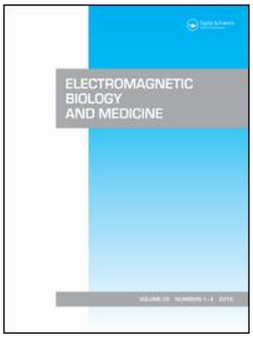

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Effects of mobile phone exposure on biochemical parameters of cord blood: A preliminary study

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ABSTRACT

The purpose of this study is to investigate foetal impact of radiofrequencies (RFs) emitted from mobile phones in postnatal cord blood. The study carried on 149 pregnant women divided into four groups such as nonusers of mobile phone (*n*: 37; control group), 2–15 min/d (*n*: 39; group 1), 15–60 min/d (*n*: 37; group 2) and participants using mobile phone for more than 60 min/d (*n*: 36; group 3). Cord blood of the infants was taken in all groups for biochemical analyses immediately after birth. The results of the study showed that the biggest foetal impact was observed in the third study group which was pregnant exposed RFRs (RF radiation) more than 1 h/d (1 hour per day). AST (aspartat aminotransferaz), ALT (alanine aminotransferase), LDH (lactate dehydrogenase), CK (creatine kinase), CK–MB (creatine kinase–miyocardial band), CRP (c-reactive protein), PCT (procalcitonin), TnT (troponin T), uric acid and lactate levels of third group were found higher than the other groups ($p < 0.001$). However, Mean platelet volume values of third group were found lower than the other groups ($p < 0.001$). Finally, this is the first human study which was performed on pregnant and infants because there is no previous work in this area. However, the results of this study revealed that long-term RFR exposure of pregnant may result in some biochemical changes in the infants. Therefore, our suggestion to pregnant is to avoid from RFR exposure emitted from mobile phones at least during pregnancy.

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Mobile phone; radiofrequency radiation (RFR); cord blood; biochemical parameters; pregnant

Introduction

The use of mobile phones increased drastically in the recent century (Makker et al., 2009). Radiofrequency waves (RF) are used for image and information transmission in mobile phones. RF fields cause torques on biomolecules, which can end up displacement of ions from imperturbable positions, oscillation in bound charges (both electrons and ions), turning and reorientation of dipolar molecules (SCENIHR, 2015). The results of research on the effects of RF radiation emitted from mobile phones on health are increasingly worrying the public. Investigations on the biological effects of RF exposure from mobile phones have resulted in the classification of these radiations as "possible carcinogenic, i.e. group 2B" by World Health Organization. Also, various studies have shown that foetuses and embryos are more susceptible to environmental toxins (Infante-Rivard & Deadman, 2003; Lowenthal et al., 2007), because foetuses and babies have a large number of stem cells and insufficient immunity-mediated resources. Physical and chemical agents in the environment affect even the DNA epigenetic expression (Lowell & Davis, 2008). Czyz et al. (2004) stated that GSM cell phone exposure influenced gene expression grades in embryonic stem cells (p53-lacking) and considerably increased heat shock protein HSP 70 formation. Belyaev (2010) stated that the most powerful effects of microwaves were seen in stem cells. The current FCC and ICNIRP public safety limits seem to be unable to adequately protect public health, especially for the embryo, foetus, neonate. However, the results of studies carried out on the effects of RF radiation (RFR) on the pregnant and infants during the pregnancy period were not consistent.

As it is known, peripheral blood consists of blood cells and plasma composed of lipids, proteins, electrolytes etc. The homeostasis of these cells and molecules ensures that the body remains healthy (Agus et al., 1982; Scheiermann et al., 2015). Also, Mcree (1979) and Roberts et al. (1986) stated that some haematological parameters are susceptible to RFR exposure in animals and humans. It has been reported that RFR exposure during pregnancy results in haematological changes in certain populations (Repacholi, 1998). Some researchers stated that the magnetic field

