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Self-reported mobile phone use and semen parameters among men from a fertility clinic

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Abstract

There is increasing concern that use of mobile phones, a source of low-level radio-frequency electromagnetic fields, may be associated with poor semen quality, but the epidemiologic evidence is limited and conflicting. The relationship between mobile phone use patterns and markers of semen quality was explored in a longitudinal cohort study of 153 men that attended an academic fertility clinic in Boston, Massachusetts. Information on mobile phone use duration, headset or earpiece use, and the body location in which the mobile phone was carried was ascertained via nurse-administered questionnaire. Semen samples ($n=350$) were collected and analyzed onsite. To account for multiple semen samples per man, linear mixed models with random intercepts were used to investigate the association between mobile phone use and semen parameters. Overall, there was no evidence for a relationship between mobile phone use and semen quality.

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Keywords

Mobile phones; electromagnetic fields; semen quality; reproductive health; epidemiology; longitudinal studies

1. INTRODUCTION

Infertility, defined as the inability to conceive after one year of regular, unprotected sexual intercourse, affects approximately 15% of couples during their reproductive life span [1]. In the U.S., the direct health care costs of diagnosing and treating infertility are estimated to be greater than \$5 billion annually [2], a figure that does not include the tremendous impacts that this disease can have on the emotional well-being and quality of life of affected individuals [3]. The Centers for Disease Control and Prevention (CDC) has identified infertility as a “public health priority” in the U.S. and, consequently, established an initiative to improve its detection, prevention, and management [3].

Among couples with infertility, about half are attributable to the male partner [1]. Some studies have reported secular declines in semen quality [4–6] and serum testosterone levels [7–9] among U.S. and European men. The etiology of poor semen quality is not well understood, but given that spermatogenesis is a sensitive physiological process, environmental factors may play a key role [1]. Heat stress [10], diet [11], physical activity [12], psychosocial stress [13], and exposure to chemicals, such as bisphenol A [14], phthalates [15], pesticides [16], and metals [17], have been explored as potential determinants of semen quality.

In addition, there is increasing concern that use of mobile phones, a source of low-level radiofrequency electromagnetic fields (RF-EMF), may be associated with decreased semen quality [18]. Epidemiologic studies of self-reported mobile phone use have reported associations with some semen quality parameters, but the results across these studies are not entirely consistent for the examined parameters [19–25]. There is also some experimental evidence in rats that exposures to mobile phone RF-EMF may lead to histological changes to the testes, disrupted spermatogenesis, and increases in rectal temperature, but, again, the results are also conflicting [26–29]. Both thermal and non-thermal mechanisms (e.g., increased production of reactive oxygen species resulting in DNA damage) have been proposed as potential explanations for the reported associations [30,31]. The state-of-the-science on this topic is limited and continued research has been encouraged to refine our understanding of the potential relationship between mobile phone use and semen quality [30,32].

To build upon previous research, this longitudinal cohort study examined the potential association between self-reported mobile phone use patterns and semen quality in multiple samples among men recruited from a fertility clinic in Boston, Massachusetts. As far as we are aware, only one other study on this topic among U.S. men has been conducted to date [19].

2. MATERIALS AND METHODS

2.1 Study population

Participating men ($n=384$) were enrolled in the Environment and Reproductive Health (EARTH) Study between 2004 and 2015. The EARTH Study is a longitudinal cohort study that recruits couples seeking infertility treatment from the Massachusetts General Hospital (MGH) Fertility Center, and difficulty conceiving may be related to a male factor, a female factor, or a combination of both male and female factors. Men between the ages of 18 to 56 years were eligible to participate. Men who had a vasectomy were ineligible. Of those men that were approached, about 40% consented to participate in the EARTH Study. Most men who declined to participate in the study cited lack of time on the day of their clinic visit as the reason for not participating. At the time of initiating the EARTH study, we conducted a retrospective review of anonymized semen analyses of non-participants from the Fertility Center who met the same eligibility criteria as the study subjects and found that there were no differences between participants and non-participants in regards to semen parameters [33]. After the study procedures were explained and all questions were answered, participants signed an informed consent form. Height and weight were then measured, and the participants provided health information and completed a nurse-administered questionnaire. The EARTH Study received approval by the Human Studies Institutional Review Boards of MGH, the Harvard T.H. Chan School of Public Health, CDC, and the University of Michigan.

