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Hypothetical model for explaining yoga mediated modulation of pathways implicated in obesity

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Obesity is a state of energy imbalance characterized by inflammation, dysregulated autonomic nervous system function, altered brown adipose tissue activity, basal metabolic rate alterations, and changes at the psychological level. Adipose tissue is not only a metabolic organ but also an endocrine organ. Adipokines released by the fat cells play an important role in regulating the local metabolic processes and maintaining the homeostasis between food intake and energy balance. The most common pro-inflammatory cytokines involved are TNF-α, IL-6, IL-1, leptin, adiponectin, resistin, visfatin, irisin, which are involved in the pathophysiology of obesity. Yoga as lifestyle-based intervention influences the adipokine levels, autonomic nervous system functioning, brown adipose tissue activity, basal metabolic rate, and stress levels in the body. With this, yoga can help bring back the energy balance and weight management in obese individuals.

Keywords: Brown adipose tissue, Craving, Energy balance, Mechanism, Obesity, Yoga

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Obesity is a state of increased adipocytes[1], in which an imbalance in energy intake and energy expenditure is clearly evident. It is characterized by inflammation, dysregulated autonomic nervous system function, altered brown adipose tissue activity, basal metabolic rate alterations, and changes at the psychological level, as given in Figure 1a-b.

Role of adipokines in obesity

In obesity, numerous pro-inflammatory cytokines circulate in the blood, which also creates a state of insulin resistance and impaired insulin signaling in them[2]. The chronic elevated levels of inflammatory cytokines not only influence the development of obesity but also, through its influence on the lipid and carbohydrate metabolism, significantly determines the etiology of various ailments like hypertension, insulin resistance and other metabolic disorders. Some of the most common pro-inflammatory cytokines involved are TNF-α, IL-6, IL-1, etc. Other adipokines (cytokines secreted by adipose tissue) like, leptin, adiponectin, resistin, visfatin, irisin are also involved in the pathophysiology of obesity[3]. Adipose tissue, in addition to being a metabolic organ, is also an endocrine organ and the adipokines released by it play an important role in regulating the local metabolic processes and maintaining the homeostasis between food intake and energy balance[4]. These have their role to play in the body, but when synthesized in excess, some of these adipokines exert harmful effects due to their inflammatory nature, whereas some are beneficial, such as adiponectin. The excess of these adipokines is responsible for various metabolic complications. Some of the common complications are high blood pressure, Type-2 diabetes mellitus, hyperinsulinemia, and insulin resistance. This is further associated with an increased risk of cardiovascular complications like stroke. Obesity-associated inflammation can also lead to different types of cancer, heart failure, arthritis, hernia, cholelithiasis, fatty liver, etc., which in itself are serious problems[5,6].

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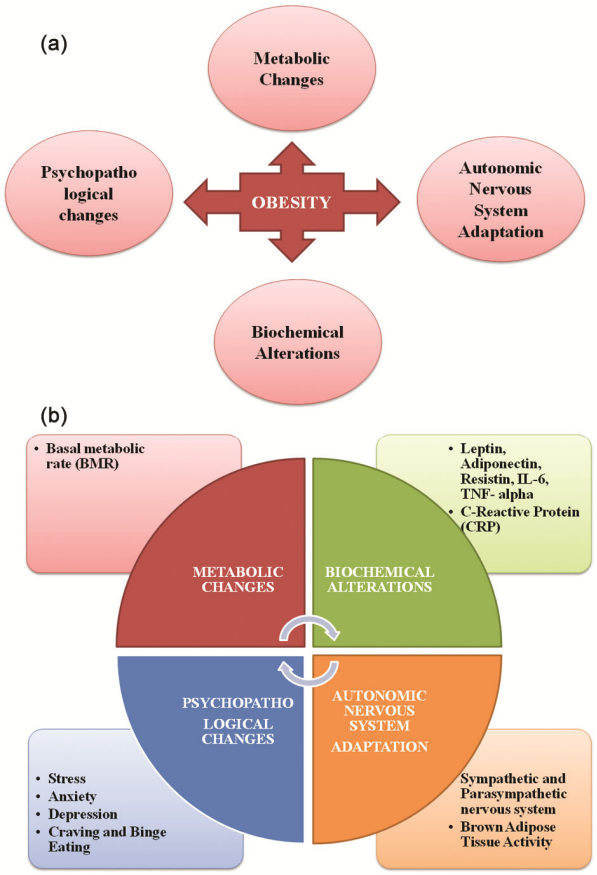