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applied a dominant controlling effect on the thermoregulation, metabolism and haematology in rats (Amara et al., 2006). Trosic et al. (2004) have investigated the effects of exposure to RFR (2.45 GHz, 30 d) on erythropoiesis in rats: temporary effects have been observed, which were connected to adaptive responses to stress related to exposure. Jin et al. (2011) observed the sporadic variations in a serum chemistry of young rats after exposure (5 d per week for 1 year) to united CDMA and WCDMA signals. Wong et al. (1985) exposed rats to RFR (20 MHz RF, at 1920 mW/cm^2, 0.3 W/kg, 6 h/d, 5 d/week) and reported no significant changes in RBC count, haemoglobin or any of the biochemistry parameters. In a different study, Forgács et al. (2005) observed that applied RFR (1800 MHz GSM-like, 0.018–0.023 W/kg, 100 μW/cm^2) exposure may induce slight but statistically important changes in some haematological of male mice. Abdel Aziz et al. (2010) noticed that RF exposure (900 MHz GSM like, 1.2 W/kg, 1.4–4.7 mW/cm^2) results in significant difference in haematological and biochemistry parameters of blood of albino rats. Dasdag et al. (2000) examined the effects of being subject to GSM RF exposure emitted from cell phones (900 MHz, 217 Hz modulation frequency, pulse width 577 μs) throughout a pregnancy on the peripheral blood parameters. The results were that there was no determinable difference in the peripheral blood parameters. St-Pierre et al. (2008) observed that prenatal exposure to the complex sequenced magnetic fields (very low 5–20 nT, low 30–50 nT, medium 90–580 nT and high 590 nT–1.2 μT) resulted in significant intensity-dependent changes in biochemistry of rats. Moreover, Kismali et al. (2012) noted that prenatal RFR (GSM, 1800 MHz, whole-body) exposure might lead to changes on some biochemistry parameters of infant rabbits. However, Galvin et al. (1982) reported that serum biochemistry parameters of rats were not affected by RFR (2.45 GHz RF for 8 h at 2 or 10 mW/cm^2, 0.44 or 2.2 W/kg) exposure. Also, Chung et al. (2003) stated that exposure of pregnant rats to 60 Hz at magnetic field strengths up to 500 mT during gestation day 6–20 did not produce any significant change on serum biochemistry parameters.

Because of discussion stated above, aim of this study is to investigate whether pregnant exposed to RFRs emitted from mobile phones during prenatal period are under the risk of health problems. For this, we examined biochemical parameters such as aspartat aminotransferaz (AST), alanine aminotransferase (ALT), lactate dehydrogenase (LDH), creatine kinase (CK), creatine kinase–miyocardial band (CK–MB), c-reactive protein (CRP), troponin T (TnT), uric acid, lactate including some blood parameters such as procalcitonin (PCT), MPV (mean platelet volume) in cord blood of pregnant women exposed mobile phone for different times. Most of the researches claim that pregnant women and the foetuses may negatively be affected by RFRs. However, overwhelming majority of the studies performed on the RFR exposure and pregnancy until today were not based on pregnant women and infants. The lack of human studies on this topic is making the subject controversial and this situation causes both time and economic loss. Therefore, the results of this human study will make an important contribution enlightenment of the issue.

Materials and methods

Cord blood biochemical parameters of 149 infants whose mothers exposed to different RFR exposure duration during pregnancy were investigated in this study. Without the use of any assisted reproductive technology, self-pregnancy was included in the study. Women with any medical treatment, chronic systemic disease and multiple pregnancy were excluded from the study. A total of 149 pregnant women between the ages of 18 and 40, who volunteered to participate in the study, signed an approval form. Based on their daily mobile phone usage periods, pregnant women were divided into four groups as

Control group: Composed of no mobile phone users (*n*: 37).

Group 1. 2–15 min mobile phone exposure (*n*: 39).

Group 2. 15–60 min mobile phone exposure (*n*: 37).

Group 3. Mobile phone exposure more than 60 min (*n*: 36).

AST, ALT, LDH, CK, CK–MB, CRP, PCT, TnT, uric acid, PLT (platelet count), MPV and lactate were examined in the cord blood of the postpartum with complete blood count. The blood parameters investigated in this study were analysed by autoanalyzer (PCT: Boditech Med Inc. Korea; AST, ALT, LDH, CK, CK–MB, CRP, TnT, uric acid: Roche Diagnostics GmbH Mannheim, Germany; Lactate: Radiometer Medical ApS, Denmark; PLT, MPV: Sysmex Corporation Kobe, Japan). The study was approved by the Ethics Committee of the Medical Faculty of Istanbul Medeniyet University, Report No: 2016/0037.

