PERSPECTIVE

Effects of yoga on epigenetics, and gene expression: Emerging evidence

Radhika Agarwal[1], Utkarsh Singh[1], Bharti Bhandari[1*], Manisha Singh[2]

ABSTRACT

Yoga is being used as a form of physical exercise and for stress management worldwide, with documented benefits. Recently, research has begun to explore its potential influence on epigenetics and gene expression. The interplay between yoga, gene expression, and epigenetic mechanisms is complex, with research increasingly suggesting that yoga may have profound effects on the molecular processes governing our health. It has been shown to influence molecular processes, including gene expression and epigenetic regulation, which may lead to potential clinical benefits. Various mind-body therapies (MBT) are found to epigenetically affect genes implicated in inflammation, stress, and distress, offering potential therapeutic benefits. Meditative practices have been shown to have a positive impact on stress-reduction pathways, which are known to be epigenetically sensitive, suggesting the importance of integrating these practices into mainstream medicine. Additionally, a yoga-based lifestyle intervention has been found to affect gene expression related to oxidative stress, inflammation, and aging. Furthermore, yoga practice has been shown to upregulate the expression of the Methylenetetrahydrofolate reductase gene, involved in critical metabolic processes, and has implications for various diseases. This perspective aims to synthesize current scientific evidence on how yoga might influence epigenetics and gene expression, thereby offering insights into its potential clinical benefits.

Keywords: Epigenetics, Mind-body therapy, Mindfulness meditation, Tai-chi, Yoga.

Indian Journal of Physiology and Allied Sciences (2025); DOI: 10.55184/ijpas.v77i03.505 **ISSN:** 0367-8350 (Print)

INTRODUCTION

Yoga, a mind-body practice with origins in ancient India, encompasses a range of practices, including physical postures (asanas), breathing exercises (pranayama), and meditation (dhyana). Its benefits on physical and mental health are well-documented, but recent studies have begun to explore its impact at the molecular level, particularly concerning epigenetics and gene expression.[1-6] Epigenetics refers to changes in gene activity and expression that do not involve alterations to the underlying DNA sequence.[2] These changes can result from various factors, including lifestyle, environment, and physiological stress, which can have significant impacts on health and disease. Gene expression, the process by which information from a gene is used to synthesize a functional gene product (often proteins), is intricately regulated and can be modulated by epigenetic mechanisms, including DNA methylation, histone modification, and RNA-based mechanisms.

Several studies have investigated the impact of yoga on gene expression, with a particular focus on its stress-reducing effects. A study by Qu *et al*. demonstrated that a comprehensive yoga program could downregulate genes associated with the inflammatory response, which is often triggered by stress.[3] This suggests that yoga could mitigate stress-induced inflammatory responses at the molecular level.

The field of epigenetics offers insights into how environmental factors, including lifestyle choices such as yoga, can influence gene expression without altering the underlying DNA sequence. These modifications occur through mechanisms such as DNA methylation and histone modification, which can activate or silence genes. A pivotal study by Kaliman *et al*.[4] found that an intensive day of mindfulness meditation (which shares common practices with yoga, such as focused breathing and mental discipline) led to reduced levels of pro-inflammatory genes. This suggests that practices like yoga could exert their effects through epigenetic modifications that decrease inflammation.

[1]Department of Physiology, Government Institute of Medical Sciences, Greater Noida-201310, Uttar Pradesh, India.

[2]Department of Biochemistry, Government Institute of Medical Sciences, Greater Noida-201310, Uttar Pradesh, India.

***Corresponding author:** Bharti Bhandari, Department of Physiology, Government Institute of Medical Sciences, Greater Noida-201310, Uttar Pradesh, India, Email: drbhartibhandari@yahoo.co.in

How to cite this article: Agarwal R, Singh U, Bhandari B, Singh M. Effects of yoga on epigenetics, and gene expression: Emerging evidence. *Indian J Physiol Allied Sci* 2025;77(3):5-8.

Conflict of interest: None

Submitted: 10/07/2025 **Accepted:** 20/08/2025 **Published:** 17/09/2025

This perspective examines the connections between mind-body interventions (MBIs) and stress, as well as their relationship to epigenetics. To explore the link between mind-body therapies (MBIs) and epigenetics, we searched for studies that included yoga, meditation, tai chi, or meditative practices (meditate) along with epigenetics.