Fig. 1a-b — Impact of obesity at different levels in body

Role of brown adipose tissue & basal metabolic rate in obesity

Present in all mammals, brown adipose tissue (BAT) is concerned with thermoregulation. There is a direct connection between the hypothalamus and sympathetic nervous system (SNS) supply to brown adipose tissue. Stimulation of the hypothalamus induces thermogenesis in brown adipose tissue[7]. The uncoupling protein (UCP) is a mitochondrial protein present on its inner wall and found exclusively in mammals. It acts as a protein transporter that dissipates the heat and causes uncoupling oxidative phosphorylation. Thermogenesis depends mostly on the activity of this uncoupling protein. Norepinephrine released from the rich sympathetic innervations into BAT influences its activity leading to lipolysis. The sympathetic nervous system regulates the uncoupling protein activity in brown adipose tissues, thereby regulating the thermogenesis and its effects[8].

Basal metabolic rate (BMR) is the rate in the zone of thermoneutrality. It signifies the amount of energy required to maintain the basal activities in the body[9]. BMR is proportional to body mass, particularly the amount of fat-free mass or the lean body mass (LBM)[10]. BMR accounts for 65–75% of total energy expenditure in the body. Various factors like gender, age, height, body mass, and estimated LBM influence BMR, of which LBM is the single predictor of BMR[11]. Physical activity reduces the fat mass and improves the fat-free mass by enhancing the muscle mass and bone mass, thereby leading to an increase in energy expenditure[12].

Role of stress in obesity

The autonomic nervous system is an essential factor in regulating the energy balance and storage of fat in the body. Obese people show altered autonomic nervous system function with altered sympathetic nervous system activity. This becomes not only a risk factor for the mortality from the disease and its complications but also the cause of the disease (obesity) in itself[13].

Stress is a state of threatened homeostasis which is counteracted by the repetition of physiologic and behavioral responses to regain the body equilibrium. It may be caused by various intrinsic and extrinsic adverse forces. Response to stress manifests in the form of different physical reactions governed by the hypothalamo-pituitary-adrenal (HPA) axis and sympatho-adrenal system[14]. Various psychological factors like anxiety, depression, etc., influence the eating behavior of an individual by activating certain neural stress response networks. The altered emotional brain network promotes the increased behavior of food intake and, thereby, obesity. Altered HPA axis activity leads to excess secretion of corticotrophin-releasing hormone (CRH) and glucocorticoids in the body[15]. Elevated CRH level activates the sympathetic locus coeruleus-norepinephrine system, and glucocorticoids enhance neuronal excitability to norepinephrine, which in turn activates hypothalamic CRH secretion[16]. Excess secretion of glucocorticoids further increases the craving for food[17]. According to a meta-analysis on longitudinal studies, psychological stress is positively correlated with increased adiposity[18].

Impact of yoga on adipokines

In obese individuals, there is an imbalance in adipokine levels. Herbs and herbal formulations have shown to be effective in obesity[19,20], However, yoga as a lifestyle-based non-pharmacological intervention has also demonstrated encouraging results in obesity

by modulating the levels of adipokines in the human body. Twelve week yoga practice reduces serum visfatin, resistin levels, and fat percentage in the body[21]. Regular practice of yoga reduces inflammation, evident through a decrease in inflammatory markers like IL-6, TNF-alpha, and C-reactive protein[22,23]. In a study, 28% increase in adiponectin, 36% decrease in leptin and a significant increase in adiponectin to leptin ratio was observed in yoga experts compared to the novices. The duration of Yoga practice was negatively associated with leptin levels and positively associated with adiponectin and adiponectin to leptin ratio[24]. In a recent study, eight weeks of yoga intervention showed to significantly decrease the leptin levels and increase the adiponectin levels in overweight and obese women when compared to the group who was on energy-restricted diet[25].

