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Effects of Electromagnetic Wave from Mobile Phones on Human Sperm Motility and Viability: A Systematic Review and Meta-Analysis

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ABSTRACT

Nowadays humans are constantly exposed to electromagnetic wave (EMW), especially mobile phone. Recently concerns about the potential risks of EMW it's increasing. A possible risk of the EMW is adverse effect on human semen quality. In this study, it was tried to do meta-analysis on the results obtaining the evaluation of sperm quality (motility and viability) after in vitro exposure to EMW of mobile phone. We carried out a Systematic Review in databases of ISI, Pubmed, Scopus, Ovid, Embase and VIP till December 2015. Then was performed meta-analysis of data extracted by comprehensive meta-analysis 2.2 software. Finally, 10 studies [8: sperm motility (17 subgroups), 6: sperm viability (6 subgroups)] were reviewed and meta-analysis was done. The percentage ranges of sperm motility in the unexposed and exposed samples were 17.70±10.9 % to 87.20±7.32% and 18.40±11.90% to 87.5±8.57%, respectively. The mean differences for sperm motility and heterogeneity were REM:-4.57;CI(-7.11 to -2.03) and I^2=69.38%; $\rho_{heterogeneity}$<0.001, respectively. The percentage range of sperm viability in the unexposed and exposed samples were 50.78±5.98% to 90.9±3.7% and 4 8.43±13.99 to 90.4±4.1% respectively and for sperm viability, the mean differences for sperm motility and heterogeneity were REM-1.19; CI (-2.04 to -0.34) and I^2=96.9%; $\rho_{heterogeneity}$<0.001, respectively. Exposure to EMW of mobile phone decreased significantly sperm motility and sperm viability decreased but not-significantly. Results of this study supported the negative effects of EMW of mobile phone on the sperm motility

Keywords: Electromagnetic, Mobile Phones, Sperm Motility, Sperm Viability

INTRODUCTION

Today, exposure to electromagnetic wave (EMW) emitted from the mobile phones, telecommunication antennas, TV, tablets, laptops, high voltage power cables is inevitable [1-3]. Concerns about the exposure to EMW of mobile phone is increasing because of the potential health risks [4]. The ownership of mobile phone from 12% in 1999 is reached to 76% in 2009 [5,6]. Mobile phone portability causes more concerns regarding the harmful effects of emitted EMW on human health because it provides its further connection with the body [7,8]. Although several global and national guidelines and standards regarding the exposure to EMW have been developed since 1950, but the concerns about the unknown effects of these waves even at a lower level of the guidelines is increasing [9].The World Health Organization (WHO) has classified the emitted EMW of mobile phones in terms of carcinogenicity in class 2B (possibly carcinogenic) [10]. Mobile phones can be exploited in the frequency range of 400 to 2000 MHz that can be absorbed by body [11]. Studies have shown that the EMW can have detrimental effects on health at frequencies greater than 100 MHz [12,13]. Exposure to EMW cause adverse effect on mammalian cells (impaired intra-chromosomal combination, aneuploidy enhanced micronuclei) [14,15], Infertility, affecting on brain system, heart and endocrine glands leads to fatigue, headache and poor concentration [4,16,17]. Infertility is defined as the lack of fertility after one year of unprotected vaginal sexual intercourse [18]. The studies have shown that 15% and 50% of infertility are related to the reproductive age of couples and male infertility factors, respectively[19]. EMW can affect the sperm parameters include motility, viability, morphology and sperm concentration [20,21]. Studies have shown that EMW can reduce testosterone with effect on sertoli and leyding cell function [22].

Review of the conducted literatures regarding the effects of EMW on the quality of semen, showed different and confusing results. Agarwal et al study showed that exposure to EMW of mobile phone can be effective on the sperm motility but no concentration [23]. It was obtained from Fejes et al study that the EMW of mobile phone have negative effects on sperm quality [24]. Feijo et al and Dasdag et al studies showed that exposure to EMW of mobile phone have not effects on sperm quality [25,26]. Also, some of the input data in certain review studies such as Liu et al study was a mistake [27]. So in this study, we tried to evaluate the effect of EMW of mobile phone on the motility and viability of human sperm in vitro by a systematic review and meta-analysis and an exact evaluation of effects from exposure to EMW emitted from mobile phone on the quality of human sperm is performed.

