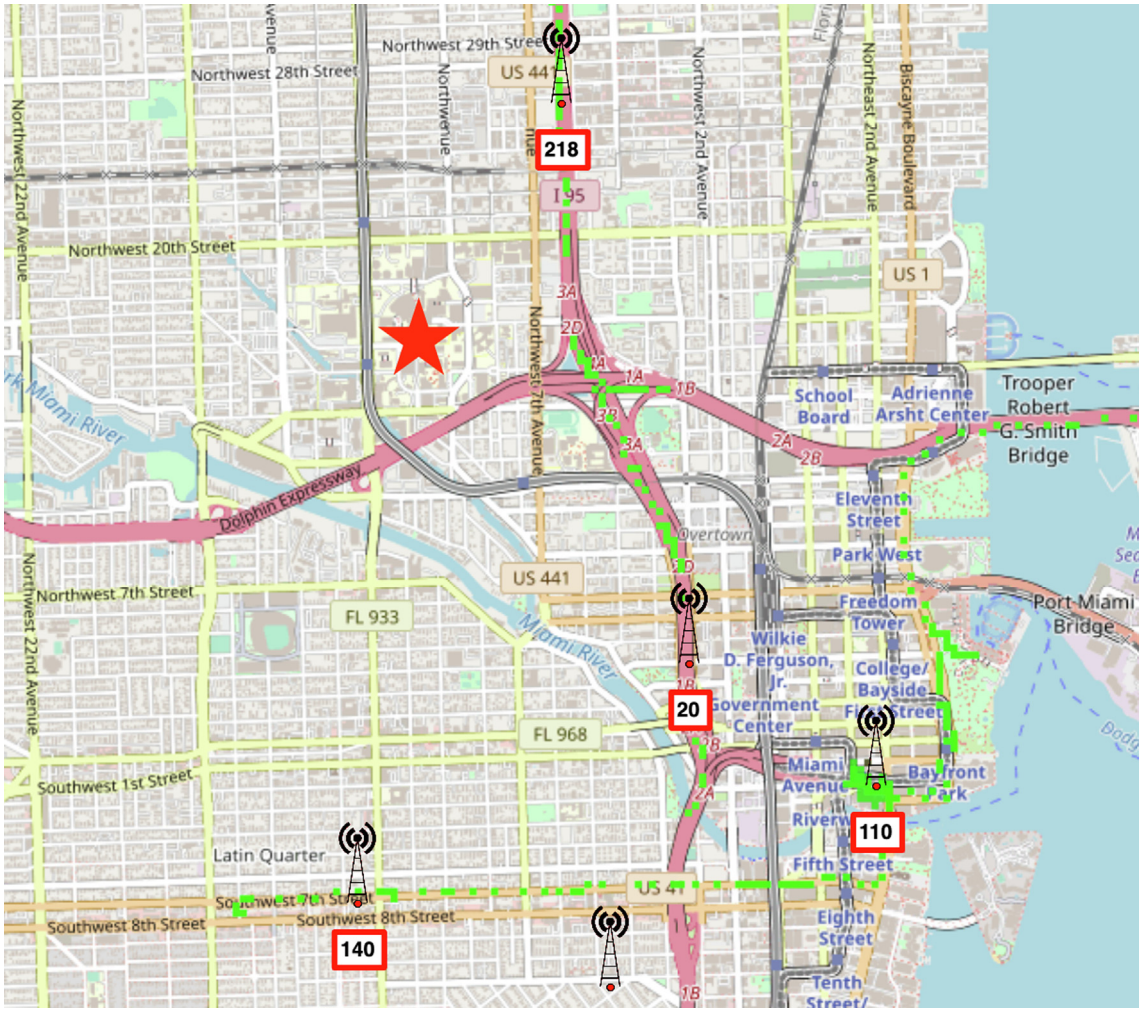


**Fig. 1 – Map of cellphone tower locations. The star indicates the approximate location of the hospital where the experiments took place.**

