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Effect of mobile phone usage duration during pregnancy on the general motor movements of infants

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ABSTRACT

Radiofrequency radiation (RFR) emitted from wireless devices increases rapidly and the most sensitive groups are pregnant women and children. Therefore, we aimed to evaluate the fidgety movements (FMs) and motor repertoires of the infants of pregnant women with different durations of mobile phone usage (DOMFU) in the prenatal period by performing a general movement assessment (GMA) using the Prechtl method. Infants suitable for the study were divided into 4 groups according to their mothers' duration of mobile phone usage during pregnancy, comprising those who did not talk on a mobile phone (Control Group, *n*: 31), those with mobile phone usage (MFU) of ~20 min a day (Group 1, *n*: 33), those with MFU of ~40 min a day (Group 2, *n*: 31), and those with MFU of ~2 h a day (Group 3, *n*: 28). The analysis showed that the abnormal fidgety (AF) and absent fidgety (F–), suboptimal motor optimality score (MOS) and reduced motor repertoire were statistically higher in Group 3 compared to the other groups. Normal posture and the quality of other movements were statistically higher in the Control, and Groups 1 and 2 compared to Group 3. According to the findings, infants of mothers with different DOMFU during pregnancy differed with regard to the quality of FMs, MOS, repertoire, posture and other movements. In conclusion, the findings suggested that there may be a relationship between prenatal RFR exposure and motor development in infants. More long-term studies are needed to determine whether these changes are temporary or permanent.

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KEYWORDS
Radiofrequency radiation; pregnancy; infant; fidgety movements; general motor movements

Introduction

Along with developments in technology, the level of radiofrequency radiation (RFR) created by various wireless communication tools in the environment, especially mobile phones, is increasing rapidly, day-by-day, and has caused an environmental problem called Electromagnetic Pollution. Widespread use of mobile phones causes adverse effects on the nervous system, such as cognitive and neurological disorders [1,2], memory impairment [3], increased parasympathetic nerve activity [4], increased thyroid function [5], weakening of the immune system [6], increased permeability of the blood-brain barrier [7], changes in amygdala morphology and emotional behaviour [8], changes in cerebral cortex neurotransmitter release [9], cytotoxicity in hippocampal neuronal HT22 cells [9], and degenerative changes in hippocampus pyramidal cells [10], and has adverse effects on the nervous system.

Studies have shown that even gene and protein expression can be affected by radiofrequency radiation (RFR) exposure [11–13]. Some authorities developed safety limits to protect the public against the negative health effects of RFR but the limits are presently valid for more susceptible groups, such as pregnant women, foetuses, or embryos [11].

Studies have suggested that prenatal RFR exposure might be associated with anomalies and growth retardation in foetuses or embryos [14,15], speech problems in children [16], oxidative stress in mothers and offspring [17], and changing electrophysiological properties in the Purkinje cerebellum neurons and ion currents [18]. It was reported that the research on the sensitivity of children to electromagnetic fields should be increased [11]. Research on the effects of RFR emitted in the environment by communication tools, such as mobile phones and Wi-Fi, on the foetus and mother is very limited. In most of the studies on the subject, the majority of which consist of animal studies, there are differences between the parameters, such as the experimental setups, techniques used and specific radiation absorption rates (SAR), etc [11].

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The complex, fluid and variable-speed movements involving the whole body are called general movements (GMs). GMs begin at week 9 after menstruation and last up to 6 months postterm [19,20]. The quality of these GMs accurately reflects the infant's neural development and is an excellent way to identify early brain damage and dysfunction [20]. GMs differ in three periods: preterm, writhing, and fidgety. The normal movement patterns in newborns 3–5 months after birth are called fidgety movements (FMs) [21]. These FMs are evaluated as normal (F+), absent fidgety (F–), and abnormal fidgety (AF). AF and F– have high predictive values in predicting whether the baby is clinically developing normally or whether there is mild or severe neurological impairment [19]. In the last few decades, evidence has accumulated that FMs are a particularly accurate marker for the neurological outcome of high-risk infants. Recent systematic reviews and meta-analyses have recognized the qualitative analysis of GMs, using the Prechtl method, to be equally powerful or even more powerful than classical neurological examination and neuroimaging findings [22]. The GMs of 3–5-month-old infants include not only FMs, but also age-appropriate movement patterns and postural patterns [23].

In this study, we aimed to compare the FMs, motor optimality score (MOS), repertoire of co-occurring movements, posture and the quality of other movements in the 3–5 month period of the infants of women with mobile phone usage (MFU) of different durations during the prenatal period by performing a general movement assessment (GMA) using the Prechtl method.

Subjects and methods

Ethics statement

This study was initiated by the approval of Health Sciences University Van Training and Research Hospital Ethics Committee (Report No: 2021/20) after statistical power analysis. Parents or legal guardians provided written informed consent forms.

