Journal of Recent Advances in Medicine

Journal of Recent Advances in Medicine
AFMG
Al-Azhar University Faculty of Medicine for Girls
Print ISSN: 2636-252X
Online ISSN: 2636-2538

Original Article

Electroencephalographic brain mapping changes before and after maternal skin to skin care

Pediatric

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ABSTRACT

Background: Mother-infant skin to skin care (SSC) has gaining increasing interest as an effective method for infant care. Electroencephalogram (EEG) is effective inexpensive tools for evaluation of maturational brain changes through assesses resting EEG wave powers.

Objectives: To evaluate the relationship between maternal SSC and changes in brain activity detected by electroencephalographic brain mapping.

Methodology: This study is a non-randomized QUASI experimental study using a pre and posttest on the infants in the form of maternal-infant SSC for 30 minutes without a control groups. The study was carried out on 100 apparently healthy infants aged 4 to 6 months of both sex and exclusive breastfeeding. All infants underwent full history taking, thorough clinical examination of all body systems, and electroencephalographic brain mapping analysis before and 30 minutes after maternal-infant SSC.

Results: There was a statistically significant increase in mean power of alpha and theta frequency bands after 30 min of SSC in comparison to before SSC. There was a statistically significant increase in mean power of both alpha and theta frequency bands in females infants in comparison to males. There was a statistically significant decrease in heart rate and respiratory rate in the studied infants after 30 min SSC in comparison to before SSC.

Conclusion: maternal-infant SSC is associated with global improvement of brain activity regardless of the area of the brain. The brain of female infants has a better response to the SSC than male.

JRAM 2022; 3(1):10-18

Keywords: Maternal skin to skin contact, electroencephalographic brain mapping, infants.

Submission Date: 23 February 2021 **Acceptance Date:** 17 April 2021

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Please cite this article as: Amer AS, Koraa AA, Elhady MA. Electroencephalographic brain mapping changes before and after maternal skin to skin care. JRAM 2022; 3(1):10-18. DOI: 10.21608/jram.2021.63477.1110

INTRODUCTION

During early infancy the human brain undergoes a rapid rate of growth with enhanced myelination of the central nervous system that directly correlated to developmental maturation of the brain function domains including motor, language, vision, social skills, and cognition. [1] There is emerging interest in parent-infant skin-to-skin contact (SSC). In this method of care the bared skin of the infant is placed directly on the parent chest wall skin. Several evidences demonstrated the great benefits of this method that is not limited to neonatal period but may extend throughout infancy. [2]

EEG Mapping is a spatially orientated technique through interpolation tools that calculates the EEG wave amplitude and frequency patterns which is detected from scalp electrodes. The raw data is extracted from EEG are analyzed to produce color-coded topographic brain maps illustrating the brain cortical electrical activities. [3]

EEG power is commonly used method for assessment of brain developmental and maturational progression. EEG wave signals represent the post-synapses electrical activities while EEG wave powers represent changes in neuronal excitability. EEG power is determined by analysis of EEG raw data that measured from 10-20 system scalp electrodes using Fourier analysis tool. Advances in brain maturation are associated with increased neural activities that represented as higher EEG powers. [4]

Exploring the influences of parent SSC on infant physical and mental development is gaining great interest. Parent-infant SSC are included as a simple effective method for neonatal care in many hospitals guidelines. [5] Nutrition and environment are great contributors for brain development and maturation throughout infancy. There is increasing evidences demonstrated the benefits of parent-infant SSC and its impact to brain maturation and cerebral blood flow during early infancy.[6] We aim in the present study to evaluate the relationship between maternal SSC and changes in brain activity detected by EEG brain mapping.

SUBJECTS AND METHODS

Study design:

The current study is a non-randomized QUASI experimental study using a pre and post-test on the infants in the form of maternal-infant SSC for 30 minutes without a control groups.