Stress Reduction and Inflammatory Response

Chronic stress is a known risk factor for numerous health conditions, partly due to its adverse effects on gene expression and inflammatory responses. Yoga, recognized for its stress-reducing properties, may positively affect gene expression patterns associated with stress and inflammation. Studies have shown that regular yoga practice can lead to significant reductions in markers of inflammation, such as C-reactive protein and interleukin-6, as well as stress (including cortisol levels), potentially through epigenetic modifications that downregulate genes involved in the stress response and pro-inflammatory pathways. A study by Chaix *et al*. investigated the potential link between meditation and changes in the human methylome, which is essentially the chemical tag on our DNA that influences gene expression.[5] The study involved experienced meditators who participated in an eight-hour meditation session. A control group with no meditation experience spent a day doing leisure activities. By comparing DNA samples before and after the activities, researchers found that only the meditation group showed changes in these chemical tags on their DNA. Interestingly, the changed genes were linked to the immune system, metabolism, and even aging. The control group, on the other hand, showed no change. This suggests that even a single day of meditation in experienced practitioners might influence genes in ways that could affect the immune system. While this is a promising initial finding, more research is needed to confirm these results and see if meditation has long-term effects on our genes.[5]

Another study with a subsample (n = 28) of a larger clinical trial (N = 116) explored the psychophysiological effects of yoga intervention in women reporting psychological distress. Researchers looked at protein levels and DNA methylation of immune system genes in a smaller group of these women. While some connections were found between immune markers and psychological factors, a key result was the reduced methylation of a specific immune gene (TNF) in the yoga group compared to the controls. This suggests that yoga may influence the immune system on a molecular level. Still, the study acknowledges its limitations and emphasizes the need for larger studies to confirm these initial findings. Notably, this is one of the first investigations into the impact of yoga on immune system markers and DNA methylation in everyday individuals rather than just clinical populations.[6]

Telomere Length, Cellular Aging, and Oxidative Stress

Telomeres, protective caps at the ends of chromosomes, shorten with each cell division, and their length is considered a marker of cellular aging. Stress and inflammation can accelerate telomere shortening, leading to premature cellular aging. Research indicates that yoga and meditation practices may enhance telomerase activity, an enzyme responsible for maintaining telomere length, suggesting a possible mechanism by which yoga could exert anti-aging effects at the cellular level, potentially mediated through epigenetic modifications.

In a randomized clinical trial of 298 healthy adults examining the effectiveness of meditation for nine months, no significant impact on leukocyte telomere length (TL) was observed. However, a remarkable correlation was found between changes in telomeres and changes in cortical thickness in specific brain regions.[7] A pilot study by Lavretsky *et al*.[8] focused on family dementia caregivers and discovered that brief daily meditation practices led to improved mental and cognitive functioning, as well as lower levels of depressive symptoms. Furthermore, the study found that this improvement was accompanied by an increase in telomerase activity, thereby suggesting an improvement in stress-induced cellular aging. However, it is crucial to note that these results must be confirmed in a larger sample. While some studies show links between meditation and telomeres, the results are mixed, and further research is needed. There is evidence of meditation's impact on brain health and stress reduction, as demonstrated by telomerase activity.[9-15]

A study by Tolahunase *et al*.[16] suggests that a 12-week Yoga and meditation-based lifestyle intervention (YMLI) program, which included yoga asanas (postures), pranayama (breathing exercises), and meditation, has a positive impact on cellular aging in healthy individuals. It lowered the levels of biomarkers of cellular aging, including 8-hydroxy-2' -deoxyguanosine (8-OHdG), a product of DNA damage, and other oxidative stress markers. Additionally, antioxidant capacity and telomerase activity were increased. All these changes suggest that yoga has the potential to slow cellular aging.

Obesity-related gene expression and MTHFR

Epigenetic modifications play a crucial role in the expression of genes associated with obesity. These modifications can mitigate the effects of various environmental factors on gene expression, ultimately leading to the clinical manifestation of obesity.[17] Exposure to environmental elements during critical periods of development can have a profound influence on epigenetic tags, thereby leading to the development of obesity. Additionally, the dietary choices and lifestyle decisions made by individuals can also significantly influence the gene expression patterns associated with obesity. The field of epigenetics is widely recognized as a pivotal regulator of the intricate interactions between genes and the environment in the context of obesity development. Epigenetic mechanisms, including DNA methylation, histone modifications, and microRNA regulation, have been extensively studied in relation to obesity. Numerous studies have successfully identified the differential expression of multiple genes both before and after interventions aimed at combating obesity, thereby providing valuable insights into the complex etiology of this condition. Epigenetic markers have been found to contribute to both common and severe forms of obesity, highlighting their potential importance in understanding the underlying mechanisms involved in gene expression. Consequently, gaining a comprehensive understanding of obesity necessitates a thorough exploration of the genetic and epigenetic factors that influence gene expression.