MATERIALS AND METHODS

2.1. Search and selection of studies

A list of titles and abstracts of all articles available in databases; ISI Web of Science, Pubmed, Scopus, Ovid, Embase and VIP from 2015/12/09 to 2015/12/27 were prepared at first by three reviewers in order to determine and select the related titles to be evaluated independently. Then, the studies related to blinding method of initial evaluation were entered to the process. The main inclusion criterion was effects of in vitro exposure to mobile phone EMW to sperm motility and viability. The studies that were not a part of initial researches or in an unrelated field with the title and review studies were excluded. In the second step using a check list of STROBE (Strengthening the Reporting of observational studies in Epidemiology) which is a standard check list, studies were evaluated. This check list was included 43 various parts and evaluates various aspects of methodology such as measuring methods, measuring variables, statistical analysis and aims of study. The minimum and maximum obtained scores were considered as 40 and 45, respectively [28]. Finally, the superior studies which had obtained the minimum score of 40 were entered into the research and its related data were extracted for meta-analysis. At the end, the in vitro studies which had studied effects of exposure to mobile phone EMW to sperm motility and viability, were evaluated accurately. Used to term "AND" for combination of the keywords. The keywords which were used for searching, generally includes the following: mobile phone and EMW, reproductive system, semen quality, sperm motility and viability, specific absorption rate and sperm quality, cell phone and reproductive system, humans and sperm, cell phone and sperm quality

2.2. Data extraction

According to the standard method for data extraction, three independent reviewers extracted and shape of the table all data (YF, HH and HK). Nonconformity's points resolved by discussion or consultation between three reviewers. Information extracted included first author, specific absorption rate, frequency EMW, publication year, sample size, sperm motility, sperm viability, population under study and outcome study.

2.3. Assessment of heterogeneity and data synthesis

We pooled the mean differences of sperm motility and viability associated with EMW of mobile phone by Comprehensive Meta-Analysis V2.0 software. Heterogeneity was evaluated using the I2 statistic and associated confidence intervals (CI) [29]. If significant heterogeneity was observed ($p < 0.10$ or $p > 0.10$ but $I2 > 50\%$), the meta-analyses were conducted using a random effect model. A fixed effect model was used for the meta-analysis

where heterogeneity was acceptable ($p > 0.10$, or $p < 0.10$ but $I2 < 50\%$). Heterogeneity were more than 50% in both sperm motility and viability, hence used the REM for evaluating the effects of exposure to EMF of mobile phone to motility and viability sperm in each study. Since, the number of studies in review studies were low, hence the significance level was p value<0.001 [30].

RESULTS

From 321 studiesISI (94), Pubmed/Medline (123), Embase (56), VIP (37), Ovid (13) excluded 229 studies were duplicated records and remained 94 ones were reviewed title and abstracts. Then, excluded reviews, editorials (n=24), animal studies and human in vivo studies (n=19) and irrelevant exposures or outcomes (n=41). From 10 studies remaining, excluded studies that outcome was in vitro but unrelated parameter sperm (n=2). Finally, 10 studies [6; sperm viability (7 subgroup), 8; sperm motility (17 subgroup)] remained to meta-analysis (Figure 1). In the some studies have changed variables such as SAR and group participants hence divided into several subgroups.

Risk assessment of the effects of EMW of mobile phone exposure on the sperm motility and viability in vivo cannot be accurate because determining the intervening factors such as EMW emitted from other devices (antenna, laptop, high voltage cables and etc.), exposure time and distance is difficult. Unlike the in vivo, risk assessment obtained from in vitro would be the most scientific method [31,32]. Thus, in vivo studies were excluded from the review.

The studies whose results were too different from the other studies excluded and analysis was conducted again. If removal of intended studies made a significant change in the results, there were removed from the analysis and otherwise were returning to study.