Population

One hundred healthy exclusive breastfeeding infants of both sexes were included in this study; their ages range from 4 to 6 months. They were selected consecutively from the outpatient clinic of the pediatric department of Al-Zahraa University Hospital, Cairo, Egypt during the period from January 2020 to January 2021. We have excluded infants who suffered from any neurological, genetic, metabolic disorder or congenital heart disease and any infants with acute or chronic illness. An informed consent was taken from the mother before their inclusion in the study and approved by the ethics committee of Al-Azhar University. All studied infants were subjected to:

- **Full history taking:** including age, sex, demographic data, maternal age, gestational age, type of feeding (to ensure exclusive breast feeding and exclude infants who were not exclusive breastfed), mode of delivery, past medical history, and neurodevelopmental milestone.
- **Thorough clinical examination:** assessment of heart rate before and 30 minutes after maternal skin to skin care, anthropometric measurement of weight, length and head circumference, complete general and all body systems examination with special stress on neurological examination.
- **Electroencephalographic brain mapping:** using Nihon Kohden EEG 1200 machine (Japan) at the pediatric neurophysiology unit of Al-Zahraa University hospital. It was done before and 30 minutes after maternal-infant SSC.

Procedure

After obtaining consent from the mother and explaining the procedure, EEG was recorded from infant scalp in a wake status at the pediatric neurophysiology unit while infant sat on the mother's lap using EEG stretch cap applied to infant head. The recordings were obtained with the international 10–20 system from 16 left and right electrode sites [Frontal pole (Fp1-Fp2), Mid-frontal (F3 and F4), lateral frontal (F7 and F8), Temporal (T5-T6), central (C3 and C4), parietal (P3 and P4) and occipital (O1 and O2)] All electrodes were referenced to the vertex (Pz).

EEG activity was measured during calm-alert state for 5 minutes while the infant sat in mother's lap with no interaction with the infant. After EEG recording, mother asked to place infant skin-to-skin contact for 30 minutes then EEG recording started again for another 5 minutes. Raw EEG data were examined and analyzed using a Discrete Fourier Transform (DFT). Computation of power at the 4–13 Hz frequency band was recorded and expressed as mean square microvolts.

The 8– 13 Hz EEG wave band is considered "infant alpha" that usually associated with infant working memory and inhibitory control. The 4–8 Hz EEG wave band is considered "infant theta" that usually associated with infant attention and emotion. [7] Mapping photos were taken for EEG frequency bands to show color indication of brain activity before SSC and 30 min after. Calibration bars in frequency maps begin at zero and increase continuously. Red and yellow colors represent high brain activity while violet and blue represent low activity. [8]

Statistical analysis

Results were collected and analyzed by personal computer and statistical package for social science (SPSS Inc., Chicago, Illinois, USA) version 20. Parametric data were expressed as mean and standard deviation (SD). Comparing the mean ±SD between the two groups was done using independent student t-test. The level of significance was set as P-value <0.05.

RESULTS

The current study enrolled 100 apparently healthy infants. They were 43 females and 57 males with a mean age of 5.55 ± 0.63 months. Comparison of heart rate and respiratory rate before and after 30 minutes of SSC demonstrated a significant decrease in heart rate and respiratory rates after SSC as shown in table 1. Regarding EEG power activities, there was a significant increase in the mean of EEG power of alpha and theta frequency bands ($p < 0.001$) after 30 min of skin-to-skin contact than before SSC in all electrode sites of the right and left brain areas as shown in table 2, photo 1 and 2.

There is was no statistically significant difference in the mean of EEG power of alpha and theta frequency bands on different brain areas between left and right sides before skin-to-skin contact in all electrode sites as shown in table 3. Also there is was no statistically significant difference in the mean of EEG power of alpha and theta frequency bands on different brain areas between left and right sides after 30 minutes of skin-to-skin contact in all electrode sites as shown in table 4. There was a statistically significant increase in mean EEG power of alpha and theta frequency bands in females in comparison to males as shown in table 5.