Possible mechanism of the impact of yoga on obesity

Yoga is a lifestyle-based intervention that includes asanas (physical posture), pranayama (breath control), meditation and relaxation techniques. Yoga texts, like Patanjali Yoga Sutras and the Bhagavad Gita, expound mastering the mind by calming it and bringing balance at the physical and mental level[26,27]. Regular practice of yoga for varied duration has shown to be effective in lowering inflammation by reducing the inflammatory cytokine levels in the body[28]. Twelve weeks of a yoga-based lifestyle intervention (YBLI) 2hrs each day for two weeks followed by ten weeks of home practice significantly reduces the leptin and leptin: adiponectin ratio, inflammatory markers (tumor necrosis factor [TNF]-α, interleukin [IL]-6), markers of oxidative stress (thiobarbituric acid reactive substances [TBARS], 8-hydroxy-2'-deoxyguanosine [8-OHdG] and significantly increases the superoxide dismutase [SOD] and adiponectin levels in people diagnosed with metabolic syndrome. Yoga significantly reduces the weight, waist-hip ratio (WHR), systolic and diastolic blood pressure[29] and Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) of the participants, along with the significant reduction in interleukin-6 (IL-6) and serum leptin levels and a significant increase in serum adiponectin levels[30]. By reducing the inflammation, yoga as a lifestyle intervention reduces the risk of appearance of obesity-related complications like cardiovascular disease, insulin resistance, etc. Yoga being a lifestyle intervention is useful not only for unhealthy people suffering from various diseases but also for healthy people to maintain their health. In a study by Papp *et al.*[31], high-intensity yoga as an intervention for 60-minutes, weekly once for six weeks, with additional home training was administered to half of the participants out of total 54 healthy students. This high-intensity yoga (HIY) mainly consists of sun salutations sequences performed at rapid speed and with inversions at the end. Both ApoA1 and adiponectin increased significantly and HbA1c lowered nearly significantly in the HIY group.

Different practices in yoga have a stimulatory and inhibitory effect on healthy individuals, which are practiced in combination in our daily yoga practice. The regular practice of yoga for 12 weeks has demonstrated to improve the lean mass in the practitioners[32]. In a controlled study with yoga as an intervention containing asana, pranayama and meditation for six months showed that the net effect of these practices has a lowering effect on the basal metabolic rate (BMR)[33]. Whereas in another study, the 8-week practice of yoga resulted in an increase in BMR from the baseline[34]. It could be hypothesized that yoga practice has a time and duration effect on the basal metabolic rate of individuals. Brown adipose tissue activity is an important component of energy expenditure. Though there is no direct research evidence of the effect of yoga practice on brown adipose activity, however, there is extensive evidence of the impact of physical activity on brown adipose tissue activity[35]. It is clear from research evidence that yoga practice influences autonomic nervous system activity[36]. From this, it can be hypothesized that by doing certain yoga practices, sympathetic nervous system activity can be enhanced directly as well as indirectly by the release of some biomolecules like irisin and FGF21 and thereby upregulating the brown adipose tissue (BAT) activity. This upregulation of BAT activity increases the energy expenditure in the body, which is necessary for weight loss[37]. Various studies support Yoga /meditative practices to have a measurable effect at the molecular level helping in the regulation of gene expression[38,39] and therefore it might even enhance the brown adipose tissue gene expression, leading to the increased brown adipose tissue activity. The environment influences gene expression and may contribute to the development and the progression of the disease. In one of the

