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Impact of Maternal Separation on Long-Term Potentiation: Insights from Rodent Models

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ABSTRACT

Maternal separation (MS) is a well-characterized model of early life stress, based on the postnatal disruption of the mother-infant interaction. Studies on rodents have demonstrated that MS, as an early adverse life event, leads to spatial memory deficits and lasting changes in brain plasticity. Here, we review data from animal studies regarding the impact of MS on long-term potentiation (LTP). Evidence shows that animal models are useful for evaluating the effects of MS on LTP. Overall, studies suggest that MS impairs LTP.

Keywords: maternal separation, long term potentiation, rodent model

INTRODUCTION

Mother-infant interactions significantly influence the development of physiology and behavior during the first weeks after birth. Since rodent pups are completely dependent on their mothers during the first three weeks of life, separation from their dams is particularly stressful at that time (1). Brain plasticity is highly vulnerable to stress, and the early postnatal period is critical for the development of normal brain function (2). During the first weeks after birth, there is an increase in the proliferation, differentiation, and migration of neurons. Neurogenesis of hippocampal granule cells peaks in the second week of rodent life and during the third month in humans (3).

Electrophysiological studies have been conducted to uncover the cellular basis of the reduction in learning and memory functions in rats that experienced early-life stress. Specifically, LTP was evaluated because hippocampal LTP is widely considered a putative mechanism of memory storage and has proven to be a valuable model for studying neuronal plasticity at the cellular level (4-7). Stress affects hippocampal LTP (8), and exposure to glucocorticoids reduces hippocampal LTP (9). In this mini review, we will focus on the effects of MS on LTP.

MS as an animal model

MS has been proposed as a well-established animal model of early life stress (10-12). The MS method involves the repeated separation of rodent pups from their dam for either short periods (less than 60 minutes) or prolonged periods (more than 180 minutes) during the first 2–3 weeks of life (13). Short MS simulates naturalistic conditions,

whereas prolonged MS is considered a risk environment (14-16).

Effect of MS on LTP in adolescence

Adolescence is the final stage in a series of neurodevelopmental phases during which synaptic balance and stabilization are achieved, and cognitive function and synaptic plasticity mature (17). The timing and duration of early life stress are crucial for the proper organization of neurons and can increase the risk of developing lasting behavioral disorders (18).

In our previous study, we demonstrated that separating female pups from their mother for 3 hours daily from postnatal day (PND) 1 to 14 impairs LTP induction in the CA1 area of the hippocampus during adolescence (19). Another study found that separating litters from their dams for 4 hours per day from PND 2 to PND 20 reduced the magnitude of LTP at the mossy fiber-CA3 synapse (20). Cao et al. revealed that both the EPSP slope and PS amplitude were reduced in maternally separated male rats (21). According to Gruss et al., a single 24-hour MS episode at PND 9 prevents LTP reinforcement induced by swim stress in adolescent male rats (22). Another study evaluating the effect of MS on LTP in the medial prefrontal cortex (mPFC) of adolescent rats showed that MS induced impairment in LTP (23). Additionally, it was found that the magnitude of hippocampal LTP at CA3-CA1 synapses induced by PBS stimulation was significantly lower in MS animals during adolescence compared to controls. In this study, animals underwent MS for 180 minutes per day from PND 1 to 2 (24-25).

Effect of MS on LTP in adulthood

Some experiments have demonstrated that MS causes alterations in synaptic plasticity extending into adulthood. Xiong et al. found that adult female rats subjected to MS from postnatal day (PND) 2 to 14 exhibited significant LTP impairment in both the infralimbic prefrontal cortex and hippocampal SC-CA1 pathways (26). Herpfer et al. reported that LTP was impaired in adult mice following early deprivation from PND 1 to PND 14 (27). Another research group observed that senescent MS animals exhibited a lower magnitude of hippocampal LTP. These results support the hypothesis that the neuronal and endocrine alterations induced by early-life stress are long-lasting and can exacerbate the mild age-associated deficits observed in normal aging animals (28). Guo et al. demonstrated that in vivo LTP induced by high-frequency stimulation (HFS) at hippocampal SC-CA1 synapses was suppressed in rats with neonatal MS (29).

The underlying mechanisms for the impairment of functional synaptic plasticity in the mPFC and hippocampus are likely complex. Factors may include a reduction in dendritic complexity and spine density (30, 31), apoptosis of pyramidal neurons in the dentate gyrus region (32), and a reduction in the expression of hippocampal brain-derived neurotrophic factor (BDNF) levels and NMDA receptor subunits (33, 34).

Most studies on the effect of MS in rats or mice have concluded that maternal care is crucial for brain development. Consequently, its absence, even if transient, has been proposed to disrupt maturational processes, ultimately impairing synaptic long-term potentiation in the medial PFC and hippocampus of adolescent and adult MS rats.

DECLARATIONS

Authors have no conflict of interest to declare.

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