The methylenetetrahydrofolate reductase (MTHFR) gene mutation is a rare autosomal recessive inborn error of metabolism that has the potential to result in a range of diseases. A study conducted by Borthakur *et al.*[18] examined MTHFR polymorphisms, specifically 677 C>T and 1298 A>C, which have been linked to neural tube defects, congenital heart disease, and neuropsychiatric disorders. MTHFR polymorphisms exhibit independent associations with a variety of pediatric diseases. The diagnosis of MTHFR deficiency in children presents a considerable challenge, requiring a high level of suspicion and ongoing vigilance. A yoga-based lifestyle may be adopted by both parents planning conception and adolescent children suffering from this condition to mitigate the repercussions of mild to moderate MTHFR deficiency.

Another study observed that a supervised 21-day yoga regimen enhanced sperm characteristics in patients with idiopathic male infertility and led to alterations in DNA methylation at nearly 400 genes, including those associated with fertility and genomic integrity.[19] Mind-body therapies, including yoga, have demonstrated the ability to epigenetically influence genes involved in inflammation, stress, and distress. Another investigation discovered that practitioners of Hatha Yoga exhibited a distinct global DNA methylation pattern compared to non-practitioners, suggesting that yoga may operate at the epigenetic level. Although additional research is required, these findings suggest that yoga may influence MTHFR gene expression and epigenetic modifications.[20]

Clinical Implications

By influencing gene expression and epigenetic states, yoga may offer a non-pharmacological means to influence the course of diseases characterized by inflammation, stress responses, and even cancer. For instance, the modulation of genes related to stress response and inflammation could be particularly relevant for conditions like cardiovascular disease, diabetes, and various mental health disorders. Additionally, the potential for yoga to impact epigenetic aging markers could have implications for healthy aging and longevity.

Future Directions

The precise molecular pathway through which yoga exerts its effects, ultimately leading to long-term health outcomes, remains largely unexplored. Furthermore, the mechanisms by which yoga may induce epigenetic changes are still not fully understood, and the long-term clinical significance of these modifications remains to be established. Future research should aim to conduct more extensive, randomized, controlled trials with standardized yoga interventions better to assess their impact on epigenetics and gene expression. Additionally, longitudinal studies are needed to understand the long-term effects of yoga practice on epigenetic markers and their clinical implications.

CONCLUSION

The current scientific evidence suggests that yoga has the potential to influence gene expression and epigenetic mechanisms in ways that promote health and may mitigate disease processes. As research in this area continues to evolve, yoga could become increasingly integrated into holistic approaches to health and wellness, supported by a growing understanding of its molecular mechanisms. With its potential to serve as a low-cost, accessible intervention with minimal side effects, further research in this field is a promising and necessary endeavour in the quest to optimize human health.