Table (1): Comparing vital signs before and after 30 min of skin-to-skin contact (SSC)

Vital sign	Before SSC	After SSC	t-test	P-value
	Mean ±SD	Mean ±SD		
Heart rate (beat/min)	126.3 ± 6.2	122.0 ± 6.8	4.719	0.001*
Respiratory rate (cycle/min)	45.7 ± 3.8	41.3 ± 4.2	7.874	0.001*

SSC: skin to skin contact, *: Significant p value

Table (2): Comparison of the mean power of Alpha and Theta frequency band at the right and left sides of the brain before and after skin to skin contact in the studied infants

Electrode sites	Alpha frequency band			
	Before skin-to-skin contact (n=100)	After skin-to-skin contact (n=100)	t-test	P-value
	Mean ± SD	Mean ± SD		
FP1	4.76±2.31	5.10±2.47	-6.98	0.001*
FP2	4.76±2.31	5.11±2.47	-7.199	0.001*
F3	4.76±2.31	5.14±2.51	-6.898	0.001*
F4	4.87±2.51	5.12±2.50	-3.752	0.001*
F7	4.82±2.45	5.11±2.55	-4.87	0.001*
F8	4.83±2.39	5.15±2.49	-5.085	0.001*
T5	4.79±2.33	5.14±2.55	-6.982	0.001*
T6	4.83±2.37	5.15±2.54	-5.228	0.001*
P3	4.78±2.34	5.14±2.50	-5.787	0.001*
P4	4.89±2.59	5.10±2.54	-2.625	0.001*
O1	4.78±2.34	5.10±2.48	-5.059	0.001*
O2	4.76±2.30	5.08±2.62	-6.225	0.001*
Electrode sites	**Theta frequency band**			
	Before skin-to-skin contact (n=100)	**After skin-to-skin contact (n=100)**	**t-test**	**P-value**
	Mean±SD	**Mean±SD**		
FP1	4.85±2.62	5.40±2.63	-8.495	0.001*
FP2	5.25±2.64	5.41±2.64	-5.74	0.001*
F3	4.87±2.63	5.42±2.63	-8.351	0.001*
F4	5.02±2.65	5.42±2.65	-7.323	0.001*
F7	5.07±2.68	5.42±2.68	-6.336	0.001*
F8	5.25±2.64	5.41±2.64	-5.17	0.001*
T5	4.98±2.66	5.45±2.66	-7.896	0.001*
T6	4.99±2.66	5.42±2.66	-6.783	0.001*
P3	4.93±2.66	5.43±2.66	-7.605	0.001*
P4	5.03±2.64	5.41±2.64	-7.117	0.001*
O1	4.94±2.63	5.40±2.63	-7.547	0.001*
O2	4.90±2.64	5.41±2.64	-7.752	0.001*

*: Significant p value, NB: odd number represents the left side of the brain and even number represent the right side of the brain

Table (3): Comparison of the mean power of Alpha and Theta frequency band between the left and right sides before skin-to-skin contact

Brain areas	Alpha power before skin-to-skin contact			
	Left side (n=100)	right side (n=100)	t-test	p-value
	Mean±SD	Mean±SD		
FP1/2	4.76±2.31	4.76±2.31	-0.077	0.939
F3/4	4.76±2.31	4.87±2.51	-1.451	0.148
F7/8	4.82±2.44	4.83±2.39	-0.256	0.798
T5/6	4.79±2.33	4.83±2.37	-0.803	0.423
P3/4	4.78±2.34	4.89±2.59	-1.086	0.279
O1/2	4.78±2.42	4.76±2.30	0.441	0.659
Brain areas	**Theta power before skin-to-skin contact**			
	Left side (n=100)	**right side (n=100)**	**t-test**	**p-value**
	Mean±SD	**Mean±SD**		
Fp1/2	4.95±2.42	5.03±2.62	-0.931	0.353
F3/4	4.97±2.43	4.99±2.50	-0.315	0.753
F7/8	5.01±2.53	5.09±2.62	-1.103	0.271
T5/6	5.01±2.48	5.02±2.49	-0.283	0.778
P3/4	4.99±2.46	5.01±2.51	-0.178	0.859
O1/2	4.98±2.46	4.98±2.45	0.083	0.934