**Table 2 – Overall comparison of total motility, progressive motility, and viability among the different exposure modalities.[a] Bolded values represent p values that attained significance (p < 0.05).**

| **4G and 5G** | | | | | | |
|---|---|---|---|---|---|---|
| | Control | 4G | 5G | *p* value vs control | | |
| | (*n* = 9) | (*n* = 9) | (*n* = 9) | 4G | 5G | |
| Total motility (%) | 41 (26.5–53) | 40 (22–48) | 35 (21–42.5) | 0.353 | 0.216 | |
| Progressive motility (%) | 40 (22.5–53) | 40 (18–48) | 33 (19.5–42.5) | 0.288 | 0.185 | |
| Viability (%) | 53 (40–60.5) | 40 (28–59.5) | 39 (32 -51) | 0.427 | 0.085 | |
| **WiFi and CN** | | | | | | |
| | Control | WiFi | CN | *p* value vs control | | |
| | (*n* = 9) | (*n* = 9) | (*n* = 9) | WiFi | CN | |
| Total motility (%) | 50 (43–57.5) | 41 (35.5–45.5) | 46 (34.5–53) | **0.030** | 0.171 | |
| Progressive motility (%) | 50 (43–57.5) | 38 (35–43) | 46 (34.5–53) | **0.024** | 0.171 | |
| Viability (%) | 60 (52–66) | 47 (43–52) | 51 (48.5–60.5) | **0.003** | 0.063 | |
| **Distance** | | | | | | |
| | Control | DE | CB | Distance | *p* value vs control | |
| | (*n* = 18) | (*n* = 18) | (*n* = 18) | (*n* = 18) | DE | CB | Distance |
| Total motility (%) | 56 (24–63.5) | 17 (11.8–27.8) | 34 (17.5–49) | 35 (16.8–49.8) | **<0.001** | 0.079 | **0.022** |
| Progressive motility (%) | 54 (20.8–63.5) | 12 (3.5–27.3) | 32.5 (17–48.8) | 31 (9.5–49.3) | **<0.001** | 0.057 | **0.013** |
| Viability (%) | 65 (38.8–68) | 30 (14.8–39.3) | 42 (21.8–50) | 40.5 (20–49.8) | **<0.001** | **0.004** | **0.002** |

CB = covered with a barrier (cellphone case); CN = cellular network; DE = direct exposure.
[a] Motility and viability results are presented as median (interquartile range).

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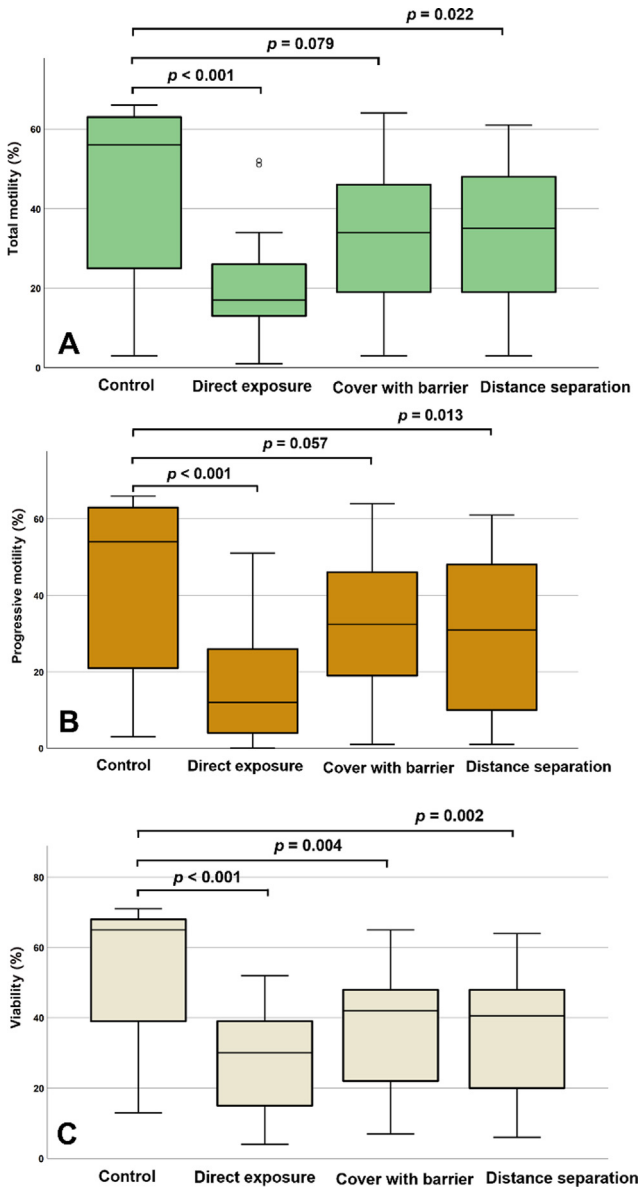


**Fig. 2 – Results for mitigation against the effect of WiFi exposure on semen parameters.**

### 3.2. *Control versus WiFi/cellular network calling*

For ejaculated semen samples exposed to WiFi we noted a negative impact on total and progressive sperm motility in comparison to the control group. Total motility was 41% in the WiFi exposed group, in comparison to 50% for the control group ($n$ = 9; $p$ = 0.030). Progressive motility was 38% for the WiFi group and 50% for the control group ($n$ = 9, $p$ = 0.024). Sperm viability also significantly differed between the WiFi and control groups (47% vs 60%; $n$ = 9; $p$ = 0.003; Table 2). There was no impact on sperm total motility, progressive motility, or viability in the cellular network group in comparison to the control group.

