

# Epigenetic Mechanisms of Foetal Imprinting: Integrating Garbha-Sanskar with Prenatal Stress and Cognitive Development

Manoj Mahavir Khavate<sup>1,2</sup>, Dipess Ramdas Chikane<sup>2</sup>, Sanket Rajendra Vakte<sup>2,3,\*</sup>

<sup>1</sup>CEO and Founder, Epiic Market Research and Consultancy, Mohan Nagar, Dhankwadi, Pune, Maharashtra, INDIA.

<sup>2</sup>SPM's Prin. B. V. Bhide Foundation for Research, Innovation and Incubation 1658, Sadashiv Peth, Lokamanya Nagar, SP College Campus, Pune, Maharashtra, INDIA.

<sup>3</sup>Director, Center for Natural Products Research, Vadner Bhairav, Chandwad, Nashik, Maharashtra, INDIA.

## ABSTRACT

This review focused on the transfer of memory and foetal imprinting specifically the effect of Garbha Sanskar in neurocognitive development. It talks of the interaction of the maternal stress, Hormonal milieu, nutrition and the overall psychosocial environment with epigenetic mechanisms that affect gene expression and development of neuronal networks in the developing foetus. Keywords were used to identify literature contained in key biomedical databases based on stress hormones, cortisol, memory, learning, pregnancy, maternal environment, transgenerational memory transfer, chromatin regulation, inheritance of behaviours, cognitive well-being, Garbha Sanskar, Traditional prenatal practices and meditation. Experimental literature on DNA methylation, histone modification and small RNAs in animal and cellular models is coupled with epidemiological research of prenatal stress and neurodevelopment in humans, and emerging literature about yoga, meditation and mindful interventions. The review identifies the possibility of traditional Garbha Sanskar approaches to regulate the intrauterine environment by reducing stress and achieving autonomic balance with plausible downstream epigenetic consequences that can impact cognition, emotional regulation and behaviour trajectories in offspring. The article postulates a biologically plausible correlation between prenatal behavioural interventions and neurodevelopmental later outcomes by merging Ayurvedic theories with a modern scientific view of epigenetics and neuroscience. It also finds conceptual and methodological gaps, such as a shortage of controlled human evidence regarding Garbha Sanskar as such, and requirements of longitudinal and mechanistically informed studies, incorporating clinical, behavioural and molecular endpoints. This cross-scientific viewpoint implies that a prenatal intervention that is consciously developed can be used to complement the present-day antenatal care in facilitating ideal brain development and intergenerational mental health.

**Keywords:** Cognitive development, Epigenetics, Foetal imprinting, *Garbha-Sanskar*, Memory transfer.

## Correspondence:

**Mr. Sanket Rajendra Vakte**

SPM's Prin. B. V. Bhide Foundation for Research, Innovation and Incubation 1658, Sadashiv Peth, Lokamanya Nagar, SP College Campus, Pune and Director, Center for Natural Products Research, Vadner Bhairav, Chandwad, Nashik-423111, Maharashtra, INDIA.  
Email: sanketvakte832@gmail.com

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## INTRODUCTION

Cortisol is a hormone that is secreted when one experiences stress which can cross through the placental barrier and influence the process of offspring brain development. It has been postulated that pregnant women with elevated stress levels can have an impact on early cognitive development, including learning components (Davis & Sandman, 2010). Various factors related to stress during pregnancy have been reported, including physical

discomfort, weight gain, mental instability, work-related issues, financial concerns, and changes in living patterns (Singh J. 2018). The proportion between genetic heredity, and environmental factors in shaping human behaviour is also still a topic of scientific study (Breed & Sanchez, 2010). There is debate that poor parenting, aggression or addiction can be predetermined by the DNA of a person. Nevertheless, the degree of the effect of DNA on the success of life as a whole is still multifaceted and ambiguous. Evolution, which entails the interaction of genes and the environment, is significant in the process of animals adjusting to their environment in order to increase their chances of survival (Dick, 2011). Animals have inborn behaviours that are inbuilt like eating or moving that help them to survive. Also, experience teaches animals to behave, to find food or to escape predators, which makes them adjust to new conditions (Sih *et al.*, 2011). These findings create a biological and epigenetic



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paradigm to comprehend classic notions like Garbha-Sanskar that focus on deliberate positive prenatal effects on foetal cognition and behaviour. Although there is mounting evidence that prenatal stress and epigenetic regulation are interconnected with neurodevelopment, there is scanty review that has been conducted to determine how conventional forms of prenatal rituals like Garbha-Sanskar can affect these biological processes.