2.2 Mobile phone use patterns

A component of the nurse-administered questionnaire asked participating men about their mobile phone use patterns during the three months prior to enrollment in the EARTH Study. Information was collected on mobile phone use duration (no use, <2 hours/day, 2–4 hours/day, >4 hours/day), headset or earpiece use (never, occasionally, some of the time, most of the time, all of the time), and location in which the mobile phone was carried (pants pocket, belt, bag, other).

2.3 Semen quality parameters

Semen was collected on site at MGH in a sterile plastic specimen cup following a recommended 48-hour abstinence period. Some men provided multiple semen samples because their female partner underwent more than one cycle of infertility treatment. Semen quality parameters were measured at the clinic after liquefaction at 37°C for 20 to 60 minutes as described previously [16,34,35]. Briefly, semen volume (mL) was measured with a graduated serological pipet. Sperm concentration ($10^6/\text{mL}$) and total motility (% motile) were assessed using a computer-aided semen analyzer (CASA; 10HTM-IVOS, Hamilton-Thorne Research, Beverly, MA). To measure semen concentration and total motility, 5 ml of semen from each sample was placed into a pre-warmed (37°C) Makler counting chamber (Sefi-Medical Instruments, Haifa, Israel). A minimum of 200 sperm cells from at least four different fields were analyzed from each specimen. Motile sperm were defined as according to the World Health Organization (WHO) classification and included progressive sperm (moving actively, either linearly or in a large circle, regardless of speed) and non-progressive sperm (all other patterns of motility with an absence of progression) [36]. Total sperm count

(10^6 /ejaculate) was calculated by multiplying sperm concentration by semen volume. Total motile sperm count (10^6 /ejaculate) was calculated by multiplying total sperm count by total motility. Sperm morphology (% normal) was measured on two slides per specimen (with a minimum of 200 cells assessed per slide) with a microscope using an oil-immersion 100 × objective (Nikon, Tokyo, Japan). Strict Kruger scoring criteria was used to classify men as having normal or below normal morphology [37]. Semen analysts were blinded to the participants' mobile phone use patterns as well as their fertility treatment status, prior semen quality results, and related clinical outcome data. For quality assurance/quality control purposes, the laboratory conducted weekly monitoring of sperm morphology smears, and reevaluated any slides when reports deviated from acceptable ranges of variation. In addition, the laboratory performed quarterly competence evaluations of all technicians and proficiency testing by an outside evaluator every six months.

2.4 Statistical analysis

The statistical analysis plan was developed prior to data analysis. Descriptive statistics summarizing demographic characteristics were calculated, along with distributions of semen quality parameters, which were also compared with current WHO reference values [36,38]. Mobile phone use was modeled in several different ways as it was hypothesized that variability in use patterns may influence the intensity, frequency, and/or duration of RF-EMF exposure and, consequently, associations with semen quality. In particular, relationships were evaluated for users relative to non-users and, to explore the potential for a dose-response, categories of duration of use relative to non-users. The cut points for duration of use categories (<2 hours/day and ≥2 hours/day) were selected based on the distribution of the data. The potential relationship between the single measure of mobile phone use per participant and multiple measures of semen quality was assessed using linear mixed-effects models with random subject effects to account for repeated semen measurements within the men. Total sperm count, sperm concentration, total motile sperm count, and sperm with normal morphology were ln-transformed, whereas semen volume and total motility followed an approximate normal distribution so they were modeled without transformation. Relationships with semen quality for users and duration of use relative to non-users were reexamined adjusting for headset or earpiece use. In addition, associations with semen quality parameters were assessed based on the location in which the mobile phone was carried (categories: pants pocket and other) relative to non-users.

The aforementioned relationships were first explored in models that were unadjusted and then in models that were adjusted for age, race, body mass index (BMI), and abstinence time. These variables were selected as covariates of interest based on biological and statistical considerations [16,39]. Each model was adjusted for the same covariates to maintain consistency. In adjusted models, BMI (<25 kg/m² vs. ≥25 kg/m²), race (White vs. non-White), and abstinence time (<3 days vs. ≥3 days) were categorized based on distribution of these variables, whereas age was considered as a continuous covariate and the assumption of a linear relationship with the semen outcomes was verified via graphical methods with smoothed spline models. *Post hoc*, we also re-ran the models stratifying on conditions or surgeries related to the male reproductive system (no vs. yes), fever >101°F in the past three months (no vs. yes), smoking status (never smoker vs. past or current smoker),

alcohol consumption (no vs. yes), medication, vitamin, herb, or supplement use (no vs. yes), and season (warm vs. cold). To facilitate interpretation of the results for the models for total sperm count, sperm concentration, total motile sperm count, and sperm with normal morphology, effect estimates were back-transformed by exponentiation. A p -value <0.05 was defined as statistically significant. Statistical analysis was performed using SAS version 9.3 for Windows (SAS Institute, Cary, NC, USA).