*: Significant p value

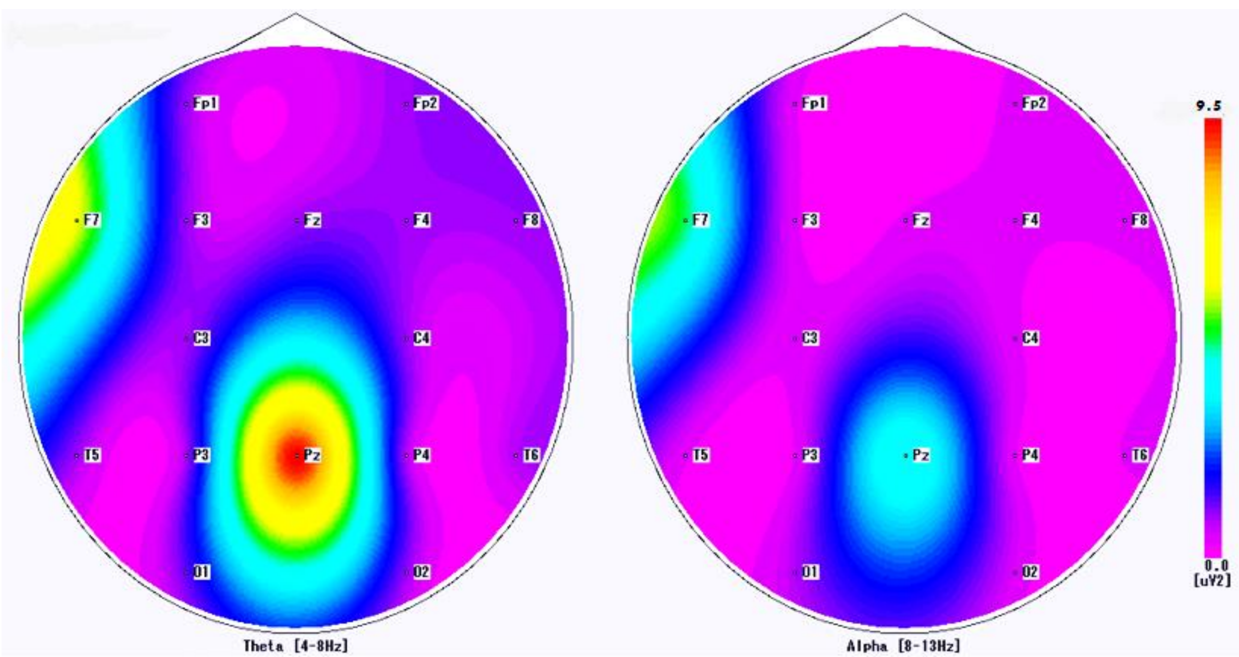

Figure (1): 4-month-old male infant before SSC (infant number 11)