All used frequencies of 850–900 MHz, with the exception of De Iuliis et al. study that was 1800 MHz. Specific absorption rate, where reported was in the range 1-5.7 W/Kg with the exception of three studies that were mentioned; and duration of exposure ranged from direct to 24 h.

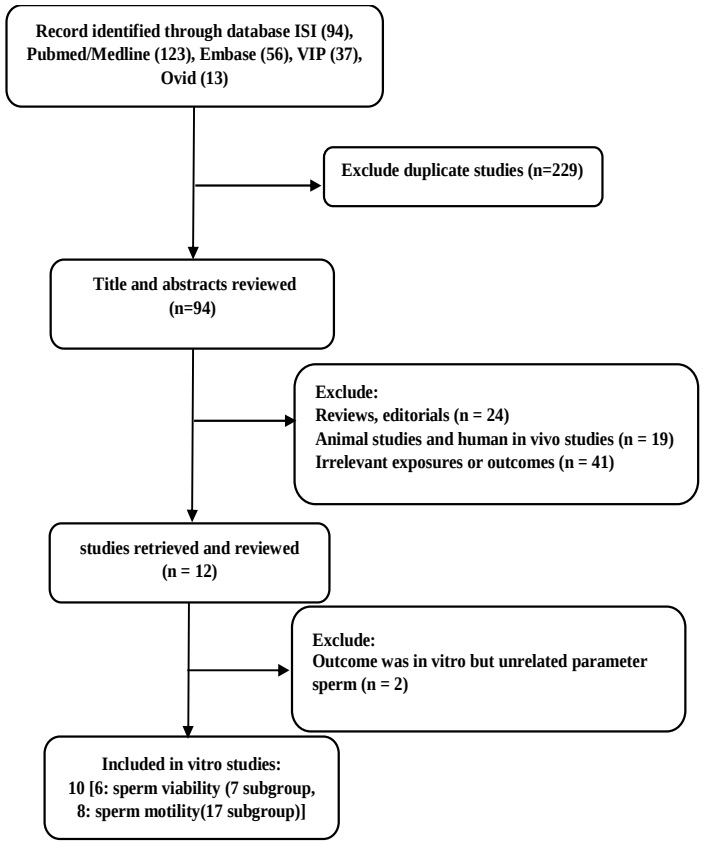

Figure1. Results of literature review following description of the full search process.

3.1. Motility

Eight studies (17 subgroups) with 178 samples were analyzed. The percentage range of sperm motility in the unexposed and exposed samples were 17.70±10.9 to 87.20±7.32% and 18.40±11.90 to 87.5±8.57%, respectively.

Table1.Characteristics of studies included in the systemic review and meta-analysis

								Exposed		**Unexposed**			
First Author(year)	Study design	Participant group	Countries	Radio-frequency (MHz)	SAR (W/Kg)	Exposure time	Sample Size	Motility (%)	Viability (%)	Motility (%)	Viability (%)	Comments/Outcome	**Reference**
Agarwal et al (2009)	In Vitro	Healthy donors	USA	850	1.46	60 min	23	50.60±17.49	53.52±13.05	54.80±17.61	61.00±13.71	Exposed to RF-EMWS significantly decreased sperm motility and viability, increased ROS level, and decreased ROS-TAC score. No statistically significant effect of RF-EMWS exposure on Levels of TAC and DNA damage.	[34]
		Infertile patients					9	43.56±16.94	48.43±13.99	45.25±19.42	52.29±17.41		
Ahmed Baig et al (2010)	In Vitro	Volunteer male	Pakistan	900	1.3	60 min	22	46.21±11.10		51.36±10.87		Mobile phone radiation, decreases the fast progressive motile sperms percentage, and increases the non-motile sperms percentages	[35]
Dkhil, et al (2011)	In Vitro	Healthy donors	Saudi Arabia	850	1.46	60 min	20		80.60±1.40		84.10±1.30	A significant decrease in sperm vitality and viability as well as sperm motility. Sperm cells, will become weakened after EMR exposure. Sperm cells may start functioning poorly after EMR emitting by cell phone, and this means that a potential decrease in male fertility	[36]
De Iuliis et al (2009)	In Vitro	Healthy donors	Australia	1800	1	16 h	4		65.00±1.00		89.00±3.00	SAR correlated negatively with sperm motility and vitality, and positively with the mitochondrial generation of ROS and DNA fragmentation after RF-EMR exposure	[37]
Erogul et al (2006)	In Vitro	Healthy donors	Turkey	900	Not mentioned	5 min	27	49.40±22.27		63.30±22.16		EMR emitted by cellular phone influences human sperm motility.	[23]
Falzone et al (2008)	In Vitro	Healthy donors	South Africa	900	2	Directly	12	86.50±7.44		86.80±5.34		The two kinematic parameters straight line velocity (VSL) and beat-cross frequency (BCF) were significantly. Reduced after the exposure at	[38]
					2	2 h		87.50±8.57		86.10±8.36			
					2	24 h		70.00±14.51		65.00±16.45			
					5.7	Directly		86.60±9.3		87.20±7.3			