3. RESULTS

Data on mobile phone use began to be collected in 2008 and was available on 169 (44%) of the 384 men. The present analysis includes the subset of these men who also had semen analyses performed ($n=162$ men, 96%). Semen samples with missing data on abstinence time were excluded ($n=45$ semen samples), resulting in a final sample of 153 men with 350 semen samples. Demographic characteristics for men without mobile phone use data were comparable to those in the present analysis (data not shown). In addition, distributions of semen parameters and mobile phone use patterns for the excluded semen samples were similar to those included in the present analysis (data not shown).

The 153 men included in the present analysis were primarily White (86%), and had a median age and BMI of 36 years and 26.5 kg/m², respectively (Table 1). Of the participating men, 44% provided one semen sample, 28% provided two semen samples, and 28% provided three or more semen samples (Table 2). The first semen sample was collected about 9 weeks after enrollment, and, if applicable, subsequent semen samples were collected about 10 weeks apart. Of the 350 semen samples, the median values for semen volume, total sperm count, sperm concentration, total motility, total motile sperm count, and sperm with normal morphology were 2.7 mL, 149×10^6 /ejaculate, 60.9×10^6 /mL, 47%, 71×10^6 /ejaculate, and 6%, respectively (Table 2). Most of the semen samples (60–93%) were above current WHO reference values. Mobile phone use in the three months prior to enrollment was reported among 69% of the men (Table 3). Among mobile phone users, 29% reported using a headset or earpiece during use and most of these men used a mobile phone for <2 hours/day (53%). The pants pocket was the primary location in which the mobile phone was carried (55%).

Table 4 presents the results of the adjusted linear mixed-effects models (see Supplementary Material for the results of the unadjusted linear mixed-effects models). Relative differences are presented for total sperm count, sperm concentration, total motile sperm count, and sperm with normal morphology (an effect estimate for a difference in the ln-scale becomes a ratio in the original scale when back-transformed), whereas absolute differences are shown for semen volume and total motility. For example, the first adjusted model for semen volume (0.39) can be interpreted as an average difference of 0.39 mL more semen among mobile phone users relative to non-users. The first adjusted model for ln-count (1.21) can be interpreted as an average 21% increase in total sperm count among mobile phone users relative to non-users.

While there were some statistically significant findings, overall, no consistent pattern or exposure-response relationship was observed between mobile phone use and semen volume,

total sperm count, sperm concentration, total motility, or sperm with normal morphology (Table 4). For example, there was a statistically significant ($p=0.03$) increase in the percentage of total motile sperm among men that used a mobile phone for a duration of <2 hours/day with a headset or earpiece compared to those that did not use a mobile phone [β_{adjusted} (95% confidence interval (CI)): 13.05 (1.57, 24.53)]. However, a similar relationship was not observed for men that used a mobile phone for ≥ 2 hours/day with a headset or earpiece relative to those that did not use a mobile phone [β_{adjusted} (95% CI): 3.06 (−9.39, 15.50)]. Statistically significant ($p=0.02$ – 0.03) increases in semen volume, total sperm count, and total motile sperm count were also noted for certain groups of mobile phone users, but, similar to the findings for total motility, there was no consistency in the exposure-response relationships. Furthermore, men that carried their mobile phone in the pants pocket had a statistically significant ($p=0.04$) increase in total motile sperm count [$\exp(\beta_{\text{adjusted}})$ (95% CI): 1.65 (1.02, 2.67)], whereas men that carried their mobile phone in a location other than the pants pocket (on the belt, in a bag, or by other means) had a statistically significant ($p=0.03$) increase in semen volume [β_{adjusted} (95% CI): 0.70 (0.06, 1.33)] (Table 4). The results of the *post hoc* analyses were comparable to those of the main analysis, but, for some models, they were unstable and therefore difficult to interpret due to small sample size related to stratification and/or missing data (data not shown).