Statistical analyses

All statistical analyses were performed with the STATA/MP11 programme. Data were expressed as number and percentage in mean ± standard deviation. Normal distribution data were analysed by ANOVA and *post-hoc* Bonferroni test, while those without normal distribution were analysed by Kruskal–Wallis and *post-hoc* Dunn test. A value of $p < 0.05$ was considered statistically significant.

Table 1. Cord blood parameters of pregnant women.

Cord blood parameters	Reference range	Control	2–15 m/d (Group 1)	15–60 m/d (Group 2)	>60 m/d (Group 3)	*p*
AST (IU/L)	35–100	44.54 ± 19.94	46.61 ± 17.17	64.83 ± 18.75[a,b]	75.05 ± 23.39[a,b]	<0.001
ALT (IU/L)	6–40	49.29 ± 28.27	42.51 ± 22.28	47.81 ± 14.94	61.38 ± 31.25[a,b,c]	<0.001
LDH (IU/L)	170–580	386.75 ± 147.98	765.97 ± 483.77[a]	807.10 ± 262.77[a]	866.91 ± 279.63[a]	<0.001
CK (IU/L)	70–380	84.18 ± 35.72	110.28 ± 95.21	172.35 ± 118.73[a]	497.88 ± 156.09[a,b,c]	<0.001
CK–MB (IU/L)	0–25	67.18 ± 40.91	81.69 ± 23.85[a]	95.00 ± 29.14[a]	127.66 ± 49.53[a,b]	<0.001
CRP (IU/L)	0.06–1.58	0.71 ± 0.46	0.80 ± 0.38	1.01 ± 0.58	3.77 ± 2.03[a,b,c]	<0.001
PCT (ng/mL)	<2	0.38 ± 0.40	0.63 ± 0.50	0.80 ± 0.45[a]	1.18 ± 0.65[a,b]	<0.001
TnT (ng/mL)	12.7–24.9	18.57 ± 4.81	18.32 ± 3.54	26.16 ± 7.16[a,b]	70.03 ± 15.05[a,b,c]	<0.001
Uric acid (mg/dL)	1.8–5	3.04 ± 0.64	3.31 ± 0.68	3.53 ± 0.80	4.72 ± 1.01[a,b,c]	<0.001
Lactate (mmol/L)	0–0.3	2.00 ± 0.17	2.01 ± 0.19	2.22 ± 0.20[a,b]	4.62 ± 1.13[a,b,c]	<0.001
PLT (k/mm^3)	84,000–478,000	271,955.56 ± 70,826	283,953.97 ± 82,324	278,397.00 ± 64,684	241,356.77 ± 62,525[b,c]	0.029
MPV (fL)	8.9 ± 1.5	11.48 ± 0.31	11.03 ± 0.32[a]	10.90 ± 2.02[a]	8.64 ± 1.37[a,b,c]	<0.001

[a]Significant difference from control group.
[b]Significant difference from 2 to 15 min group.
[c]Significant difference from 15 to 60 min group.
m/d: minutes/day; h/d: hour/day.