Subjects

A total of 123 infants, aged 3–5 months, who came to our polyclinic, were included in the study. The infants were divided into four groups according to the duration of their mothers' mobile phone usage during pregnancy: 1) those with no MFU (Control Group, *n*: 31), 2) those with MFU of ~20 min a day (Group 1, *n*: 33), 3) those with MFU of ~40 min a day (Group 2, *n*: 31), and 4) those with MFU of ~2 h a day (Group 3, *n*: 28). All of the parameters that may affect the infants' GMs and neural development, such as birth weight, head circumference, birth length, gender, week of birth, status according to birth week, delivery type, and presence of foetal distress and meconium, were recorded. In addition, records were kept of some maternal information (maternal age, paternal consanguinity, hypertension, placental disease, systemic diseases, amniotic fluid status, vitamin, iron, vitamin D, folic acid use, toxoplasma, rubella, cytomegalovirus, herpes simplex, urinary tract infection, upper respiratory tract infection, vaginitis, chorioamnionitis, amount of medically exposed radiation, presence of base station, paternal smoking and alcohol habits, SAR values of mobile phones, and mobile phone usage times). The MOSs of the infants were calculated according to FMs and other accompanying movements.

Observational GMA

Observational GMA was performed by a paediatrician who had 7 years of GMA certification and experience. The evaluator completed the assessments blindly, without knowing the infants' clinical histories and or which group they belonged to. The Prechtl method was used for the observational GMA. The MOS of all of the infants were determined and the groups were compared with each other. The MOS, which has a maximum of 28 points and a minimum of 5 points, consists of five subsections and is scored as follows [24,25]:

1. Fidgety Movements: F+: 12 points, AF: 4 points, and F–: 1 point
2. Motor Repertoire: Age-appropriate motor repertoire: 4 points, decreased motor repertoire: 2 points, absence of age-appropriate motor repertoire: 1 point.
3. Motor Patterns (Except for FMs): Movement patterns can have a normal or abnormal appearance. Abnormal patterns are mostly circular arm movements and asymmetric segmental movements. It is 4 points if normal movement patterns are dominant, 2 points if normal and abnormal movements exist at an equal level, 1 point if abnormal movement patterns are dominant.
4. Posture: Normal postural pattern is 4 points, equal predominance of normal and abnormal postural pattern is 2 points, abnormal postural pattern is 1 point.
5. Quality of Other Movements: 4 points are given if all movements are normally fluid, in various sequences and smooth. If the movements are jerky, rigid and less complex, they are considered abnormal, 2 points are given. If the

cramped-synchronized (CS) movement pattern is dominant, 1 point is given [23].

Statistical analyses

Whether the variables were suitable for normal distribution was tested using the Shapiro–Wilk test. Variables that did not fit the normal distribution were presented as median (minimum–maximum) values, the Mann–Whitney *U* test was used for comparisons between two independent groups, and the Kruskal–Wallis H test was used for comparisons of 3 or more independent groups. Categorical variables were expressed as frequencies and percentages, *n* (%), and the Fisher exact *chi*-square test was used for the comparisons. Statistical analyses were conducted using IBM SPSS Statistics for Windows 22.0 (IBM Corp., Armonk, NY, USA). Differences were considered statistically significant at the level of $p < 0.05$.

Results

The evaluations of the FMs, MOS, repertoire of co-occurring movements, posture, and quality of other movements of all infants are shown in Table 1. A minor neurological disorder (MND) was found in 1.6% of the infants.

During the prenatal period, the infants of mothers with different DOMFU differed in terms of the FMs, MOS, repertoire, posture, and quality of other movements ($p < 0.05$) (Table 2).

Table 1. Descriptive statistics of the FMs, MOS, repertoire of co-occurring movements, posture and quality of other movements.

	Frequency	Percentage
Fidgety		
F+	116	94.3
F–	2	1.6
AF	5	4.1
Total	123	100
MOS		
Optimal (25–28)	116	94.3
Suboptimal (24)	7	5.7
Total	123	100
Repertoire of co-occurring movements		
Age-adequate	119	96.7
Reduced	4	3.3
Total	123	100
Posture		
Normal	115	93.5
Normal = Abnormal	8	6.5
Total	123	100
Quality of other movements		
Normal > Abnormal	117	95.1
Normal = Abnormal	6	4.9
Total	123	100.0
Result		
Normal	121	98.4
MND	2	1.6
Total	123	100.0

Table 2. Investigation of the infants of mothers with different durations of mobile phone usage (DOMFU) during the prenatal period in terms of FMs, MOS, repertoire of co-occurring movements, posture and quality of other movements.