4. DISCUSSION

In the present study, self-reported mobile phone use patterns and repeated measures of six semen parameters (semen volume, total sperm count, sperm concentration, total motility, total motile sperm count, and sperm with normal morphology) were assessed among 153 men recruited from an academic fertility clinic located in Boston, Massachusetts. Overall, there was no evidence for a relationship between mobile phone use and semen parameters.

The only other epidemiologic study to explore this topic among U.S. men is that by Agarwal et al. [19] who conducted a cross-sectional study of self-reported mobile phone use among 361 men recruited through a fertility clinic in Cleveland, Ohio. Mean sperm concentration, motility, and normal morphology decreased with increasing duration of daily mobile use: no use ($86 \times 10^6/\text{mL}$, 68%, and 40%, respectively), <2 hours/day ($69 \times 10^6/\text{mL}$, 65%, and 31%, respectively), 2–4 hours/day ($59 \times 10^6/\text{mL}$, 55%, and 21%, respectively), and >4 hours/day ($50 \times 10^6/\text{mL}$, 45%, and 18%, respectively). Differences in semen parameters between most mobile phone use groups were statistically significant. Sperm concentration, motility, and normal morphology were also strongly correlated with each other. Discrepancies between the results of Agarwal and colleagues [19] with that of the present study potentially could be explained by differences in study design. The Agarwal study was cross-sectional with only a general description of daily active mobile phone usage. This is unlike the approach of the present study in which semen was collected at multiple time points and there was a clear temporal sequence from mobile phone use to semen collection. In addition, while Agarwal et al. [19] considered the potential effects of age in their analyses, there may have been residual confounding due additional factors, such as BMI and race, which were also adjusted for in the present study.

Most of the epidemiologic evidence to date is from studies outside the U.S. that recruited men from fertility or andrology clinics, or, in one instance [25], from a university setting. Across these studies, which have been conducted among men from Hungary ($n=371$) [20], Austria ($n=2,110$) [21], Poland ($n=304$) [24], Italy ($n=63$) [22], Iraq ($n=300$) [23], and China ($n=794$) [25], negative relationships have been reported between self-reported mobile phone use and some of the semen parameters, but they were not consistent across semen parameters.

In particular, Fejes et al. [20] reported statistically significant weak negative correlations for duration of possession and duration of daily use with the proportion of rapid progressive motile sperm ($r=-0.12$ and -0.19 , respectively) and weak positive correlations for these two exposure variables with the proportion of slow progressive sperm ($r=0.12$ and 0.28 , respectively), but mobile phone use was not related to semen volume, total sperm count, sperm concentration, or total motile sperm count. Gutschi et al. [21] found that mobile phone users relative to non-users had a statistically significant decrease in rapid progressive sperm (24% vs. 25%) and increase in sperm with pathological morphology (68% vs. 58%) and abnormal morphology (45% vs. 28%). Wdowiak et al. [24] observed statistically significant decreases in sperm motility and normal morphology with increasing mobile phone use, but no relationship with concentration. Rago et al. [22] reported statistically significant higher sperm DNA fragmentation among those men that used a mobile phone for >4 hour/day (mean: 6.6%) relative to other groups (means: no use, 3.0%; <2 hours/day, 3.2%; and 2–4 hours/day, 3.1%), but there were no relationships for mobile phone use with semen volume, total sperm count, sperm concentration, progressive motility, or normal morphology. Sajeda and Al-Watter [23] observed for increasing duration of mobile phone use (0, 2, 3, and 4 hours/day) statistically significant decreases in sperm concentration (means: 36, 26, 19, and $16 \times 10^6/\text{mL}$), normal morphology (means: 62, 56, 50, and 44%), and progressive motility (means: 53, 46, 38, and 31%) relative to the referent group (0 hours/day). While daily duration (hours) of mobile phone use was not related to semen volume, sperm concentration, or progressive motile sperm, Zhang et al. [25] reported that this exposure variable was inversely related to total sperm count [β_{adjusted} (95% CI): -4.87 ($-9.27, -0.27$)]. Inverse relationships were also reported by Zhang et al. [25] for daily duration (hours) of internet use via a cellular network and sperm concentration [β_{adjusted} (95% CI): -2.74 ($-4.53, -0.91$)] and total sperm count [-2.75 ($-4.76, -0.69$)], as well as monthly data traffic (GB) and semen volume [-1.47 ($-2.74, -0.19$)] and total sperm count [-3.22 ($-5.85, -0.52$)].