## METHODS

This narrative review used PubMed, Web of Science, ScienceDirect and Google Scholar to search with the key terms on prenatal stress, epigenetics, transgenerational memory and Garbha-Sanskar. They included peer-reviewed human and animal studies, systematic reviews, and high-quality narrative reviews that were related to foetal development and prenatal interventions. Data were synthesized thematically, focusing on epigenetic mechanisms, prenatal stress, memory formation, and Garbha-Sanskar, with critical evaluation of evidence quality. As a narrative review, no formal risk-of-bias assessment was conducted.

### Impact of Stress and Diet on Foetal Development

Human behaviour and neurodevelopment are shaped by dynamic interactions between genetic predispositions and environmental exposures across early life (Sih *et al.*, 2011). The Garbha-Sanskar is an old tradition, which dates to ancient times. Pre-natal practices in various cultures have stressed the issue of maternal mental health and a conducive intrauterine environment. Understanding of the role of prenatal stress minimization and maternal wellbeing in foetal neurodevelopment is increasingly supported in the current literature. Most families nowadays are even worrying about the health and future of their children even before they are born.

### Foetal development and imprinting

Maternal health and socio-demographic and lifestyle factors all have an impact on foetal growth and brain development (Gaillard *et al.*, 2014). There are critical neurodevelopmental events that start during prenatal and early postnatal life, which are directives of tightly regulated programs of gene expression (Stiles & Jernigan, 2010). These genetic programs can be altered by environmental conditions in late gestation and early infancy, which highlights the susceptibility of the developing brain in this phase (Vasung *et al.*, 2018). Maternal stress influences foetal neurodevelopment in biological pathways between maternal and placental factors, which have impacts on neurogenesis and neurotrophic factors. This kind of stress may be indicative of cumulative life adversity, culminating in endocrine dysregulation that may be transferred into gestational physiology and intergenerational risk transmission occurs (Buss *et al.*, 2017). Small RNAs represent an important epigenetic mechanism identified primarily in animal models, where they mediate the inheritance of environmental

information related to stress, infection, and nutrition. Maternally inherited piRNAs participate in chromatin silencing and suppression of transposable elements during early embryogenesis, with effects that may persist across one or more generations, though such inheritance is not permanent and remains largely model-organism-based (Cecere, 2021).

### Garbha-Sanskar and Prenatal Influences

The epigenetic change transmission across generations is a complicated question because of the issues of logistics, financial and ethical aspects of human research. During fetal development, prenatal environmental exposures such as maternal stress have the capacity to cause epigenetic changes that can affect health and neurodevelopmental outcomes in one or more generations, even though the causal relationship is hardly causally inferred in humans. Current evidence supports both intergenerational and transgenerational effects on various health outcomes relevant to humans (Breton *et al.*, 2021).

### Transgenerational Memory Transfer

The few researches that have been conducted has not investigated whether the effects are transferred to the future generations. Prenatal exposure of pollutants such as arsenic and lead can cause neurobehavioral, epigenetic and neurological changes in the F2 generation. In addition, transgenerational defects may be transferred to the following generations due to immunological complications and infections during pregnancy. Even though genetic risk factors or gene environment interactions have been implicated in the genetic predisposition to asthma, non-biological, genetic, and non-genetic interactions of genetic and non-genetic risk factors can also exist. Altogether, these research articles offer epidemiological evidence of the relationship between child asthma outcomes and grand-maternal smoking (Breton *et al.*, 2021).

### Epigenetic Regulation and Transgenerational Imprinting

It has been shown that DNA methylation, histone modifications, and noncoding RNAs work together in the same manner to regulate stem cell differentiation and developmental plasticity through experimental studies (Di Tizio *et al.*, 2018), (Boland *et al.*, 2014). Amniotic fluid stem cells are epigenetically responsive to development related to developmental cues in the intrauterine environment, which is a model of prenatal epigenetic regulation (Di Tizio *et al.*, 2018). Animal studies further illustrate transgenerational transmission of environmentally induced behavioural sensitivity. In mice, parental fear conditioning to specific odours resulted in heightened olfactory sensitivity in subsequent generations, accompanied by epigenetic modifications in germ cells, including hypomethylation of odorant receptor genes (Dias & Ressler, 2013). These effects occurred independently of social learning, supporting a gamete-mediated

mechanism. The synthesis of such findings into reviews reiterates that the environmental experiences are epigenetically coded and passed on to influence inherited behavioural phenotypes (Dias *et al.*, 2014). In addition to behavioural characteristics, epigenetics governs the basic stem cell proliferation and differentiation in foetal development. Prenatal exposure to environmental determinants of these processes can have long-term impacts on neural development and susceptibility to neurodevelopmental or neurodegenerative conditions, making epigenetic regulation a potential molecular mediator between prenatal environments and neurological outcomes in the long term (Srinageshwar *et al.*, 2016).