		Duration of use				
		Control	20 min	40 min	2 h	
		(*n* = 31)	(*n* = 33)	(*n* = 31)	(*n* = 28)	*p* Value
FMs	F+	31 (100)	33 (100)	29 (93.5)	23 (82.1)	**0.011**
	F–	0 (0)	0 (0)	0 (0)	2 (7.1)	
	AF	0 (0)	0 (0)	2 (6.5)	3 (10.7)	
MOS	Optimal (25–28)	31 (100)	33 (100)	30 (96.8)	22 (78.6)	**<0.001**
	Sub-optimal (24)	0 (0)	0 (0)	1 (3.2)	6 (21.4)	
Repertoire of co-occurring movements	Age-adequate	31 (100)	33 (100)	31 (100)	24 (85.7)	**0.002**
	Reduced	0 (0)	0 (0)	0 (0)	4 (14.3)	
	Absent	0 (0)	0 (0)	0 (0)	0 (0)	
Posture	Normal	31 (100)	33 (100)	29 (93.5)	22 (78.6)	**0.001**
	Normal = Abnormal	0 (0)	0 (0)	2 (6.5)	6 (21.4)	
	Abnormal	0 (0)	0 (0)	0 (0)	0 (0)	
Quality of other movements	Normal > Abnormal	31 (100)	33 (100)	31 (100)	22 (78.6)	**<0.001**
	Normal = Abnormal	0 (0)	0 (0)	0 (0)	6 (21.4)	
	Normal < Abnormal	0 (0)	0 (0)	0 (0)	0 (0)	

$p < 0.05$, Fisher's exact *chi*-square test.

Table 3. Investigation of the F– and AF status of the infants' FMs according to the MOS, repertoire, posture and quality of other movements and outcome.

	Fidgety		
	Absent fidgety	Abnormal fidgety	*p* Value
	(*n* = 2)	(*n* = 5)	
MOS			
Optimal (25–28)	0 (0)	1 (20)	0.999
Sub-optimal (24)	2 (100)	4 (80)	
Repertoire			
Age-adequate	0 (0)	3 (60)	0.429
Reduced	2 (100)	2 (40)	
Quality of other movements			
Normal > Abnormal	0 (0)	2 (40)	0.999
Normal = Abnormal	2 (100)	3 (60)	
Outcome			
Normal	0 (0)	5 (100)	**0.048**
MND	2 (100)	0 (0)	

Fisher's exact *chi*-square test

The AF and F– ($p < 0.05$), suboptimal MOSs ($p < 0.001$), reduced motor repertoire ($p < 0.05$) in Group 3 were statistically significantly higher than the other groups. Normal posture ($p = 0.001$) and quality of other movements ($p < 0.001$) were statistically significantly higher in the Control, and Groups 1 and 2 when compared to Group 3.

In the infants, the F– and AF did not differ in terms of the MOS, repertoire, or quality of other movements ($p > 0.05$). The F– and AF differed in terms of the outcome ($p < 0.05$). The infants with AF were neurologically normal, while the infants with F– developed MNDs (Table 3).

According to the findings, the repertoire of the infants differed according to the gestational week, and all of the infants with reduced repertoire were borderline premature. In other words, the rate of reduced repertoire was higher in the borderline premature infants when compared to the term, post-term and premature infants (Table 4).

In the results obtained, there was a relationship between the number of abortions by the mothers and the FMs. The number of F+was higher in the infants of mothers who had not had an abortion when compared to those of mothers who had 4 or more abortions. The MOS and posture also differed according to the number of abortions. Optimal MOS and normal posture were observed more often in the infants of mothers who had not had an abortion when compared to those of mothers who had 4 or more abortions (Table 4).

There was a relationship between the MOS and posture and daily mobile phone usage frequency. The number of suboptimal MOS and normal = abnormal postures was higher in the infants of mothers with MFU > 4 times a day (Table 4). The other variables did not differ according to the quality of FMs, MOS, repertoire, posture or other movements.

Discussion

To the best of our knowledge, this was the first case–control study to examine FMs and motor repertoires in infants exposed to RFR emitted from mobile phones at different durations during the prenatal period. According to the findings, the infants of mothers with different DOMFU during the prenatal period differed with regard to the quality of the FMs, MOS, repertoire, posture, and other movements.

A baby's development is not only affected by individual factors related to biological and genetic characteristics. Environmental factors, such as microsystem (family, home, surroundings, peers, etc.), exosystem (extended family, neighbourhood, school, etc.) and macrosystem (community, economic system, culture, etc.) environments are also effective [23]. It is certain that people, and therefore pregnant women, will be exposed to these rays to a greater extent in today's world, where discussions that 5G technology can be more risky on living things and the environment continue to take place. This is because with the implementation of 5G technology, the cumulative RFR level in the environment will increase involuntarily and it will be inevitable for people to be exposed to these rays [26]. It does not seem plausible that RFR, whose levels in the environment are thought to increase tremendously, do not affect babies in the womb.

The idea that the human body can tolerate tens of times more radiation at millimeter wavelengths is based on a faulty modelling of the human body as an outer structure filled with a homogeneous fluid, along with the assumption that millimeter waves do not completely pass beyond the skin, completely ignore nerves, blood vessels and other electrically conductive structures that can carry radiation-induced currents deep into the body [11].

Table 4. Analysis of the confounding factors according to the FMs, MOS, repertoire, posture and quality of other movements.