REFERENCES

1. Sharma P, Yadav RK, Khadgawat R, Dada R. Transcriptional modulation of inflammation, and aging in Indian obese adults following a 12-week yoga-based lifestyle intervention: A randomized controlled trial. Front Med (Lausanne). 2022;9:898293. Available from: doi.org/10.3389/fmed.2022.898293.
2. Borthakur D, Kumar R, Dada R. Yoga: A natural solution to decrease disease burden in children of MTHFR deficient parents. Clin Ter. 2023;174:28-32. Available from: doi.org/10.7417/CT.2023.5005.
3. Qu S, Olafsrud SM, Meza-Zepeda LA, Saatcioglu F. Rapid gene expression changes in peripheral blood lymphocytes upon practice of a comprehensive yoga program. PLoS One. 2013;8:e61910. Available from: doi.org/10.1371/journal.pone.0061910.
4. Kaliman P, Alvarez-López MJ, Cosín-Tomás M, Rosenkranz MA, Lutz A, Davidson RJ. Rapid changes in histone deacetylases and inflammatory gene expression in expert meditators. Psychoneuroendocrinology. 2014;40:96-107. Available from: doi.org/10.1016/j.psyneuen.2013.11.004.
5. Chaix R, Fagny M, Cosin-Tomás M, et al. Differential DNA methylation in experienced meditators after an intensive day of mindfulness-based practice: Implications for immune-related pathways. Brain Behav Immun. 2020;84:36-44. Available from: doi.org/10.1016/j.bbi.2019.11.003.
6. Harkess KN, Ryan J, Delfabbro PH, Cohen-Woods S. Preliminary indications of the effect of a brief yoga intervention on markers of inflammation and DNA methylation in chronically stressed women. Transl Psychiatry. 2016;6:e965. Available from: doi.org/10.1038/tp.2016.234.
7. Puhlmann LMC, Valk SL, Engert V, et al. Association of Short-term Change in Leukocyte Telomere Length With Cortical Thickness and Outcomes of Mental Training Among Healthy Adults: A Randomized Clinical Trial. JAMA Netw Open. 2019;2:e199687. Available from: doi.org /10.1001/jamanetworkopen.2019.9687
8. Lavretsky H, Epel ES, Siddarth P, et al. A pilot study of yogic meditation for family dementia caregivers with depressive symptoms: effects on mental health, cognition, and telomerase activity. Int J Geriatr Psychiatry. 2013; 28: 57-65. Available from: doi.org/10.1002/gps.3790.
9. Le Nguyen KD, Lin J, Algoe SB, et al. Loving-kindness meditation slows biological aging in novices: Evidence from a 12-week randomized controlled trial. Psychoneuroendocrinology. 2019;108:20-7. Available from: doi.org/10.1016/j.psyneuen.2019.05.

10. Mendioroz M, Puebla-Guedea M, Montero-Marín J, et al. Telomere length correlates with subtelomeric DNA methylation in long-term mindfulness practitioners. Sci Rep. 2020;10: 4564. Available from: doi.org/10.1038/s41598-020-61241-6.
11. Hoge EA, Chen MM, Orr E, et al. Loving-Kindness Meditation practice associated with longer telomeres in women. Brain Behav Immun. 2013;32:159-63. Available from: doi.org/10.1016/j.bbi.2013.04.005.
12. Alda M, Puebla-Guedea M, Rodero B, et al. Zen meditation, length of telomeres, and the role of experiential avoidance and compassion. Mindfulness (NY). 2016,7:651-9. Available from: doi.org/10.1007/s12671-016-0500-5
13. Carlson LE, Beattie TL, Giese-Davis J, et al. Mindfulness-based cancer recovery and supportive-expressive therapy maintain telomere length relative to controls in distressed breast cancer survivors. Cancer. 2015;121:476-84. Available from: doi.org/10.1002/cncr.29063.
14. Conklin QA, King BG, Zanesco AP, et al. Insight meditation and telomere biology: The effects of intensive retreat and the moderating role of personality. Brain Behav Immun. 2018;70:233-245. Available from: doi.org/10.1016/j.bbi.2018.03.003.
15. Duraimani S, Schneider RH, Randall OS, et al. Effects of lifestyle modification on telomerase gene expression in hypertensive patients: A pilot trial of stress reduction and health education programs in African Americans. PLoS One. 2015;10:e0142689. Available from: doi.org/10.1371/journal.pone.0142689.
16. Tolahunase M, Sagar R, Dada R. Impact of Yoga and Meditation on Cellular Aging in Apparently Healthy Individuals: A Prospective, Open-Label Single-Arm Exploratory Study. Oxid Med Cell Longev. 2017;2017:7928981. Available from: doi.org/10.1155/2017/7928981.
17. Trang K, Grant SFA. Genetics and epigenetics in the obesity phenotyping scenario. Rev Endocr Metab Disord. 2023;24:775-793. Available from: doi.org/10.1007/s11154-023-09804-6.
18. Bisht S, Banu S, Srivastava S, et al. Sperm methylome alterations following yoga-based lifestyle intervention in patients of primary male infertility: A pilot study. Andrologia. 2020;52:e13551. Available from: doi.org/10.1111/and.13551.
19. Mody JK. Epigenetics and Yoga. Journal of clinical epigenetics. 2018;4:10-14. Available from: doi.org/10.21767/2472-1158.100095

PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.