								3		2		SAR 5.7 W/kg and progressive motility were not significantly different between the groups.	
					5.7	2 h		86.20±7.69		84.60±9.18			
					5.7	24 h		62.71±15.14		65.70±19.15			
Veerachari et al (2012)	In Vitro	Healthy donors	India	900	1.46	60 min	20	45.75±7.49	47.7±5.24	52.30±8.97	50.78±5.98	Statistically significant decrease in sperm motility and viability, also significant increase in reactive oxygen species (ROS) and DNA fragmentation index (DFI) between the groups after EMR exposure.	[39]
Zalata et al (2015)	In Vitro	Healthy donors	Egypt	850	1.46	60 min	26	56.50±4.20		60.80±4.5		Sperm motility, sperm linear velocity, sperm linearity index, and sperm across in activity were significantly reduced, whereas sperm DNA fragmentation index, CLU gene expression and CLU protein levels in the exposed semen samples to RF-EMF compared with non-exposed samples in OAT>AT>A>N groups, significantly increased.	[40]
		Asthenozoospermia			1.46	60 min		26.50±5.00		30.90±5.4			
		Asthenoteratozoospermia			1.46	60 min		18.40±11.90		23.30±9.4			
		Oligoasthenoteratozoospermia			1.46	60 min		12.70±7.90		17.70±10.9			
Gorpinchenko et al (2014)	In Vitro	Normozoospermia	Ukraine	900	Not mentioned	5 h	32	66.50±6.30	90.4±4.10	81.30±7.2	90.9±3.70	Progressive motility was significantly reduced and non-progressive motility was significantly increased, also DFI was significantly higher after electromagnetic radiation by mobile phone.	[41]
Farahani et al (2015)	In Vitro	healthy donors	Iran	900	Not mentioned	10 min	18	64.46±11.67	68.5±7.88	73.94±11	85.46±9.48	Exposure group show a significant decrease in the rapid progressive, slow progressive sperm motility and viability	[21]

The minimum and maximum sperm motility in the unexposed samples were for Zalata et al (Oligoasthenoteratozoospermia) and Falzone et al (Directly) studies and in exposed samples were for Zalata et al (Oligoasthenoteratozoospermia) and Falzone et al studies (SAR; 2 W/Kg, 2 hours) (Table 1). The mean differences for sperm motility and heterogeneity were REM: -4.59; CI (-7.11 to -2.03) and I^2:69.38%; $\rho_{heterogeneity}$<0.001, respectively (Figure 2). The minimum and maximum weight percentage of sperm motility were for Agarwal et al (Infertile patients) and Zalata et al (healthy donors), respectively (Figure 2).