	Fidgety movement			MOS		Repertoire of co-occurring movements		Posture		Quality of other movements	
	F+	F–	AF	Optimal (25–28)	Sub-optimal (24)	Age-adequate	Reduced	Normal	Normal = abnormal	Normal > abnormal	Normal = abnormal
Daily mobile phone usage frequency											
Less than 2 times a day	8 (6.9)	0 (0)	0 (0)	8 (6.9)	0 (0)	8 (6.7)	0 (0)	8 (7)	0 (0)	6 (6.1)	0 (0)
2–4 times a day	31 (26.7)	0 (0)	0 (0)	31 (26.7)	0 (0)	31 (26.1)	0 (0)	31 (27)	0 (0)	25 (25.5)	0 (0)
More than 2 times a day	45 (38.8)	2 (100)	5 (100)	45 (38.8)	7 (100)	48 (40.3)	4 (100)	44 (38.3)	8 (100)	39 (39.8)	6 (100)
Absent	32 (27.6)	0 (0)	0 (0)	32 (27.6)	0 (0)	32 (26.9)	0 (0)	32 (27.8)	0 (0)	28 (28.6)	0 (0)
p		0.184		**0.025**		0.269		**0.013**		0.078	
Abortion											
Absent	95 (81.9)	2 (100)	2 (40)	95 (81.9)	4 (57.1)	96 (80.7)	3 (75)	94 (81.7)	5 (62.5)	95 (96.9)	4 (66.7)
1	12 (10.3)	0 (0)	0 (0)	12 (10.3)	0 (0)	12 (10.1)	0 (0)	12 (10.4)	0 (0)	0 (0)	0 (0)
2	3 (2.6)	0 (0)	1 (20)	3 (2.6)	1 (14.3)	4 (3.4)	0 (0)	3 (2.6)	1 (12.5)	0 (0)	0 (0)
3	3 (2.6)	0 (0)	0 (0)	3 (2.6)	0 (0)	3 (2.5)	0 (0)	3 (2.6)	0 (0)	0 (0)	0 (0)
4 or more	3 (2.6)	0 (0)	2 (40)	3 (2.6)	2 (28.6)	4 (3.4)	1 (25)	3 (2.6)	2 (25)	3 (3.1)	2 (33.3)
p		0.041		0.029		0.378		0.041		0.259	
Gestational age (weeks)											
Term (37–42)	85 (73.3)	0 (0)	2 (40)	85 (73.3)	2 (28.6)	87 (73.1)	0 (0)	84 (73)	3 (37.5)	72 (73.5)	1 (16.7)
Post-term (42+)	3 (2.6)	0 (0	0 (0)	3 (2.6)	0 (0)	3 (2.5)	0 (0)	3 (2.6)	0 (0)	2 (2)	0 (0)
Premature (29–32)	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
Borderline premature (33–37)	27 (23.3)	2 (100)	3 (60)	27 (23.3)	5 (71.4)	28 (23.5)	4 (100)	27 (23.5)	5 (62.5)	23 (23.5)	5 (83.3)
p		0.086		0.051		0.011		0.130		0.163	
Kinship											
Absent	54 (46.6)	2 (100)	3 (60)	54 (46.6)	5 (71.4)	56 (47.1)	3 (75)	53 (46.1)	6 (75)	55 (47)	4 (66.7)
1st degree	44 (37.9)	0 (0)	2 (40)	44 (37.9)	2 (28.6)	45 (37.8)	1 (25)	44 (38.3)	2 (25)	44 (37.6)	2 (33.3)
2nd degree	11 (9.5)	0 (0)	0 (0)	11 (9.5)	0 (0)	11 (9.2)	0 (0)	11 (9.6)	0 (0)	11 (9.4)	0 (0)
Distant relative	5 (4.3)	0 (0)	0 (0)	5 (4.3)	0 (0)	5 (4.2)	0 (0)	5 (4.3)	0 (0)	5 (4.3)	0 (0)
No Kinship Same Village	2 (1.7)	0 (0)	0 (0)	2 (1.7)	0 (0)	2 (1.7)	0 (0)	2 (1.7)	0 (0)	2 (1.7)	0 (0)
p		0.902		0.752		0.805		0.668		0.884	
Hypertension											
Preeclampsia	23 (22.3)	0 (0)	2 (40)	23 (22.3)	2 (28.6)	25 (23.6)	0 (0)	23 (22.5)	2 (25)	19 (21.3)	1 (16.7)
Eclampsia	11 (10.7)	0 (0)	1 (20)	11 (10.7)	1 (4.3)	11 (10.4)	1 (25)	11 (10.8)	1 (12.5)	10 (11.2)	1 (16.7)
Not evaluated	6 (5.8)	0 (0)	0 (0)	6 (5.8)	0 (0)	6 (5.7)	0 (0)	6 (5.9)	0 (0)	6 (6.7)	0 (0)
Absent	63 (61.2)	2 (100)	2 (40)	63 (61.2)	4 (57.1)	64 (60.4)	3 (75)	62 (60.8)	5 (62.5)	54 (60.7)	4 (66.7)
p		0.695		0.818		0.430		0.999		0.999	
Birth											
Normal spontaneous vaginal delivery	55 (47.4)	1 (50)	2 (40)	55 (47.4)	3 (42.9)	57 (47.9)	1 (25)	54 (47)	4 (50)	45 (45.9)	3 (50)
Emergency caesarean spinal anaesthesia	5 (4.3)	1 (50)	0 (0)	5 (4.3)	1 (14.3)	5 (4.2)	1 (25)	5 (4.3)	1 (12.5)	4 (4.1)	1 (16.7)
Emergency caesarean general anaesthesia	10 (8.6)	0 (0)	0 (0)	10 (8.6)	0 (0)	10 (8.4)	0 (0)	10 (8.7)	0 (0)	8 (8.2)	0 (0)
Elective caesarean spinal anaesthesia	27 (23.3)	0 (0)	1 (20)	27 (23.3)	1 (14.3)	28 (23.5)	0 (0)	27 (23.5)	1 (12.5)	24 (24.5)	0 (0)
Elective caesarean general anaesthesia	19 (16.4)	0 (0)	2 (40)	19 (16.4)	2 (28.6)	19 (16)	2 (50)	19 (16.5)	2 (25)	17 (17.3)	2 (33.3)
p		0.405		0.511		0.098		0.594		0.269	
Foetal distress											
Present	22 (19)	1 (50)	0 (0)	22 (19)	1 (14.3)	22 (18.5)	1 (25)	22 (19.1)	1 (12.5)	18 (18.4)	1 (16.7)
Absent	91 (78.4)	1 (50)	5 (100)	91 (78.4)	6 (85.7)	94 (79)	3 (75)	90 (78.3)	7 (87.5)	77 (78.6)	5 (83.3)