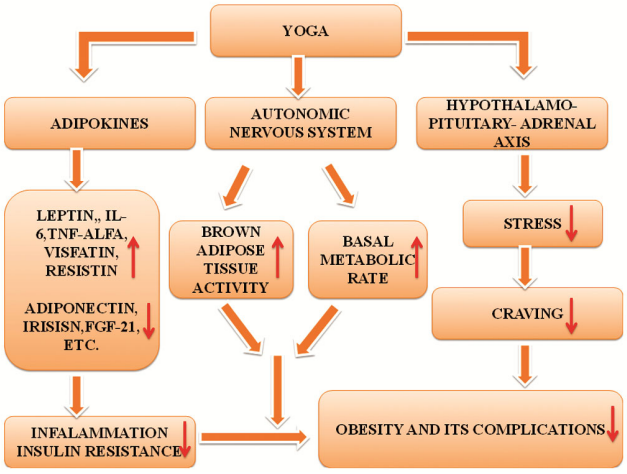

Fig. 2 — Possible mechanisms of effect of yoga in obesity

studies, it was found that Sudarshan KriyaYoga, a form of breathing practice, can positively affect immunity, aging, cell death, and stress regulation through transcriptional regulation[40]. Psychological and oxidative stress enhances the release of inflammatory markers in the body commonly seen in obesity, which increases the chance of the development of complications[41,42]. Yoga practice helps in regulating the immune responses of the stress and thus reducing their effects[43]. Growing evidence supports the belief that yoga practice reduces stress and promotes physical and mental health by the downregulation of the hypothalamo-pituitary-adrenal axis[44]. The physical, mental relaxation, and mindfulness induced by these practices reduce the mental rush and hence the craving towards food. In an exploratory study among women with disordered eating behavior, the mindfulness-based intervention significantly decreased the food cravings, the concern of body image, external and emotional eating, and dichotomous thinking in them[45].

Conclusion

From the various direct and indirect evidence, we conclude that Yoga practice appears to have a beneficial impact on obesity and related complications through several pathways given in Figure 2. Overall, we understand that in obesity, pro-inflammatory adipokines like leptin levels are increased and anti-inflammatory adipokines are decreased. Yoga practice produces its impact on obesity and its complications by modulating the different pathways like adipokines, autonomic nervous system, and the HPA axis. By modulating the adipokine levels, like decreasing the leptin resistance and increasing the adiponectin levels, the inflammation reduces. Correcting the imbalance in the autonomic nervous system may affect the brown adipose tissue activity thereby increasing the energy expenditure. Stabilizing the HPA- axis reduces psychological stress and, therefore, the food-related craving. By this yoga practice helps to reduce energy intake, increase energy expenditure and correct the biochemical imbalances, which ultimately would result in preventing the obesity-related complications and better weight management.

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Conflict of interest

None

Author Contributions

MPC- Concept designing, literature review, original draft writing and editing; RMN- Technical inputs, paper review and editing; and SVC- Literature review and paper review.

References

1 Jameson J L, Harrison's principles of internal medicine, (New York: Mcgraw-hill) 2018.

2 Goossens G H, The role of adipose tissue dysfunction in the pathogenesis of obesity-related insulin resistance, *Physiol Behav*, 94 (2008) 206-18.

3 Zorena K, Jachimowicz-Duda O, Ślęzak D, Robakowska M, & Mrugacz M, Adipokines and obesity. Potential link to metabolic disorders and chronic complications, *Int J Mol Sci*, 21 (10) (2020) 3570.

4 Ahima R S & Lazar M A, Adipokines and the peripheral and neural control of energy balance, *Mol Endocrinol*, 22 (5) (2008) 1023-1031.

5 Gnacińska M, Małgorzewicz S, Stojek M, Łysiak-Szydłowska W & Sworczak K, Role of adipokines in complications related to obesity. A review, *Adv Med Sci*, 54 (2) (2009) 150-57

6 Manuha M I, Paranagama P A, Nageeb B M & Iqbal N Z, Comperative study on the intervention of 'Spice Mixture' (SM) prepared by Natural Food Additives (NFA) alone or intervention of SM with mind calming exercise in the management on female obesity, *Indian J Tradit Know*, 19 (4) (2020) 889-896.

7 Houtz J, Liao G Y, An J J & Xu B, Discrete TrkB-expressing neurons of the dorsomedial hypothalamus regulate feeding and thermogenesis, *Proc Natl Acad Sci*, 118 (4) (2021) e2017218118

8 Cannon B & Nedergaard J A N, Brown adipose tissue: function and physiological significance, *Physiol Rev,* 84 (2004) 277-359.

9 Auer S K, Solowey J R, Rajesh S & Rezende E L, Energetic mechanisms for coping with changes in resource availability, *Biol Lett,* 16 (11) (2020) 20200580.