### 3.3. *Effect of RF-EMR mitigation strategies*

Since WiFi exposure had deleterious effects on sperm motility and viability, we studied potential mitigation strategies (Table 2). Direct exposure to WiFi led to a significant decrease in all three parameters evaluated. When a cellphone case was in place, total and progressive sperm motility were preserved, but sperm viability decreased to 30%, in comparison to 65% for the control group ($n$ = 18; $p$ = 0.004). A distance of 6 inches between the cellphone and the sample resulted in a significant decrease in total motility to 35%, in comparison to 56% for the control group ($n$ = 18; $p$ = 0.022) and progressive motility decreased to 31%, compared to 54% in the control group ($n$ = 18; $p$ = 0.013). Viability decreased to 40.5%, compared to 65% for the control group ($n$ = 18; $p$ = 0.002). These comparisons are depicted in Figure 2.

## 4. Discussion

Recent studies showed that RF-EMR emitted by cellphones has negative effects on semen quality [12,13]. In our in vitro experimental study we investigated the effects of 4G/5G and WiFi RF-EMR emitted from modern cellphones on semen parameters. We found that 4G/5G RF-EMR exposure had no negative effects on semen quality, but WiFi RF-EMR exposure negatively affected sperm motility and viability. We also investigated use of a cellphone case as a physical barrier and separation at a distance of 6 inches as potential measures to mitigate the harmful effects of WiFi exposure. We observed that the physical barrier preserved sperm motility, but sperm viability was still decreased in comparison to the control group. A separation distance of 6 inches mitigated some of the negative impact of cellphone RF-EMR on sperm quality.

One possible mechanism for these changes is the thermal effects of RF-EMR on sperm, which ultimately hampers the sperm quality. There has been a steady increase in the use of wireless ear buds and communication technologies, and cellphones are now often kept in men's trouser pockets, close to the testes, during use [14]. A long duration of close contact with a cellphone can excessively increase the temperature of the testicular area. Another possibility is non-thermal effects of RF-EMR, whereby an increase in the amount of ROS may lead to DNA damage in sperm [15]. The reason for an increase in ROS could be impairment of the mitochondrial electron transport chain, which would compromise sperm parameters. Although ROS play a crucial role in the sperm capacitation, the acrosome reaction, and sperm binding to the zona pellucida of oocytes for successful fertilization, excess ROS can be damaging [16]. Previous studies support the hypothesis that elevated mitochondrial ROS and DNA damage in sperm decrease sperm motility and viability [3,17]. These two possibilities are depicted in Figure 3.

Our study is not without limitations. First, our small sample size of 18 introduces potential sources of bias. We did not collect demographic data for these patients in order to maintain privacy, so the results may be subject to confounding bias. As the first of its kind at our institution, this small trial was a pilot study to validate our experimental model and procedures. We hope that further studies on the effects of RF-EMR on semen parameters can be performed on larger samples to validate our initial results. Sec-