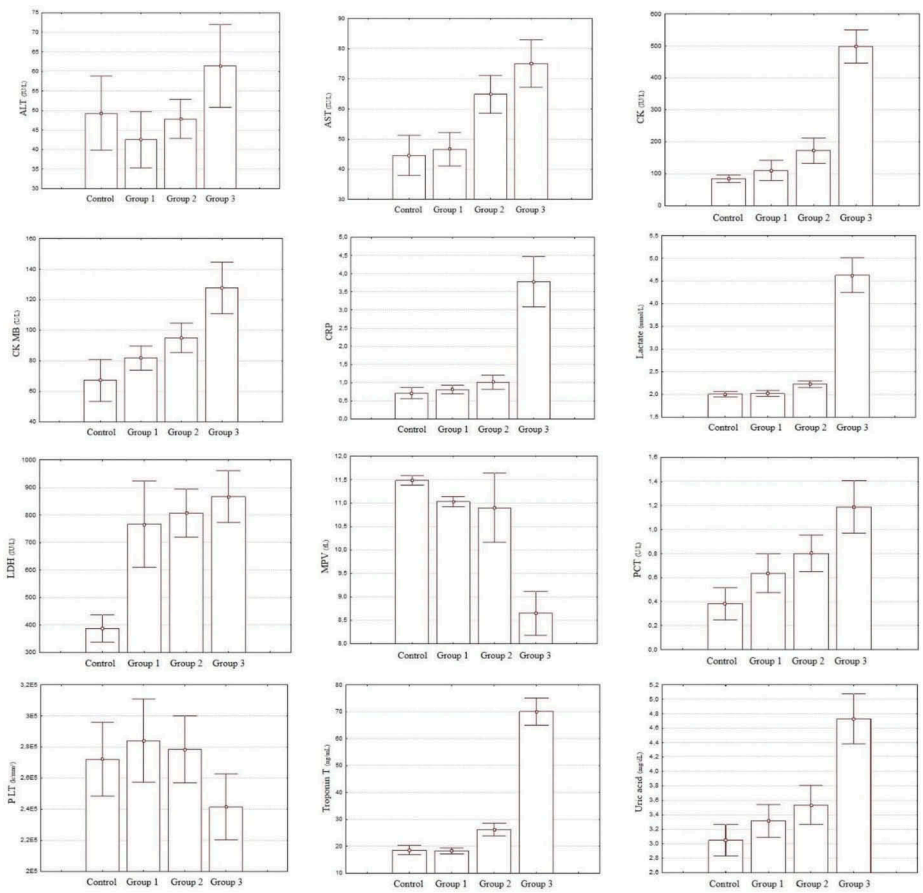

Figure 1. Results of cord blood biochemical parameters.

Results

Cord blood biochemical parameters of pregnant women in this study are shown table 1 and figure 1. Cord blood biochemical parameters of pregnant women in this study are shown table 1 and figure 1. AST, ALT, LDH, CK, CK-MB, CRP, PCT, TnT, uric acid and lactate in group 3 were found higher than the control group (p<0,001). However, MPV in group 3 were found lower than the control, group 1 and group 2 (p<0,001, p<0,001 and p<0,001respectively). LDH and CK-MB levels increased and MPV level decreased in group 1 according to the control (p<0,001). On the other hand, AST, LDH, CK, CK-MB, PCT, TnT, Lactate increased and MPV decreased in group 2 according to the control (p<0,001). We found a correlation between mobile phone talking time and alteration in cord blood parameters. For instance, all the blood parameters increased except MPV depend on

increasing of talking time. Similarly MPV decreased depend on increasing of talking time. By the way, TnT and lactate in group 3 were found higher than the other groups including the control. Similarly, level of the same parameters in group 2 were also found higher than the control and group 1 (p<0,001).In summary, we found that mobile phones RFR exposure has potential to increase AST, ALT, LDH, CK, CK-MB, CRP, PCT, TnT, uric acid and lactate and decrease MPV in the cord blood of pregnant (<0.001).

Discussion

RFR absorption of tissues and organs is different than each other. The alterations vary depending on the structural characteristics such as the conductivity of tissues etc. (Matthes, 1996). In pregnancy, the conductivity of placenta and uterus, which has higher amount of water, is higher than the other organs. The majority of recent studies reported that RFR emitted from mobile phone caused oxidative stress (Dasdag & Akdag, 2015). Oxidative stress related to RFR leads to lipid, protein and DNA damage in various tissues (Dasdag et al., 2012; Lai & Singh, 1996). RFR exposure also causes lipid peroxidation in the organism. MDA is one of the products resulting from the oxidation of polyunsaturated fatty acids in cells. Therefore, the increase in free radicals causes excessive production of MDA (Dasdag et al., 2012; Halliwel & Chirico, 1993). Cell membranes are mainly constituted of polyunsaturated fatty acids, which are especially sensitive to assault by free radicals. The attack of free radicals on membrane lipids by changing the fluidity of the membrane leads to increased membrane permeability. This situation causes compounds such as CK and CK–MB isoenzymes in the cytoplasm released to circulation (Kismali et al., 2012). CK catalyses the revolution of a high-energy phosphate from ATP to creatine. This process results in the formation of creatine phosphate. Majority of the CK exist in skeletal muscle and heart muscle (Kismali et al., 2012). The MB which is isoform of the CK enzyme is most abundant in heart. After myocardial damage, the amount of CK–MB in myocardium increases. It has been observed that CK–MB levels were elevated in peoples with hypertension, left ventricular hypertrophy and coronary artery disease (Ingwall et al., 1985). Myocardial cell death of any reason will result in an increasing and decreasing level of CK–MB (Adams et al., 1993). Also CK, CK–MB and LDH are enzymes that increased in blood serum in cardiac injury (Barberi et al., 1999). TnT, a structural protein found in the cytoplasm of myocytes, regulates actin and myosin interaction. Even though troponin T cannot be appeared in normal persons, in the early phases of myocardial injuries, it can be determined in blood serum (Kaplan, 1997). Also, Clark et al. (2001) reported that cardiac TnT may be a convenient indication for myocardial damage in infants. However, TnT values in paediatric patients seem to be more responsive than CK and CK–MB for the indication of myocardial damage (Lipshultz et al., 1997). By the way, it has been reported that CK–MB increase during pregnancy due to RF exposure (Kismali et al., 2012). In this study, we observed a statistically significant enhancement in CK, CK–MB, LDH and TnT in the cord blood of pregnant women who talking with mobile phone more than one hour/day during pregnancy (p< 0.001). However, a correlation was clinically observed between increasing of the parameters and daily mobile phone talk duration. In our study, the highest level of CK, CK–MB, TnT and LDH was observed in the fourth group pregnant, which is the most RF exposed group. Therefore, it can be stated that infant of the most RF exposed women may have a potential to be candidate of cardiovascular disease.