Placement of one's mobile phone in relation to the body has also been of interest in some of these studies. Rago and colleagues [22] reported that men who carried a mobile phone in their pants pocket had statistically significant higher sperm DNA fragmentation than those that carried one in their shirt pocket, while, similar to our study, Sajeda and Al-Watter [23] noted that placement of one's mobile phone did not impact semen quality parameters.

We identified two recent meta-analyses on mobile phone use and semen quality [30,32]. The meta-analysis by Adams et al. [30] reported a statistically significant decrease in sperm motility with mobile phone use [mean difference (95% CI): -8.1 ($-13.1, -3.2$)], but no relationship with sperm concentration when data from several epidemiologic studies

(motility: $n=4$, concentration: $n=4$) and *in vitro* studies relying on semen samples from donors (motility: $n=4$, concentration: $n=2$) were pooled by outcome measure. The results were consistent when meta-analyses were stratified on study design, except the *in vitro* findings for sperm motility on their own were not statistically significant. The meta-analysis by Liu et al. [32] reported that mobile phone use in epidemiologic studies was not related to semen volume ($n=2$), motility ($n=4$), sperm concentration ($n=4$), or normal morphology ($n=3$). However, mobile phone RF-EMF was related to significant decreases in sperm motility in *in vitro* studies $[-4.1 (-8.1, -0.1), n=4]$, as well as decreases in motility $[-17.7 (-32.8, -2.7), n=3]$ and concentration $[-8.8 (-17.4, -0.1), n=3]$ was reported in animal studies. The authors of both papers, despite inconsistent results from a small number of studies, concluded that mobile phone use may negatively affect semen quality. These meta-analyses have not fully explored the influence of various potential biases and the source of heterogeneity in the results in the epidemiologic studies. Results of the *in vitro* and animal studies should also be interpreted with caution due to inconsistent reporting of semen analysis criteria and use exposure scenarios that are likely not representative of exposures that occur during actual mobile phone use.

A unique characteristic of the present study was the use of multiple semen samples per man, which is a study design that has not been widely employed previously. Although only a single measure of mobile phone use was collected, the availability of multiple semen samples allowed greater precision in estimated associations by accounting for within-man variability in semen parameters. Mobile phone use was also modeled in a variety of ways, including accounting for headset or earpiece use, which impacts placement of the mobile phone in relation to the body during use and, as a result, RF-EMF exposure since the intensity of exposure at the target tissue (e.g., testicles) is inversely related to the distance from the mobile phone [40]. Relative to most other epidemiology studies on this topic, the sample size for this study was somewhat small and, consequently, it had limited statistical power. Given this, and the limited and conflicting scientific evidence to date, further studies are encouraged to monitor the potential relationship of mobile phone use patterns with semen quality. Nevertheless, it should be noted that this study had a sufficient number of participants to provide 80% power for detecting a 34% decrease in total sperm count, a 49% decrease in total motile sperm count, a 26% decrease in morphologically normal sperm, a 34% decrease in sperm concentration, an absolute mean difference of 11% fewer total motile sperm, and an absolute mean difference of 0.66 mL of semen volume, which is reasonable for a study of this design. A limitation of the current study is the potential for exposure misclassification associated with the use of self-reported mobile phone use as a surrogate for actual mobile phone use. For example, a validation study of 672 participants across 11 counties from the “Interphone Study” assessed network operator and software modified phone data over a period of up to 8 months against self-reported mobile phone use between 6 and 12 months after the monitoring period [41]. The correlation between reported and actual mobile phone use across all countries was 0.69 for both the number and duration of calls per month, whereas weighted Kappas for these metrics were 0.50 and 0.49, respectively. On average, participants tended to underestimate the number of calls per month and overestimate the duration of calls per month. The current study collected information on mobile phone use in the more recent past, likely resulting in less recall bias. While

participant recall of mobile phone use is associated with some degree of measurement error, it is the most common method for collecting data on mobile phone use in health studies [42], due to logistical, budgetary, and participant burden constraints associated with characterizing personal exposures to RF-EMF emitted from mobile phones. To account for this source of error with self-reported mobile phone use, regression calibration has been recommended, which ideally will improve the validity of effect estimates [42], but this option was not feasible in the present study due to lack of data on the relationship between self-reported mobile phone use and a “gold standard” (e.g., network operator data). In addition, the results of the present study may not be fully generalizable to men in the general population given that men from a fertility clinic may differ from men who do not visit a fertility clinic [12].