10 Hill J O, Wyatt H R & Peters J C, Energy balance and obesity, *Circulation*, 126 (1) (2012) 126-132.

11 Cunningham J J, A reanalysis of the factors influencing basal metabolic rate in normal adults, *Am J Clin Nutr*, 33 (11) (1980) 2372-74.

12 Irwin M L, Alvarez-Reeves M, Cadmus L, Mierzejewski E & Mayne ST *et al.*, Exercise improves body fat, lean mass, and bone mass in breast cancer survivors, *Obesity*, 17 (8) (2009) 1534-41.

13 Peterson H R, Rothschild M, Weinberg C R, Fell R D & McLeish K R, *et al.,* Body fat and the activity of the autonomic nervous system, *N Engl J Med*, 318 (17) (1988) 1077-83.

14 Crum A J, Jamieson J P & Akinola M, Optimizing stress: An integrated intervention for regulating stress responses, *Emotion*, 20 (1) (2020) 120.

15 Natalie G B, Natalia A W & Diana C-T, Hypothalamic-Pituitary-Adrenal axis modulation of glucocorticoids in the cardiovascular system, *Int J Mol Sci*, 18 (10) (2017) 2150.

16 Lucassen E A & Cizza G, The hypothalamic-pituitary-adrenal axis, obesity, and chronic stress exposure: sleep and the HPA axis in obesity, *Curr Obes Rep*, 1 (4) (2012) 208-15.

17 Dallman M F, Stress-induced obesity and the emotional nervous system, *Trends Endrocrinol Metab*, 21 (3) (2010) 159-65.

18 Wardle J, Chida Y, Gibson E L, Whitaker K L & Steptoe A, Stress and adiposity: a meta-analysis of longitudinal studies, *Obesity*, 19 (4) (2011) 771-8.

19 Joshi A, Khan A, Patrikar V, Rajurkar D & Joshi A, Effect of Madhu Haritaki in the management of sthaulya with special reference to obesity with the help of objective parameters: Experimental study, *Eur J Mol Clin Med,* 8 (1) (2021) 394-408.

20 Sfar M, Hfaiedh K B, Mahrez K B, Skhiri H A & Rayana C B, *et al.*, Effect of cinnamon supplementation on resistin and ghrelin in obese diabetic men, *Indian J Tradit Know*, 18 (4) (2019) 694-701.

21 Nazari Gt, Ebrahimi M, Foroughi Pa & Nazemian At, Investigating the changes in serum levels of resistin, visfatin and insulin resistance after 12 weeks of selected Yoga Practice In Women With Type 2 Diabetes, Int Congress On Physical Education And Sport Sciences (By Iran's Physical Education And Sports Sciences Association), 2016, p.9.

22 Gautam S, Kumar M, Kumar U & Dada R, Effect of an 8-week yoga-based lifestyle intervention on psycho-neuro-immune axis, disease activity, and perceived quality of life in rheumatoid arthritis patients: A randomized controlled trial, *Front Psychol*, 11 (2020) 2259.

23 Yadav R K, Magan D, Mehta N, Sharma R & Mahapatra S C, Efficacy of a short-term yoga-based lifestyle intervention in reducing stress and inflammation: preliminary results, *J Altern Complement Med*, 18 (7) (2012) 662-7.

24 Kiecolt-Glaser J K, Christian L M, Andridge R, Hwang B S & Malarkey W B, *et al.*, Adiponectin, leptin, and yoga practice, *Physiol & Behav*, 107 (5) (2012) 809-13.

25 Yazdanparast F, Jafarirad S, Borazjani F, Haghighizadeh M H & Jahanshahi A, Comparing between the effect of energy-restricted diet and yoga on the resting metabolic rate, anthropometric indices, and serum adipokine levels in overweight and obese staff women, *J Res Med Sci*, (2020) 25.

26 Yogananda P, God talks with Arjuna:The Bhagwad Gita, Yogoda Satsanga Society of India, 2002.

27 Saraswati S, Four chapters on freedom: Commentary on the yogasutras of Patajali, Bihar School of Yoga: India, 2006

28 Djalilova D M, Schulz P S, Berger A M, Case A J & Kupzyk K A, *et al*., Impact of yoga on inflammatory biomarkers: a systematic review, *Biol Res Nurs,* 21 (2) (2019) 198-209.