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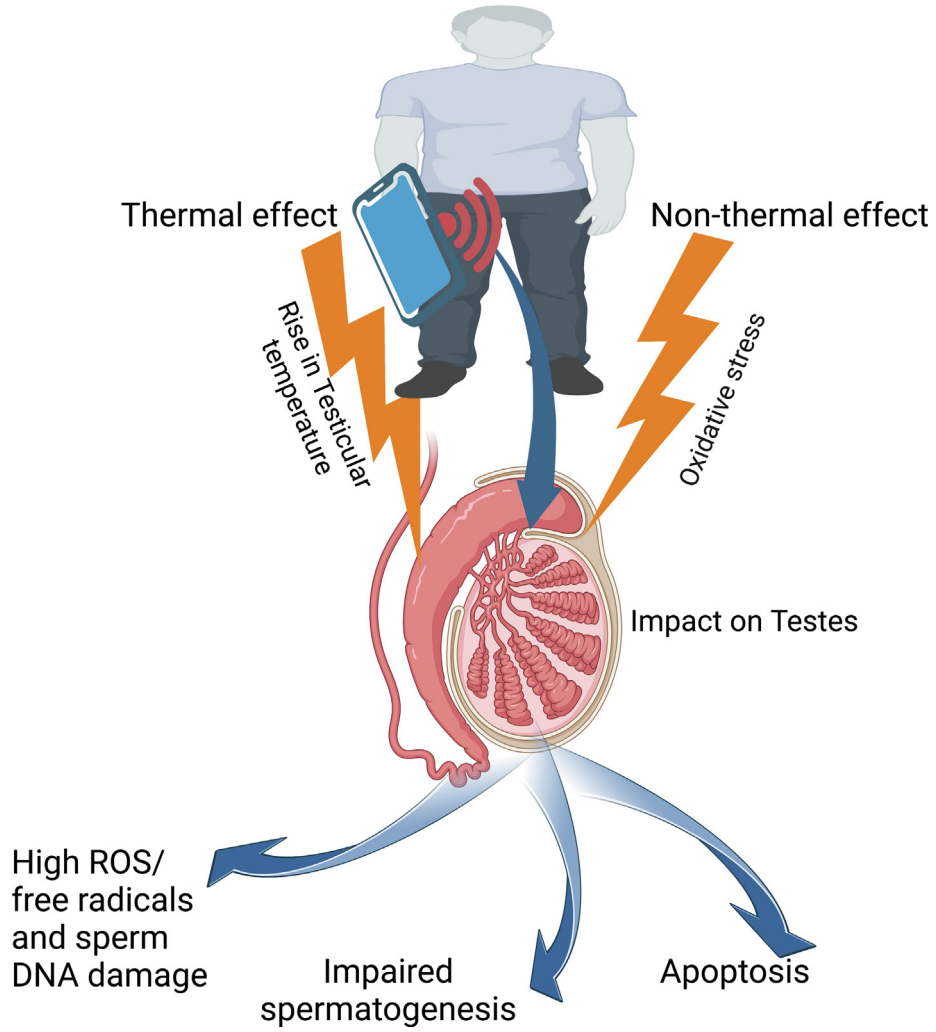


**Fig. 3 – Proposed pathophysiology of the thermal and nonthermal effects of radiofrequency electromagnetic radiation on sperm (graphic created with BioRender.com). ROS = reactive oxygen species.**

ond, we recognize that other potential variables, including temperature and radiation strength, could play a role in inducing changes in semen parameters. For this preliminary study, we were only interested in a single variable (radiation); future work should investigate the impact of temperature and radiation strength on changes in semen. This was an exploratory in vitro study, and further in vivo studies in animal models should be performed to further evaluate the impact of radiation on semen parameters.

## 5. Conclusions

Our study revealed that 4G/5G RF-EMR emitted by a contemporary cellphone did not have negative effects on sperm motility and viability. By contrast, WiFi exposure did have negative effects. During data use, there may be an increase in heat dissipated by a cellphone, depending on the power required to connect to the source. Interestingly, we observed varying effects of WiFi on sperm parameters, depending on the environment. We posit that a greater distance from the wireless router results in a need for more cellphone power, which may lead to greater heat production and result in negative effects on sperm motility and viability. Mitigation measures such as use of a cellphone case and increasing the distance between the cellphone and the sperm sample lessened the effects. Further studies need to be performed to better understand the effects of RF-EMR on sperm parameters.

***Author contributions***: Kevin Y. Chu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

*Study concept and design*: Chu, Ramasamy.
*Acquisition of data*: Khodamoradi, Bidhan.
*Analysis and interpretation of data*: Ramasamy.
*Drafting of the manuscript*: Chu, Dullea, Campbell.
*Critical revision of the manuscript for important intellectual content*: Khodamoradi, Bidhan, Ramasamy.
*Statistical analysis*: Blachman-Braun, Campbell.
*Obtaining funding*: None.
*Administrative, technical, or material support*: Israeli, Kim, Zizzo.
*Supervision*: Ramasamy.
*Other*: Petrella, Ibrahim.

Please cite this article as: K.Y. Chu, K. Khodamoradi, R. Blachman-Braun et al., Effect of Radiofrequency Electromagnetic Radiation Emitted by Modern Cellphones on Sperm Motility and Viability: An In Vitro Study, Eur Urol Focus (2022), https://doi.org/10.1016/j.euf.2022.11.004

***Financial disclosures:*** Ranjith Ramasamy certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

***Funding/Support and role of the sponsor*:** None.

***Data sharing statement*:** The subjects in this trial were not concomitantly involved in other randomized trials. Data regarding any of the subjects in the study have not been previously published. Data will be made available to the editors of the journal for review or query on request.

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