5. CONCLUSIONS

The present study found that within the range of self-reported mobile phone use there was no evidence for a relationship with semen quality. The current state-of-the-science is limited and conflicting and, consequently, additional research is recommended as it will better inform the risk assessment and management of this issue. Specifically, large prospective studies that collect detailed data on mobile phone use patterns and repeated semen samples would allow for the investigation of temporal relationships.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS

CASA	computer-aided semen analyzer
CDC	Centers for Disease Control and Prevention
CI	confidence interval
EARTH	Environment and Reproductive Health
MGH	Massachusetts General Hospital
RF-EMF	radiofrequency electromagnetic field
WHO	World Health Organization

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HIGHLIGHTS

- Evidence for a relationship between mobile phone use and semen quality is limited.
- Mobile phone use and semen quality in men from a fertility clinic was explored.
- Mobile phone use was not related to semen quality.
- Carrying a mobile phone in the pants pocket also was not related to semen quality.

Table 1Participant characteristics at enrollment ($n=153$ men unless otherwise noted)

Variable	Median (IQR) or n (%)
Age (years)	36.0 (33.0, 40.3)
BMI (kg/m ²)	26.5 (24.3, 28.7)
Race	
White	132 (86)
Black	5 (3)
Asian	11 (7)
Other	5 (3)
Conditions or surgeries related to male reproductive system ($n=149$) ^{a,b}	
No	115 (77)
Yes	34 (23)
Fever >101°F in the past three months ($n=150$) ^{a,b}	
No	144 (96)
Yes	6 (4)
Smoking status ^a	
Never	100 (65)
Past or current	53 (35)
Alcohol consumer ($n=113$) ^{a,b}	
No	16 (14)
Yes	97 (86)
Medication, vitamin, herb, or supplement user ($n=152$) ^{a,b}	
No	26 (17)
Yes	126 (83)

BMI, body mass index; IQR, interquartile range.

^aStratified on variable in *post-hoc* models only.^bData were not available on all 153 men.

Table 2Distribution of semen quality parameters ($n=153$ men with 350 semen samples)

Variable	Median (IQR) or n (%)
Semen volume (mL)	2.7 (1.8, 3.7)
<1.5 mL ^a	58 (17)
Total sperm count (10^6 /ejaculate)	149 (72, 260)
< 39×10^6 /ejaculate ^a	27 (8)
Sperm concentration (10^6 /mL)	60.9 (29.5, 105)
< 15×10^6 /mL ^a	24 (7)
Total motility ^b (% motile)	47 (28, 64)
<40% motile ^a	140 (40)
Total motile sperm count (10^6 /ejaculate)	71 (21, 154)
Normal sperm morphology (% normal)	6 (4, 9)
<4% normal ^a	51 (15)
Abstinence time	
<3 days	259 (74)
3 days	48 (13)
4–6 days	27 (8)
>6 days	16 (5)
Semen samples per man	
1 sample	67 (44)
2 samples	43 (28)
3 samples	14 (9)
>3 samples	29 (19)
Season when semen was collected ^c	
Warm	160 (46)
Cold	190 (54)

WHO, World Health Organization.

^aCurrent WHO [36] reference value.^bProgressive + non-progressive sperm.^cStratified on variable in *post-hoc* models only.