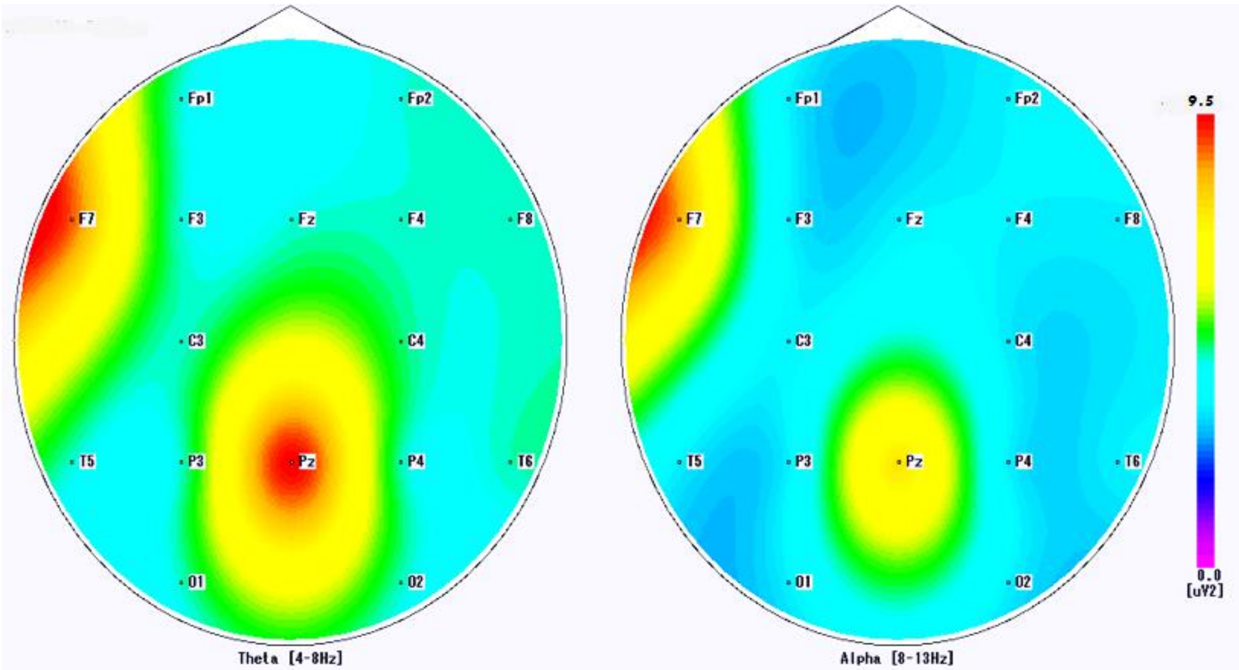

Figure (2): 4-month-old male infant after SSC (infant number 11)

Calibration bars in maps begin at zero and increase continuously, violet and blue color represents low and red color high activity.

Table (4): Mean of EEG power of Alpha and Theta frequency bands in the left and right sides after Skin-to-skin contact

Brain areas	Alpha power after skin-to-skin contact			
	Left side (n=100)	Right side (n=100)	t-test	p-value
	Mean ± SD	Mean ± SD		
Fp1/2	5.10±2.47	5.11±2.47	-0.227	0.821
F3/4	5.14±2.51	5.12±2.50	0.535	0.593
F7/8	5.11±2.50	5.15±2.55	-0.698	0.486
T5/6	5.14±2.49	5.15±2.55	-0.138	0.891
P3/4	5.14±2.54	5.10±2.50	0.65	0.517
O1/2	5.10±2.54	5.08±2.48	0.425	0.671
Brain areas	**Theta power after skin-to-skin contact**			
	Left side (n=100)	Right side (n=100)	t-test	P-value
	Mean ± SD	Mean ± SD		
Fp1/2	5.40±2.62	5.41±2.64	-0.151	0.88
F3/4	5.42±2.63	5.42±2.65	-0.052	0.959
F7/8	5.42±2.68	5.41±2.64	0.132	0.895
T5/6	5.45±2.66	5.42±2.66	0.631	0.529
P3/4	5.43±2.66	5.41±2.64	0.461	0.645
O1/2	5.40±2.63	5.41±2.64	-0.302	0.763

*: Significant p value

Table (5): Comparing the mean of EEG power in alpha and theta frequency bands according to the gender of studied infants