Our results demonstrated that ALT and AST levels were significantly enhanced following the increase in treated time to RFR emitted from mobile phones.

In agreement with our results, Moussa (2009) reported that serum transaminases (AST, ALT) showed significant increment in rats exposed to microwave radiation (3.5 GHz, SAR 1.2 W/kg). Similar findings were stated for pregnant rats by Yilmaz et al. (2017) (900 MHz, 24 h/d for 20 d) and Ragy (2015) (900 MHz for 1 h/d for 60 d). By the way, Đinđić et al. (2010) also indicated RFR as potential to increased ALT. As it is known, both ALT and AST are specific liver enzymes which are enhanced in hepatic diseases and toxic damage of hepatocytes (Pashovkina & Akoev, 2001). Mortazavi et al. (2016) reported that mobile phone RF exposure can cause light or strong inflammatory alterations in the portal areas of the liver of rat. Furthermore, oxidative stress generated by RF radiation exposure can reason tissue injury. Previous studies have shown that RFRs cause oxidative damage and lipid peroxidation in the liver (Cetin et al., 2014; Dasdag et al., 2008; Dindic et al., 2010; Ragy, 2015; Toossi et al., 2017; Yilmaz et al., 2017). In the newborns, high transaminase activity relative to adults is associated with leakage from hepatocyte membranes with high immune and permeability (Zanardo et al., 1985). LDH is a precious marker for some significant diseases in infants (Patavoukas et al., 2017). Especially, it is one of the indicators of liver cell destruction (Joanne, 2006). Ozgur et al. (2014) carried out a study examining effects of RF radiation (GSM

900, 1800 MHz, 2 W/kg) on cell viability and cell damage of the hepatocarcinoma cells under distinct exposure periods (1, 2, 3 and 4 h). They observed that supernatant levels of LDH were significantly higher in Hep G2 cell culture after 4 h RFR exposure. The seepage of liver-specific aminotransferases (LDH) into the serum might be looked as the result of cellular membrane injury and, therefore, necrosis. LDH release might be used as a cytotoxicity determinant in liver cells (Grub et al., 2000). Similarly, Ma et al. (2014) reported that the serum LDH level significantly increased in the irradiated group (900 MHz, 4 h/d, 18 successive days) on rats. However, Đinđić et al. (2010) observed that the serum level of ALT was significantly increased, while levels of AST and LDH did not change remarkably in the RFR exposed rats. In our study, ALT, AST and LDH levels were significantly increased in the cord blood of infants of pregnant exposed to RFR more than 60 m/d during the pregnancy (<0.001). The dramatic increase in these enzymes may be due to degradation of the membrane structure of the liver cells due to the oxidative damage which caused by the RFRs. However, it is indicated that RFR emitted from mobiles phones has the ability to exert a direct effect on cellular and subcellular levels by damaging cell membranes and influencing signal transduction pathways. The direct effect of this process is the leakage of cytosolic enzymes such as LDH and energy metabolism disorders in hepatocytes.