(Continued)

Table 4. (Continued)

Not evaluated	3 (2.6)	0 (0)	0 (0)	3 (2.6)	0 (0)	3 (2.5)	0 (0)	3 (2.6)	0 (0)	3 (3.1)	0 (0)
p	0.372			0.999		0.618		0.999		0.999	
Meconium											
Present	14 (12.1)	1 (50)	0 (0)	14 (12.1)	1 (14.3)	14 (11.8)	1 (25)	14 (12.2)	1 (12.5)	14 (14.3)	1 (16.7)
Absent	102 (87.9)	1 (50)	5 (100)	102 (87.9)	6 (85.7)	105 (88.2)	3 (75)	101 (87.8)	7 (87.5)	84 (85.7)	5 (83.3)
p		0.319		0.999		0.410		0.999		0.999	
Toxoplasma. rubella. cytomegalovirus. herpes simplex. HIV											
Absent	114 (98.3)	2 (100)	5 (100)	114 (98.3)	7 (100)	117 (98.3)	4 (100)	113 (98.3)	8 (100)	96 (98)	6 (100)
Not evaluated	2 (1.7)	0 (0)	0 (0)	2 (1.7)	0 (0)	2 (1.7)	0 (0)	2 (1.7)	0 (0)	2 (2)	0 (0)
p	0.999			0.999		0.999		0.999		0.999	
Placental disease											
Absent	109 (94)	2 (100)	4 (80)	109 (94)	6 (85.7)	111 (93.3)	4 (100)	108 (93.9)	7 (87.5)	92 (93.9)	6 (100)
Placenta previa	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
Placental insufficiency	6 (5.2)	0 (0)	1 (20)	6 (5.2)	1 (14.3)	7 (5.9)	0 (0)	6 (5.2)	1 (12.5)	5 (5.1)	0 (0)
p		0.383		0.383		0.999		0.426		0.999	
Systemic disease											
Diabetes mellitus	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	0 (0)	0 (0)
Hyperthyroidism	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
Vasculitis	3 (2.6)	0 (0)	0 (0)	3 (2.6)	0 (0)	3 (2.5)	0 (0)	3 (2.6)	0 (0)	2 (2)	0 (0)
Absent	111 (95.7)	2 (100)	5 (100)	111 (95.7)	7 (100)	114 (95.8)	4 (100)	110 (95.7)	8 (100)	95 (96.9)	6 (100)
p		0.999		0.999		0.999		0.999		0.999	
Amniotic fluid											
Polyhydramnios	4 (3.4)	0 (0)	0 (0)	4 (3.4)	0 (0)	4 (3.4)	0 (0)	4 (3.5)	0 (0)	4 (4.1)	0 (0)
Oligohydramnios	4 (3.4)	0 (0)	1 (20)	4 (3.4)	1 (14.3)	4 (3.4)	1 (25)	4 (3.5)	1 (12.5)	3 (3.1)	1 (16.7)
Normal	108 (93.1)	2 (100)	4 (80)	108 (93.1)	6 (85.7)	111 (93.3)	3 (75)	107 (93)	7 (87.5)	91 (92.9)	5 (83.3)
p		0.421		0.421		0.265		0.466		0.389	
Vitamin											
Not used	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
Irregular usage	56 (48.3)	2 (100)	2 (40)	56 (48.3)	4 (57.1)	58 (48.7)	2 (50)	55 (47.8)	5 (62.5)	47 (48)	3 (50)
Regular usage	59 (50.9)	0 (0)	3 (60)	59 (50.9)	3 (42.9)	60 (50.4)	2 (50)	59 (51.3)	3 (37.5)	50 (51)	3 (50)
p		0.468		0.731		0.999		0.999		0.999	
Iron											
Not used	10 (8.6)	0 (0)	0 (0)	10 (8.6)	0 (0)	10 (8.4)	0 (0)	10 (8.7)	0 (0)	7 (7.1)	0 (0)
Irregular usage	42 (36.2)	2 (100)	2 (40)	42 (36.2)	4 (57.1)	44 (37)	2 (50)	41 (35.7)	5 (62.5)	36 (36.7)	3 (50)
Regular usage	64 (55.2)	0 (0)	3 (60)	64 (55.2)	3 (42.9)	65 (54.6)	2 (50)	64 (55.7)	3 (37.5)	55 (56.1)	3 (50)
p		0.498		0.584		0.999		0.350		0.793	
Vitamin D											
Irregular usage	53 (45.7)	2 (100)	2 (40)	53 (45.7)	4 (57.1)	55 (46.2)	2 (50)	52 (45.2)	5 (62.5)	44 (44.9)	3 (50)
Regular usage	63 (54.3)	0 (0)	3 (60)	63 (54.3)	3 (42.9)	64 (53.8)	2 (50)	63 (54.8)	3 (37.5)	54 (55.1)	3 (50)
p		0.409		0.703		0.999		0.999		0.999	
Folic acid											
Irregular usage	53 (45.7)	2 (100)	2 (40)	53 (45.7)	4 (57.1)	55 (46.2)	2 (50)	52 (45.2)	5 (62.5)	44 (44.9)	3 (50)
Regular usage	63 (54.3)	0 (0)	3 (60)	63 (54.3)	3 (42.9)	64 (53.8)	2 (50)	63 (54.8)	3 (37.5)	54 (55.1)	3 (50)
p		0.409		0.703		0.999		0.470		0.999	
Radiation											
Absent	110 (94.8)	2 (100)	5 (100)	110 (94.8)	7 (100)	113 (95)	4 (100)	109 (94.8)	8 (100)	93 (94.9)	6 (100)
Unknown	6 (5.2)	0 (0)	0 (0)	6 (5.2)	0 (0)	6 (5)	0 (0)	6 (5.2)	0 (0)	5 (5.1)	0 (0)
p		0.999		0.999		0.999		0.999		0.999	
Urinary tract infections											
Present	62 (53.4)	1 (50)	1 (20)	62 (53.4)	2 (28.6)	62 (52.1)	2 (50)	62 (53.9)	2 (25)	51 (52)	2 (33.3)