Table 3

Distribution of mobile phone use patterns by the study participants during the three months prior to enrollment ($n=153$ men)

Variable	<i>n</i> (%)
Mobile phone use	
No use	47 (31)
Use	106 (69)
Headset or earpiece	31 (29)
No headset or earpiece	75 (71)
Mobile phone use duration	
No use	47 (31)
<2 hours/day	81 (53)
Headset or earpiece use	17 (21)
No headset or earpiece use	64 (79)
2 hours/day	25 (16)
Headset or earpiece use	14 (56)
No headset or earpiece use	11 (44)
Location where mobile phone was carried	
No use	47 (31)
Pants pocket	84 (55)
Other	22 (14)

Table 4

Adjusted^a differences in semen quality parameters by mobile phone use patterns (*n*=153 men with 350 semen samples)

Mobile phone use pattern in the three months prior to enrollment	Volume [β (95% CI)] ^b	In-Count [exp(β) (95% CI)] ^b	In-Concentration [exp(β) (95% CI)] ^b	Total motility [β (95% CI)] ^b	In-Total motile count [exp(β) (95% CI)] ^b	In-Morphology [exp(β) (95% CI)] ^b
No use	—	—	—	—	—	—
Use	0.39 (−0.03, 0.81)	1.21 (0.92, 1.59)	1.08 (0.83, 1.41)	5.70 (−1.56, 12.95)	1.59 (0.99, 2.52)	0.93 (0.76, 1.14)
No use	—	—	—	—	—	—
Use with headset/earpiece	0.54 (−0.01, 1.09)	1.38 (0.96, 1.97)	1.14 (0.81, 1.62)	8.59 (−0.84, 18.01)	1.93 (1.06, 3.53)*	0.89 (0.69, 1.17)
Use with no headset/earpiece	0.32 (−0.13, 0.77)	1.14 (0.85, 1.53)	1.06 (0.79, 1.41)	4.43 (−3.29, 12.16)	1.46 (0.89, 2.38)	0.95 (0.76, 1.18)
No use	—	—	—	—	—	—
Use <2 hours/day	0.47 (0.03, 0.91)*	1.19 (0.89, 1.59)	1.04 (0.78, 1.38)	6.38 (−1.25, 14.00)	1.57 (0.97, 2.56)	0.96 (0.78, 1.19)
Use 2 hours/day	0.11 (−0.48, 0.70)	1.28 (0.87, 1.88)	1.22 (0.84, 1.78)	3.59 (−6.61, 13.79)	1.63 (0.85, 3.14)	0.84 (0.63, 1.11)
No use	—	—	—	—	—	—
Use <2 hours/day with headset/earpiece	0.74 (0.08, 1.41)*	1.60 (1.04, 2.46)*	1.24 (0.81, 1.89)	13.05 (1.57, 24.53)*	2.43 (1.17, 5.07)*	0.94 (0.68, 1.31)
Use <2 hours/day with no headset/earpiece	0.40 (−0.06, 0.86)	1.09 (0.80, 1.47)	0.99 (0.74, 1.33)	4.47 (−3.53, 12.46)	1.39 (0.83, 2.31)	0.97 (0.77, 1.22)
Use 2 hours/day with headset/earpiece	0.29 (−0.43, 1.01)	1.14 (0.71, 1.82)	1.03 (0.65, 1.63)	3.06 (−9.39, 15.50)	1.44 (0.65, 3.20)	0.84 (0.59, 1.20)
Use 2 hours/day with no headset/earpiece	−0.12 (−0.93, 0.68)	1.47 (0.87, 2.47)	1.52 (0.91, 2.53)	4.10 (−9.72, 17.93)	1.89 (0.78, 4.58)	0.83 (0.56, 1.23)
No use	—	—	—	—	—	—
Pants pocket	0.31 (−0.12, 0.75)	1.25 (0.94, 1.67)	1.14 (0.87, 1.50)	6.20 (−1.32, 13.71)	1.65 (1.02, 2.67)*	0.96 (0.77, 1.18)
Other	0.70 (0.06, 1.33)*	1.02 (0.68, 1.55)	0.86 (0.58, 1.29)	3.56 (−7.38, 14.50)	1.33 (0.66, 2.67)	0.82 (0.60, 1.12)

^aModels were adjusted for age, BMI (<25 kg/m² vs. ≥25 kg/m²), race (White vs. non-White), and abstinence time (<3 days vs. ≥3 days).^bRelative differences are presented for total sperm count, sperm concentration, total motile sperm count, and normal sperm morphology (an effect estimate for a difference in the ln-scale becomes a ratio in the original scale when back-transformed), whereas absolute differences are shown for semen volume and total motility. Original scales for semen volume, total sperm count, sperm concentration, total motility, total motile sperm count, and normal sperm morphology are mL, 10⁶/ejaculate, 10⁶/mL, percent motile, 10⁶/ejaculate, and percent normal, respectively.* *p*<0.05.