Electrode site	Alpha frequency band			
	Male (n=57)	Female (n=43)	t-test	p-value
	Mean ± SD	Mean ± SD		
FP1	4.69±2.30	4.83±2.32	-2.093	0.039*
FP2	4.70±2.29	4.83±2.32	-2.051	0.043*
F3	4.70±2.30	4.83±2.32	-2.04	0.044*
F4	4.70±2.30	5.03±2.59	-2.327	0.024*
F7	4.72±2.32	4.92±2.51	-1.767	0.083
F8	4.75±2.34	4.92±2.44	-2.069	0.043*
T5	4.77±2.31	4.81±2.31	-0.736	0.463
T6	4.75±2.30	4.91±2.41	-2.156	0.035*
P3	4.70±2.65	4.87±2.36	-2.526	0.014*
P4	4.93±2.29	4.84±2.32	0.599	0.551
O1	4.71±2.30	4.87±2.37	-2.252	0.027*
O2	4.71±2.34	4.82±2.30	-1.758	0.082
Electrode site	**Theta frequency band**			
	Male (n=57)	**Female (n=43)**	**t-test**	**P-value**
	Mean ± SD	**Mean ± SD**		
FP1	4.84±2.67	5.07±2.30	-3.342	0.001*
FP2	5.00±2.35	5.08±2.46	-0.617	0.539
F3	4.86±2.35	5.09±2.49	-3.261	0.002*
F4	4.86±2.35	5.12±2.47	-2.584	0.013*
F7	4.86±2.64	5.13±2.57	-2.409	0.002*
F8	5.03±2.50	5.16±2.60	-1.048	0.297
T5	5.96±2.39	5.06±2.59	-1.27	0.207
T6	4.92±2.34	5.13±2.46	-2.487	0.016*
P3	4.86±2.34	5.11±2.54	-3.308	0.002*
P4	4.86±2.35	5.13±2.51	-2.65	0.011*
O1	4.87±2.35	5.10±2.58	-2.817	0.007*
O2	4.87±2.35	5.09±2.52	-3.003	0.004*

*: Significant p value

DISCUSSION

There is growing interest in parent infant SSC influence on infant physical and mental development. Several EEG modalities are used as neurophysiological tools for detection of brain maturational changes. [9] Resting EEG powers reflect progression in brain development and maturation in age-related pattern throughout infancy. [10]. In agreement with the previous study by Korraa, et al [6] our study revealed a decrease in heart rate and respiratory rate after SSC. These findings may reflect attenuation of the infant stress response due to decreased infant B-endorphin production in response to maternal contact. Furthermore, tactile stimulation is associated with increased oxytocin release which down-regulated cortisol reactivity so promoting infant stress regulation. [11, 12]

EEG activities are categorized into several frequency bands that are good correlated with different brain functions. Evidence showed that both theta (4 to 7Hz) and alpha (8 to 11 Hz) bands reflect changes in brain activities.[13] Theta and alpha power changes may be used as indicators for maturational progression during infancy. However, limited data are available regarding the use of theta and alpha power to evaluate topographic extent of brain development in infancy. [14]

Our study demonstrated increased alpha and theta power in response to maternal skin to skin contact. These findings reflect improved brain activity in response to maternal physical care. Supporting our findings, Bazhenova et al. [15] found that theta power increased during performing social activities, watching faces, infant-directed speech, and during playing. EEG theta power reflects the time of neuronal network processing as theta band is mainly affected by infant attention, stimulus perception, and executive function. [16] While alpha power changes are mainly related to the type of received stimulus. [17]. Supporting our findings, studies related to brain plasticity revealed that positive experiences can promote the brain function maturity in an adaptive direction. Bernier, et al [18] reported that maternal response during early mother-infant activities is the key element for enhancement of the resting frontal alpha and theta EEG power during infancy leading to individual variation in brain maturation. Infant EEG powers are greatly affected by maternal attachment. The higher mother-infant interaction is associated with more optimal EEG power scores that reflect improved functional connectivity between different brain areas leading to enhance information processing and promote cognitive abilities. [4]. Welch et al. [19] reported a positive impact of effective communication between mothers and their pre-term (26–34 weeks gestation) babies on sleep EEG; babies who had been exposed to the intervention showed higher frontal EEG power than infants who did not expose to maternal communication during quiet and active sleep strongly suggesting a causal link between maternal care and infant brain development and activity.

Our current study revealed that SSC has no significant impact on the EEG power of alpha and theta frequency bands on different brain areas with no difference in activities between the left and right sides of the brain. Our findings are in agreement with Hardin et al [20] who found that no significant hemispheric differences were obtained for EEG power in relation to kangaroo care. On the other hand, Jones et al. [14] reported greater alpha and theta EEG power in the left than right hemisphere during naturalistic social experiences between age 6-12months. This contradiction reflects variation in brain activity response that is age-dependent that varies in relation to the type of environmental stimulus.