(Continued)

Table 4. (Continued)

Absent	54 (46.6)	1 (50)	4 (80)	54 (46.6)	5 (71.4)	57 (47.9)	2 (50)	53 (46.1)	6 (75)	47 (48)	4 (66.7)
p		0.347		0.259		0.999		0.151		0.432	
Upper respiratory infections											
Present	45 (38.8)	1 (50)	1 (20)	45 (38.8)	2 (28.6)	45 (37.8)	2 (50)	45 (39.1)	2 (25)	36 (36.7)	2 (33.3)
Absent	71 (61.2)	1 (50)	4 (80)	71 (61.2)	5 (71.4)	74 (62.2)	2 (50)	70 (60.9)	6 (75)	62 (63.3)	4 (66.7)
p		0.833		0.707		0.636		0.709		0.999	
Vaginitis											
Present	52 (44.8)	1 (50)	1 (20)	52 (44.8)	2 (28.6)	52 (43.7)	2 (50)	52 (45.2)	2 (25)	44 (44.9)	2 (33.3)
Absent	64 (55.2)	1 (50)	4 (80)	64 (55.2)	5 (71.4)	67 (56.3)	2 (50)	63 (54.8)	6 (75)	54 (55.1)	4 (66.7)
p		0.694		0.465		0.999		0.464		0.691	
Placental disease											
Present	29 (25)	1 (50)	1 (20)	29 (25)	2 (28.6)	29 (24.4)	2 (50)	29 (25.2)	2 (25)	25 (25.5)	2 (33.3)
Absent	87 (75)	1 (50)	4 (80)	87 (75)	5 (71.4)	90 (75.6)	2 (50)	86 (74.8)	6 (75)	73 (74.5)	4 (66.7)
p		0.778		0.999		0.263		0.999		0.648	
Smoking habit											
Not smoking	79 (68.1)	0 (0)	3 (60)	79 (68.1)	3 (42.9)	81 (68.1)	1 (25)	79 (68.7)	3 (37.5)	64 (65.3)	2 (33.3)
Smoking	37 (31.9)	2 (100)	2 (40)	37 (31.9)	4 (57.1)	38 (31.9)	3 (75)	36 (31.3)	5 (62.5)	34 (34.7)	4 (66.7)
p		0.110		0.220		0.107		0.115		0.188	
Alcohol consumption during pregnancy											
Present	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
Absent	115 (99.1)	2 (100)	5 (100)	115 (99.1)	7 (100)	118 (99.2)	4 (100)	114 (99.1)	8 (100)	97 (99)	6 (100)
p		0.813		0.999		0.999		0.999		0.999	
Number of cigarettes											
0	79 (68.1)	0 (0)	3 (60)	79 (68.1)	3 (42.9)	81 (68.1)	1 (25)	79 (68.7)	3 (37.5)	64 (65.3)	2 (33.3)
1–3 cigarettes	19 (16.4)	2 (100)	0 (0)	18 (15.5)	3 (42.9)	19 (16)	2 (50)	18 (15.7)	3 (37.5)	17 (17.3)	3 (50)
4–10 cigarettes	17 (14.7)	0 (0)	2 (40)	18 (15.5)	1 (14.3)	18 (15.1)	1 (25)	17 (14.8)	2 (25)	16 (16.3)	1 (16.7)
More than 10	1 (0.9)	0 (0)	0 (0)	1 (0.9)	0 (0)	1 (0.8)	0 (0)	1 (0.9)	0 (0)	1 (1)	0 (0)
p		0.077		0.185		0.132		0.152		0.156	
Wi-Fi at home											
Not available	55 (47.4)	0 (0)	3 (60)	56 (48.3)	2 (28.6)	57 (47.9)	1 (25)	55 (47.8)	3 (37.5)	50 (51)	1 (16.7)
Available	39 (33.6)	1 (50)	2 (40)	38 (32.8)	4 (57.1)	40 (33.6)	2 (50)	38 (33)	4 (50)	30 (30.6)	4 (66.7)
Available in the building	22 (19)	1 (50)	0 (0)	22 (19)	1 (14.3)	22 (18.5)	1 (25)	22 (19.1)	1 (12.5)	18 (18.4)	1 (16.7)
p		0.470		0.410		0.525		0.626		0.191	
Wi-Fi in workplace											
Not available	98 (85.2)	0 (0)	4 (80)	98 (85.2)	0 (0)	100 (84.7)	2 (50)	97 (85.1)	5 (62.5)	98 (84.5)	4 (66.7)
Available	17 (14.8)	2 (100)	1 (20)	17 (14.8)	2 (100)	18 (15.3)	2 (50)	17 (14.9)	3 (37.5)	18 (15.5)	2 (33.3)
p		0.064		0.086		0.125		0.123		0.255	
Base Station Nearby											
Available	27 (23.3)	0 (0)	0 (0)	27 (23.3)	0 (0)	27 (22.7)	0 (0)	27 (23.5)	0 (0)	27 (23.1)	0 (0)
Not available	89 (76.7)	2 (100)	5 (100)	89 (76.7)	7 (100)	92 (77.3)	4 (100)	88 (76.5)	8 (100)	90 (76.9)	6 (100)
p		0.748		0.346		0.575		0.198		0.337	