3.2. Viability

Six studies (7 subgroups) with 126 samples were analyzed. The percentage range of sperm viability in unexposed and exposed samples were 50.78±5.98% to 90.0±3.7% and 90.4±4.1 to 48.43±13.99%, respectively. The minimum and maximum viability in unexposed and exposed samples were for Veerachari et al and Gorpinchenko et al, respectively (Table 1). The mean differences for sperm viability and heterogeneity were REM: -1.19; CI (-2.04 to -0.34) and I^2:96.9%; $\rho_{heterogeneity}$<0.001, respectively (Figure 2). The minimum and maximum weight percentage of sperm viability were for Agarwal et al (Infertile patients) and Dkhil et al (2011), respectively (Figure 2).Weight percentage of each study has a reverse relationship with the standard deviation [33]. Thus, Agarwal et al (Infertile patients) and Dkhilet al. had the maximum and minimum standard deviations, respectively.

DISCUSSION

The recent studies EMW effects of mobile phone on sperm parameters (motility and viability) has been controversial. In this systematic review and meta-analysis, it was tried to evaluate new studies (Till December 2015) in this regard. Exposure to mobile phones reduces the sperm motility (P value>0.001). It should be noted that in review studies, the significance level is P value<0.001 due to the low number of studies [42].

Biological effects of EMW of mobile phone on the sperm quality should be noted. EMW have thermal effects, special effects (non-thermal) and combination of them on the biological tissues [43].

Wang et al study showed that Leydig cells of mouse are very vulnerable toward the EMW and Leydig cells injury due to the production of Reactive Oxygen Species (ROS) can have a destructive effect on spermatogenesis. Also, the thermal effect of EMW reversibly impairs spermatogenesis [37,44].

The studies have shown that exposure to EMW leads to reduced melatonin secretion [45] and antioxidant levels that predisposed human to oxidative stress and sperm DNA fragmentation [46]. Agarwal et al study showed that putting the mobile phone in the pants pocket and besides the testes can raise its temperature [4]. It is reported that mobile phone can increase the skin surface temperature 2.3˚C in 6 minutes [67] and also cheek temperature can raise from 2.6 to 3.5˚C in 15 minutes [48]. The increase temperature of testis cause a disturbance in mitochondrial electron transport chain and more production of ROS. So, disruption in this chain decreased sperm motility [49].

The remarkable thing is that the some studies have shown that if SAR<2, the thermal effect of EMW will not be significant [47,48,50]. Since in all of reviewed studies were SAR<1 except Falzone et al and De Iuliis studies, so decrease in the sperm motility and viability can be due to the non-thermal effects of EMW. So, the investigators are recommended to analyze the association of sperm parameters changes in different SARs in their future studies.

The mean percentage of reduction in sperm motility in Erogul et al study was more than other studies. Therefore, meta-analysis was done with exclusion of this study and the results were reviewed again. After exclusion, the mean of sperm motility reduction and heterogeneity did not have a much difference and results remained significant (REM: -4.57% to -3.6) and I2=69.38%; ρheterogeneity<0.001 to I2=0%; ρheterogeneity<0.001. Finally, Erogul et al study remained in the analysis.

The mean difference in the Erogul et al study was high while similar to other studies participants were healthy. Thus, the role of some intervention factors such as smoking [51], age [52] and time [53]can be noted. Smoking or non-smoking of participating group was not mentioned in most of studies. So, the effect of this intervening variable cannot be examined on the results. The age range and means of 27 men participating in Erogul et al study was 19-33 and 27±3.2 that has not a much difference with the other studies [23]. The exposure time (5 min) in this study was less than other studies, hence is unclear the cause of the more mean difference in the Erogul et al.

The exposure time was more than 1 hour in some studies such as Falzone et al, De Iuliis et al and Gorpinchenko et al studies that this long time itself can have a negative effect of the sperm motility and viability. WHO sperm analysis protocol has recommended that the time between sampling and analysis should not be more than 1 hour as the effect of changes in pH and temperature and dehydration alter the sperm quality [54].

After excluding studies with a long exposure times, analysis was performed again. Although a long exposure time (5, 16 and 24 hours), the mean percentage in reduction of sperm quality after excluding these studies (REM: -4.2, p<0.001) did not have a significant difference compared to before exclusion (REM: -4.57, P value<0.001).

Agarwal et al study showed that all four sperm parameters including concentration, morphology, motility and viability have a direct and significant relationship with each other [31]. Also, our study confirmed this matter that there is a direct association between the sperm motility and viability and by decreasing the sperm motility, viability was also reduced in all studies (Figure 3).