It is reported that serum CRP and PCT are increased in infections, severe systemic inflammations, organ dysfunctions and tissue traumas (Meisner and Reinhart, 2001; Meisner, 2002). However, Balakrishnan et al. (2014) reported that the serum CRP as systemic inflammatory biomarker increased depending on the duration of exposure to radiation emitted from mobile phone. In our study, a significant increment in CRP and PCT levels was observed in cord blood of pregnant women talking with mobile phone in more than one h/d (<0.001). As it is seen above, CRP results of this study are supported by Balakrishnan et al. (2014) which is performed on adult mobile phone users.

The serum lactate level which is a reflection of the degree of global tissue anoxia can be used as a marker of organ damage. It is reported that a statistically significant relationship was observed between serum lactate level and subsequent mortality and morbidity in neonates (Simalti et al., 2015). Our results showed that serum lactate level was increased depending on the increment in exposure time to RFR emitted from mobile phones. We did not find any work that revealed the relationship between RF and lactate. However, a few studies are available on RFR exposure and lactate. For instance, Elferchichi et al. (2011) stated that the static magnetic field (128 mT) exposure (for 1 h/d during 15 consecutive days) caused an increase in the serum lactate level of rats. On the other hand, Harakawa et al. (2005) observed that the plasma lactate level does not change as depending on electric field exposure (alternating current of 50 Hz, at 17500 V/m intensity for 15 m/d during 14 d) on rats.

Serum uric acid is one of the most important antioxidants and is responsible for deactivating >50% of the free radicals in the human blood. For this reason, there is a strong relationship between the concentration of serum uric acid in blood serum and antioxidant activity (Shalaby et al., 2017). Dasdag et al. (1992) indicated that RFR emitted from TV transmitting station increased uric acid in technicians. Dasdag et al. (1999) also observed that uric acid increased in radio-link station technicians. Ozgur et al. (2013) reported that the uric acid level elevated in RF (1800 MHz GSM, 15 m/d for 7 d) exposed infant rabbits. Moreover, Guler et al. (2007) found that uric acid levels elevated after 1.8 kV/m irradiation in guinea pigs, but this increment was not statistically important. In that study, it was also noted that the uric acid levels linearly raised by the implementation of an increasing magnitude of the electromagnetic field. However, Kismali et al. (2012) stated that RF exposure (1800 MHz GSM, 15 m/d) during pregnancy did not have an effect on uric acid level. In this study, we observed that the serum uric acid level significantly increased in cord blood of infants of pregnant exposed to RFR more than 60 m/d (<0.001). The reason of elevated uric acid may have been originated from increased number of free radical. However, results of this study were supported by Dasdag et al. (1992, 1999) and Ozgur et al. (2013).

Platelets (PLT) which are astonishingly multifunctional are included in many pathophysiological processes such as homeostasis and thrombosis, clot retraction, vessel constriction and repair, inflammation, host defence (Harrison, 2005). Alghamdi and El-Ghazaly (2012) noticed that there was opposite association between the number of platelets and duration of exposure to mobile phones (GSM 900–1800 MHz, 0.49 W/kg, 0.72 W/kg). They observed that the number of platelets was reduced depending on the increase in RFR exposure duration. By contrast, Dasdag et al. (2000) reported that RFR emitted from mobile phone (GSM 890 and 915 MHz) was not affected the number of PLT in rats. Also in another study, it was noted that there was no significant difference in PLT level between the exposed to extremely low-frequency electromagnetic fields (0.97 mT, 3 h/d, 50 d) and control groups in rats (Cakir et al., 2009). The results of our study indicated that RFR exposure more than 60 m/d reduced PLT in cord blood of pregnant (<0.001). The

contradictions between the studies discuss above may have been originated from different experimental conditions. However, our result was supported by Alghamdi and El-Ghazaly et al. (2012).

MPV indicates the presence of inflammatory condition and disease activity in many diseases (Shalaby et al., 2017). We observed that the MPV level significantly was decreased by RFR in cord blood of pregnant exposed more than 60 m/d (<0.001). We did not find any study that observes relation between RFR and MPV. However, Cakir et al. (2009) found that the long-term exposure to extremely low-frequency electromagnetic field (0.97 mT, 3 h/d, 50 d) caused significant decrease in MPV level in rats.

In conclusion, the results of our study indicated that RFRs emitted from mobile phones are not innocent as stated by some studies. According to our results, we can state that exposure duration is the main parameter for the protection. Therefore, women have to avoid long-term mobile phone exposure especially during pregnancy. This preliminary human study has potential to be the base for future performances.

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