$p < 0.0$; Fisher's exact chi-square test.

The offspring of mice exposed to RFR in the prenatal period showed decreased memory, hyperactivity and glutamatergic synaptic transmission disorder in the pyramidal cells in the prefrontal cortex [27]. Another study detected changes in astrocytic and apoptotic responses in different brain regions of rats exposed to RFR during the prenatal period (2 h/day, 5 days/week, 2 weeks) and in the first weeks of the postnatal period. However, RFR did not create a permanent activation of astroglia in the brains of rats and did not trigger apoptosis [28]. There was a significant reduction in the number of dentate gyrus granule cells in the hippocampus [29], and the number of pyramidal cells [30] and the presence of picnotic cells in the cornu ammonis region of the hippocampus in rats exposed to RFR (60 min/day, 900 MHz) during the prenatal period [31]. Moreover, it was stated that exposure to RFR (900 MHz, pulsed) during pregnancy can change the electrophysiological properties of the Purkinje neurons of rats in the postnatal period, but these changes are not sufficient to affect cerebellum-related functional functions [18]. On the other hand exposure to RFR in the prenatal period did not cause any changes in the expression of the *c-fos* gene, which is an indicator of neural stress in mouse brains [32], and did not cause any measurable cognitive deficit [33].

In a study conducted by Vrijheid et al. [34] on 530 children, there were very small differences between the children of mothers who had used mobile phones during the prenatal period and those who had not. The children of mothers who had used mobile phones had higher mental scores but lower psychomotor development than those whose mothers had not used mobile phones. Kane [35] also published a hypothesis suggesting that the increase in the incidence of autism in children in recent years may be related to the dramatically increasing use of mobile phones with advancing technology. Moreover, researchers have found an association between exposure to RFR emitted from mobile phones, both prenatally and postnatally, and migraine and other headache disorders [36], and between exposure to RFR emitted from mobile phones during pregnancy and behavioural disorders, such as hyperactivity and emotional problems at school [37]. The average cognitive scores and mental activation levels were lower in children with high maternal cell phone usage intensity [38]. RFR exposure with environmental factors at different frequencies and intensities has been reported to induce neurobiological disorders [39]. However, another study conducted on 6 and 18- month-old babies, found no relationship between prenatal cell phone use and delays in motor and cognitive/language development [40]. In another study, while there was no relationship between mobile phone usage during pregnancy and foetal development or birth weight, it was found that it could cause preterm birth [41].