De Luis et al study showed by Tunnel method that exposure to the EMW of mobile phone can cause sperm DNA fragmentation and then reducing the sperm motility [37].

So significant heterogeneity in concurrent reduction of all sperm parameters after EMW exposure of mobile phone is due to sperm DNA fragmentation , finally cause a decrease in the sperm viability [55] and motility [37].

De Luis et al showed that exposure of the sperm to EMW in vitro can increased sperm DNA fragmentation and ROS production and decreased the sperm viability -24% (p<0.001) (Figure 2). Since the percentage mean of sperm motility reduction in this study had a high difference with other studies, so it was excluded from the meta-analysis and the results were analyzed again. The results before exclusion (I2: 84.37%, ρheterogeneity<0.001, REM: -4.18%, p value<0.009) had a significant difference with after exclusion (I2: 69.38%, ρheterogeneity <0.001, mean total: -4.57%, p value<0.000). Thus, De Iuliis et al study was excluded from the analysis.

Since the heterogeneity will reduce with increase the number of studies and decrease in standard deviation [56], so the heterogeneity in sperm motility studies (I2: 69.38%) is less than the sperm viability (I2: 96.9%).

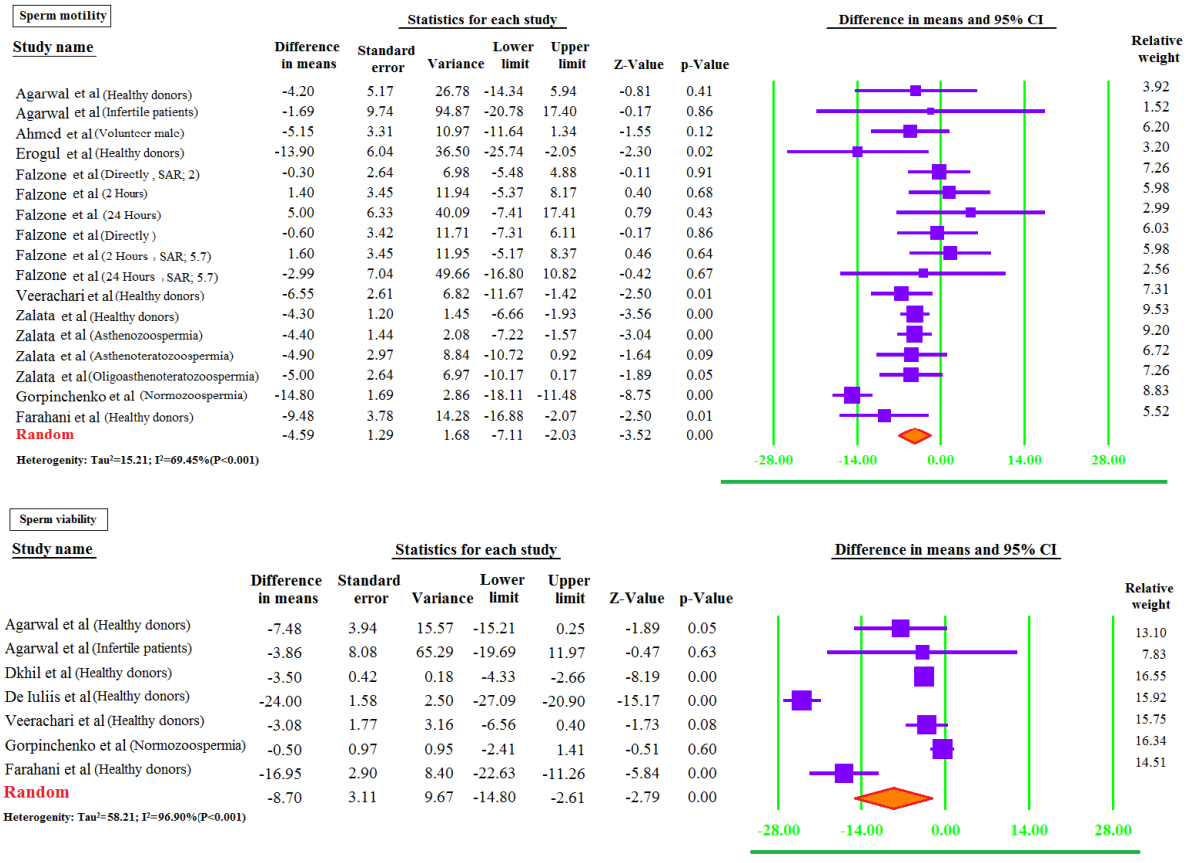

Figure 2. Forest plot showing the effect of mobile phone exposure on human sperm motility and viability

Since the mean difference of sperm viability in De Iuliis et al study was higher than other studies, so it was excluded from all studies and analysis was analysis again. The results of De Iuliis et al study before exclusion (I2: 96.9%, ρheterogeneity<0.001, REM: -8.67%, p value<0.005) did not have a significant difference with after

exclusion (I2: 84.2%, ρheterogeneity <0.001, REM: -5.08%, p value<0.002). Thus, De Iuliis et al study remained in the analysis.