29 Oza D N, Patel T A & Verma R J, Role of yogic practices in individuals with hypertension and low-peak expiratory flow rate (PEFR) of Ahmedabad city, *Indian J Tradit Know,* 18 (3) (2019) 589–594.

30 Yadav R, Yadav R K, Khadgawat R, Pandey R M, Comparative efficacy of a 12 week yoga-based lifestyle intervention and dietary intervention on adipokines, inflammation, and oxidative stress in adults with metabolic syndrome: a randomized controlled trial, *Transl Behav Med*, 9 (4) (2019) 594-604.

31 Papp M E, Lindfors P, Nygren-Bonnier M, Gullstrand L & Wändell P E, Effects of high-intensity hatha yoga on cardiovascular fitness, adipocytokines, and apolipoproteins in healthy students: a randomized controlled study, *J Altern Complement Med*, 22 (1) (2016) 81-87.

32 Madhavi S, Raju P S, Reddy M V, Annapurna N & Sahay B K, *et al.*, Effect of yogic exercises on lean body mass, *J Assoc Physicians India*, 33 (7) (1985) 465-6.

33 Chaya M S, Kurpad A V, Nagendra H R & Nagarathna R, The effect of long term combined yoga practice on the basal metabolic rate of healthy adults, *BMC Complement Altern Med,* 6 (1) (2006) 28.

34 Seo D Y, Lee S, Figueroa A, Kim H K & Baek Y H, Yoga training improves metabolic parameters in obese boys, *Korean J Physiol Pharmacol,* 16 (3) (2012) 175-80.

35 Sanchez-Delgado G, Martinez-Tellez B, Olza J, Aguilera CM & Gil Á, Role of exercise in the activation of brown adipose tissue, *Ann Nutr Metab*, 67 (1) (2015) 21-32.

36 Pal A, Srivastava N, Narain V S, Agrawal G G & Rani M, Effect of yogic intervention on the autonomic nervous system in the patients with coronary artery disease: a randomized controlled trial, *East Mediterr Health J,* 19 (5) (2013) 452-58.

37 Owen B M, Ding X, Morgan D A, Coate K C & Bookout A L, FGF21 acts centrally to induce sympathetic nerve activity, energy expenditure, and weight loss, *Cell Metab,* 20 (4) (2014) 670-7.

38 Lafer E M, Margaret M & Ann S, Yoga therapy: An overview of key research and the underlying mechanisms." Handbook of Research on Evidence-Based Perspectives on the Psychophysiology of Yoga and Its Applications, (IGI Global), (2021), p.159-178..

39 Buric I, Farias M, Jong J, Mee C & Brazil I A, What is the molecular signature of mind–body interventions? A systematic review of gene expression changes induced by meditation and related practices, *Front Immunol*, 8 (2017) 670.

40 Zope S A & Zope R A, Sudarshan kriya yoga: Breathing for health*, Int J Yoga,* 6 (1) (2013) 4.

41 Seyedsadjadi N & Grant R, The potential benefit of monitoring oxidative stress and inflammation in the prevention of non-communicable diseases (NCDs), *Antioxidants*, 10 (1) (2021) 15.

42 Anne I T, Nina S, Sarah J H, Susan J T & Mais H, *et al*., Psychological stress reactivity and future health and disease outcomes: A systematic review of prospective evidence, *Psychoneuroendocrinology*, 114 (2020) 104599.

43 Arora S & Bhattacharjee J, Modulation of immune responses in stress by Yoga, *Int J Yoga*, 1 (2) (2008) 45.

44 Gautam S & Rima D, Molecular mechanisms Uuderlying the effects of Yoga. Handbook of Research on Evidence-Based Perspectives on the Psychophysiology of Yoga and Its Applications, (IGI Global), (2021), p.103-123.

45 Alberts H J, Thewissen R & Raes L, Dealing with problematic eating behaviour. The effects of a mindfulness-based intervention on eating behaviour, food cravings, dichotomous thinking and body image concern, *Appetite*, 58 (3) (2012) 847-51.