In the present study, the AF and F– ($p < 0.05$), suboptimal MOS scores ($p < 0.001$), reduced motor repertoire ($p < 0.05$) values were statistically higher in Group 3 when compared to the other groups ($p < 0.05$). Normal posture ($p = 0.001$) and the quality of other movements were statistically higher in the Control, and Groups 1 and 2 when compared to Group 3 ($p < 0.001$).

Abnormal GMs and postural anomalies occurring at 3–5 months of age may indicate cognitive anomalies that will emerge in the following years [21]. The infants of mothers with MFU of ~2 h a day had a lower MOS values when compared to the children of mothers with MFU of other durations. These findings were similar to those found in infants at risk for motor problems [42,43]. Similarly, the MOS was significantly lower in infants of mothers who used drugs/alcohol [24]. Studies in literature showed that the GMA, including MOS, can provide important information about the later neurodevelopmental functions of infants [25].

According to the results obtained, there was no correlation between the F– and AF levels of the infants and the MOS, repertoire, and the quality of other movements. However, they differed with regard to the outcome. It was determined that the infants with AF were neurologically normal, while the infants with F– had minor neurological impairment. In the literature, abnormal simultaneous motor repertoire was associated with later impaired cognitive and motor outcomes, even in high-risk infants with FMs [44].

FM development in GMs, which occurs in infants at post-term 3–5 months, is synchronized with a series of motor repertoires, postural patterns and other age-appropriate movements [22]. An evaluation of all these movements together provides important information regarding the infant's subsequent motor function [42]. This period is ideal for evaluating neurobehavioral repertoires and predicting outcomes in high-risk infants [22]. Some of the studies applying a similar approach found that a low MOS score was associated with motor and language dysfunction, minor neurological dysfunctions, or school-age learning difficulties in the toddler age [42].

In this study, we analyzed statistically the paternal and environmental variables that may affect the infant's motor development, such as maternal and

paternal age, maternal and paternal education and occupation, weight gained during pregnancy, infant's weight according to gestational week, infant's head circumference and height, mother's history of pregnancy, number of abortions and stillbirths, cell phone SAR value, daily cell phone usage frequency, gestational week, maternal diseases (hypertension, systemic disease, vaginitis, placental infection, urinary tract infection, upper respiratory tract infection), mode of delivery, foetal distress and meconium, vitamin and folic acid use during pregnancy, alcohol and cigarette use, at home and at work Wi-Fi usage, presence of base stations around, radiation exposure during pregnancy, and the infants' FM, MOS, repertoire, posture and the quality of other movements. In addition, we also evaluated whether the pregnant women included in the study had complaints of dizziness, restlessness, ear pain, facial sensitivity or burning. The data obtained revealed that the FMs differed according to the number of abortions. The normal FM level observed in the infants of the pregnant women who had not had an abortion was higher than in those of the pregnant women who had 4 or more abortions. A difference was also observed between the number of abortions and the MOS and posture. The optimal MOS and normal posture observed in the infants of pregnant women who had not had an abortion were higher than those whose mothers had 4 or more abortions. Moreover, it was observed that there may be a relationship between the MOS, posture and daily cell phone usage frequency. For example, the sub-optimal MOS and normal = abnormal postures were higher in those who used cell phones for more than 4 times a day. However, it was understood that the other variables did not differ according to the nature of the FM, MOS, repertoire, posture and other movements. The findings showed that all of the infants with reduced repertoire were borderline premature. In other words, the incidence of reduced repertoire in borderline premature infants was higher than in the term, post-term and premature infants.

In addition to a causal relationship between the minor changes observed in the present study and prenatal mobile phone usage, other confounding parameters should also be considered. Therefore, it is difficult to predict for now what kind of problems prenatal exposure to RFR emitted from mobile phones would cause in these children in the future. However, it seems inevitable that RFR levels, which will reach incredible levels in the future, will somehow affect babies in the womb. Therefore, such studies should be long term and the children included in the study should be followed up at intervals of 5 or 10 years. Moreover, whether the changes obtained in this study are reversible or irreversible is the subject of another study. Therefore, much work is needed to elucidate this issue. The data herein suggested that there may be a relationship between prenatal RFR exposure, and the parameters discussed herein. The topicality and interestingness of the subject should be kept on the agenda.

Conclusions

The data obtained in this study suggest that there may be a relationship between prenatal RFR exposure and infant motor development. More long-term studies are needed to determine whether these changes are temporary or permanent.

Data availability statement

The data supporting the findings of this study are available within the article.

Disclosure statement

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