### Role of epigenetics in foetal imprinting

Transcriptional regulation of gene expression by epigenetic mediators, such as the action of transcription factors such as cyclic AMP Response Element-Binding Protein (CREB), is central to the determination of neuronal populations, synaptic plasticity, and circuit architecture in foetal brain development, and, as a result, the establishment of life time cognitive and behavioural capacity (Zlotnik & Vansintjan, 2019), (Bartsch *et al.*, 2000). Although protein modification and de novo protein synthesis mediate the formation of both the short- and long-term memory in mature neural systems, optional to CREB-dependent transcription (Alberini, 2009), (Lee *et al.*, 2008), in prenatal development these molecular pathways dominate neural differentiation, connectivity and plasticity, but not explicit memory storage, which is why they are of interest to foetal imprinting and developmental programming (Zlotnik & Vansintjan, 2019), (Lee *et al.*, 2008).

### Meditation Effects on Molecular Mechanisms

Recent research examined the molecular and epigenetic pathways that mindful exercises, such as meditation, affect. A randomized trial study showed that various theories of meditation have varying epigenetic effects and can alter the activity of the nervous system by autonomic control. Gene array modification shows that meditation makes changes in the expression of genes, specifically, immune system genes, inflammatory genes, cancer pathways, and cellular structure/function genes. Meditation reduces the activity of the sympathetic nervous system (fight-or-flight response) and enhances that of the parasympathetic nervous system (rest-and-digest response) which forms a physiological environment where molecular changes become possible (Venditti *et al.*, 2020), (Rapyal, 2016).

### Garbha-Sanskar Awareness and Clinical Outcomes

Although interest is on the increase, there is limited scientific understanding of Garbha-Sanskar in the antenatal mothers as the knowledge is mostly relied on the family elders and spiritual teachings as opposed to evidence-based learning. The study by Chaudhary *et al.*, 2022 examined Garbha-Sanskar effects on 200 pregnant women, demonstrating reduced maternal stress and

anxiety levels. Medical complications occurred in only 7% (PIH, GDM), with 74% normal vaginal deliveries, 20% caesareans, and 6% instrumental deliveries. The results of neonatal outcomes were positive 16% low weight at birth, 88% APGAR higher than 7, and 6% NICU admission. The research design is observational and without randomization that hinders causality. Garbha-Sanskar was demonstrably successful in enhancing maternal well-being, minimizing complications, and perinatal outcomes, but additional controlled trials and scientific education are required (Shindhe *et al.*, 2015), (Chaudhary *et al.*, 2022).

### CONCLUSION

Garbha-Sanskar is a comprehensive prenatal care where the role of maternal mental condition, reduction in stress and favorable intrauterine environment in determining foetal development is highlighted. New developments in the genetics, epigenetics and neurodevelopment literature would point to the fact that prenatal experience may have a role in shaping cognitive and behavioural outcomes in children. Garbha-Sanskar can help in enhanced neurocognitive and general well-being by combining classical traditions of yoga, meditation, and mindful awareness with contemporary scientific knowledge. More longitudinal studies that are well-designed to support its biological processes and long-term advantages are required, as well as define its use as a complementary approach in the frame of contemporary antenatal care. Nevertheless, contemporary evidence is associative, which is why there is a necessity to develop clinical and mechanistic studies of rigorous design.

### ABBREVIATIONS

**DNA:** Deoxyribonucleic acid; **RNA:** Ribonucleic acid; **piRNAs:** Piwi-interacting RNAs; **CREB:** Cyclic AMP Response Element-Binding Protein; **PIH:** Pregnancy-Induced Hypertension; **GDM:** Gestational Diabetes Mellitus; **APGAR:** Appearance, Pulse, Grimace, Activity, and Respiration; **NICU:** Neonatal Intensive Care Unit.

### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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