In Falzone et al study (3 subgroups), the percentage of sperm motility in exposed samples were higher than unexposed ones (P value>0.001). In general Falzone et al study showed that exposure to the EMW of mobile phone cannot have a significant reducing effect on sperm motility [38].

Falzone et al and De Iuliis studies showed that exposure to EMW can increase the risk factors of infertility in men including increased production of free radicals and reactive oxidative stress (ROS) [37,38].

In Farahani et al study similar to Agarwal et al study, the sperm motility was significantly decreased with increase in reactive oxidative stress [23].

Reduction of sperm motility in the patient donors [REM:-7.03, CI (-12.03 to -1.79), P-value=0.008; I2;85.05%, p het<0.001] was more than healthy donors [REM:-3.29,CI(-5.53 to -1.04), p value=0.004; I2;29.9%, ρheterogeneity =0.15]. Hence patient donors are more vulnerable than healthy donors may be due to the lower antioxidant capacity or high reactive oxidative stress [57].

There are limitations in this study. First, bias may exist for published data; non-English except Persian language studies were not included. Second, some studies without sufficient data to calculate the sperm motility and viability were excluded. Third, range time research was between 2000 and 2016.

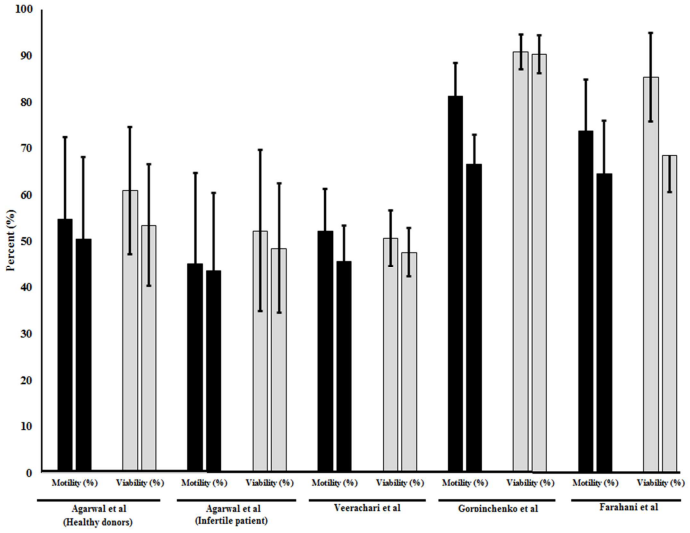

Figure 3.Comparison motility and viability of sperm before and after exposure to EMW of mobile phone

CONCLUSION

The systematic review and meta-analysis showed that exposure to EMW of mobile phone can significantly decreased the sperm motility. Although exposure to EMW of mobile phone had a reducing effect of sperm viability but it was not significant and cannot conclude accurately, so it is recommended that effects of EMW exposure from mobile phone on sperm viability should be noted more in the future studies. Results of this study supported the negative effects of EMW exposure from mobile phone on sperm motility.

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