Our study showed a significant increase of mean power of alpha and theta frequency band in female in comparison to male infants which came in agreement with Bernier, et al [18] who reported higher alpha, but not theta, EEG power at 5 and 10, but not 24 months in girls than boys. On the other hand, Jones et al [14] found greater EEG power in males than females at age 6-12 months. This could be explained by gender differences in cerebral anatomy and the localization and maturation of cerebral functions in early childhood that may be arising from prenatal exposure to gonadal steroids. Females develop more advanced progress than males in language and social development, and by middle childhood, males outperform females in selected tasks of spatial abilities. [21] Many studies have found that estrogens, especially 17β-estradiol, have a positive effect on brain function throughout the lifespan, ranging from early developmental stages to the aging processes in older adults. [22].

CONCLUSION

Maternal infant skin to skin contact is associated with global improvement of brain activity regardless of the area of the brain. The brain of female infants has a better response to the skin to skin contact than male. Brain maturation is a neurodevelopmental process that can be promoted by maternal skin to skin contact.

Acknowledgment

We would like to acknowledge the staff members of Al-Zahraa Hospital for their generous help in completing this research. Also, we thank the participants in this research for their cooperation.

Financial support: No fund was received for this research.

Conflict of interest: Authors declare any conflict of interest.

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الملخص العربي

رسم خرائط الدماغ بالتخطيط الكهربائي للمخ قبل وبعد تلامس الجلد للجلد بين الأم والطفل

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ملخص البحث

الخلفية: يكتسب تلامس الجلد للجلد بين الأم والطفل اهتمامًا متزايدًا كطريقة فعالة لرعاية الرضع. يعد مخطط كهربية الدماغ أحد الأدوات الفعالة و الغير مكلفة لتقييم تغيرات الدماغ اثناء النمو من خلال تقييم قوى الموجات الكهربية للمخ.

الهدف: تقييم العلاقة بين تلامس الجلد للجلد بين الأم والطفل والتغيرات في نشاط الدماغ المكتشفة عن طريق رسم خرائط الدماغ الكهربائية.

الطرق: هذه الدراسة عبارة عن دراسة تجريبية بدون مجموعات ضابطة باستخدام الاختبار القبلي والبعدي على الرضع قبل و بعد تلامس الجلد للجلد بين الأم والطفل لمدة 30 دقيقة. أجريت الدراسة على 100 رضيع يتمتعون بصحة جيدة تتراوح أعمارهم بين 4 إلى 6 أشهر من كلا الجنسين يتم ارضاعهم رضاعة طبيعية مطلقه. خضع جميع الأطفال لأخذ التاريخ الكامل، والفحص السريري الشامل لجميع أنظمة الجسم، وتحليل رسم خرائط الدماغ بالتخطيط الكهربائي للدماغ قبل وبعد 30 دقيقة من تلامس الجلد للجلد بين الأم والطفل.

النتائج: كانت هناك زيادة ذات دلالة إحصائية في متوسط قوة نطاقي التردد ألفا وثيتا بعد 30 دقيقة من تلامس الجلد للجلد بين الأم والطفل مقارنة بما قبل تلامس الجلد للجلد بين الأم والطفل. كانت هناك زيادة ذات دلالة إحصائية في متوسط القوة لكل من نطاقي التردد ألفا وثيتا عند الرضع الإناث مقارنة بالذكور. كان هناك انخفاض معتد به إحصائيًا في معدل ضربات القلب ومعدل التنفس عند الرضع بعد 30 دقيقة من تلامس الجلد للجلد بين الأم والطفل مقارنةً بما قبل تلامس الجلد للجلد بين الأم والطفل.

الاستنتاجات: يرتبط تلامس الجلد للجلد بين الأم والطفل بالتحسين في النشاط الدماغي في اجزاء المخ المختلفة كما تبين أن استجابة الدماغ عند الرضع الإناث أفضل من الذكور.

الكلمات المفتاحية: تلامس الجلد للجلد بين الأم والطفل، رسم خرائط الدماغ بالتخطيط الكهربائي للمخ، الرضع.

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