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REVIEW ARTICLE

# *Kapalabhati*: A Scientific Analysis of its Physical, Mental, and Biochemical Effects

Sheelendra Kushwah[1]*, Khagendra Kushwah[2], Meera Antiwal[1]

[1]Department of Kayachikitsa, Faculty of Ayurveda, IMS, Banaras Hindu Universty, Varanasi, Uttar Pradesh, India.
[2]Department of Panchkarma, Faculty of Ayurveda, IMS, Banaras Hindu Universty, Varanasi, Uttar Pradesh, India.

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**ABSTRACT**

*Kapalabhati*, a revered ancient yogic breathing practice, serves as a powerful tool for enhancing physical, mental, and hormonal equilibrium. Through rapid, rhythmic inhalations and exhalations, this technique optimizes oxygen delivery across the body, promoting detoxification, energy homeostasis, and improved blood circulation. Scientifically, it has been shown to activate mitochondrial function, enhance protein synthesis, and regulate neurotransmitters such as dopamine and serotonin, thus fostering mental clarity and emotional stability. Moreover, *Kapalabhati* stimulates the endocrine system, harmonizing the secretion of key hormones such as adrenaline, noradrenaline, and insulin. This leads to improved metabolic efficiency and better regulation of blood pressure. By mitigating oxidative stress, it activates antioxidant enzymes and supports cellular repair and regeneration. Empirical evidence substantiates that this offers a comprehensive approach to physical, psychological, and emotional well-being, establishing it as a scientifically validated and effective method for holistic health optimization.

## 1. INTRODUCTION

*Kapalabhati* is an ancient and highly effective yogic breathing technique, celebrated not only as a pathway to spiritual advancement but also as a catalyst for biochemical, physiological, and pathological enhancements.[1] Derived from the Sanskrit terms "*kapal*," meaning skull or brain, and "*bhati*," meaning light or clarity, it symbolizes the promotion of mental lucidity and sharpness.[2] Through rapid respiratory movements, this practice augments oxygen delivery, fostering detoxification, and energy homeostasis.[3]

*Kapalabhati* maintains neurotransmitter balance, particularly dopamine and serotonin, thereby supporting mental clarity and emotional stability.[4] Furthermore, it harmonizes hormonal secretions such as adrenaline, noradrenaline, and insulin, promoting endocrine equilibrium.[5] Scientifically, this mitigates oxidative stress by activating antioxidant enzymes[6] and plays a crucial role in inflammation control.[7] By enhancing blood circulation,[8] it nourishes organs and Stissues effectively.[9]

*Corresponding Author:*
Sheelendra Kushwah,
Research scholar (yoga), Department of Kayachikitsa, Faculty of Ayurveda, IMS, Banaras Hindu Universty, Varanasi, Uttar Pradesh, India.
Email: sheelendrakushwah39@gmail.com

With its profound biochemical and physiological impacts, *Kapalabhati* has been scientifically validated as a tool for optimizing bodily and cognitive functions.[10] It not only improves physical health but also fosters robust mental and emotional well-being.[11]

## 2. BIOCHEMICAL PROCESSES FACILITATED BY KAPALABHATI

### 2.1. Fat and Glucose Oxidation

*Kapalabhati* stimulates a cascade of biochemical processes within the body, facilitating the conversion of fats and glucose into usable energy.[12] The metabolism of fats begins with lipolysis, where triglycerides stored in adipose tissues are hydrolyzed by lipase enzymes into glycerol and free fatty acids:[13]

Triglycerides Lipase. Glycerol + 3Fatty Acids

Free fatty acids are transported to the mitochondria, where they undergo beta-oxidation, a process that converts these fatty acids into acetyl-CoA:[14]

Fatty Acid+CoA Beta-Oxidation. Acetyl-CoA

Acetyl-CoA then enters the citric acid cycle (Krebs cycle), where it reacts with oxygen to produce carbon dioxide ($CO_2$), water ($H_2O$), and energy in the form of ATP:

$$\text{Acetyl-CoA} + O_2 \rightarrow CO_2 + H_2O + \text{ATP}$$

Simultaneously, glucose metabolism begins with glycolysis, where one molecule of glucose is broken down into pyruvate, producing ATP and NADH in the process:[15]

$$\text{Glucose} + 2\text{ATP} \rightarrow 2\text{Pyruvate} + 4\text{ATP} + 2\text{NADH}$$

Pyruvate is transported into the mitochondria, where it is converted into acetyl-CoA and subsequently enters the citric acid cycle under aerobic conditions. Finally, NADH and $FADH_2$ generated during these cycles transfer electrons to the electron transport chain, where ATP synthesis is maximized:[16]

$$NADH/FADH_2 + O_2 \rightarrow ATP + H_2O$$

The rapid and dynamic breathing pattern of *Kapalabhati* significantly increases oxygen saturation in the blood, accelerating mitochondrial processes. This boosts the metabolic rate by converting fats and glucose into energy. From a biochemical perspective, this process aids in maintaining energy homeostasis and is particularly effective in managing conditions such as obesity, diabetes, and metabolic syndrome.[17,18]

### 2.2. Antioxidant Activation

*Kapalabhati* an intensive breathing technique, enhances oxygen flow within the body, thereby stimulating the activity of key antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GPx).[19] These enzymes play a crucial role in neutralizing free radicals and mitigating oxidative stress. During Kapalabhati, the increased oxygen supply to cells activates SOD, which catalyzes the conversion of superoxide ions ($O_2^-$) into hydrogen peroxide ($H_2O_2$) and molecular oxygen ($O_2$). Subsequently, GPx reduces hydrogen peroxide into $H_2O$ and oxidized substrates, effectively diminishing the impact of free radicals.[3]

This biochemical process not only prevents cellular damage but also slows down aging and reduces oxidative stress in the body. Studies by Sharma *et al*. have corroborated the upregulation of SOD and GPx activity through *Kapalabhati.* These findings underscore its efficacy in minimizing free radical-induced damage, promoting detoxification, and supporting overall health.[12,20]

### 2.3. Neurotransmitter Release

*Kapalabhati*, an intense and dynamic breathing technique, significantly enhances the release of critical neurotransmitters such as serotonin, dopamine, and noradrenaline in the brain.[4] This practice activates both the sympathetic and parasympathetic nervous systems, stimulating the hypothalamus to elevate neurotransmitter levels. The increased oxygen supply during rapid breathing excites neuronal activity, leading to:

- Serotonin: Enhances mood and emotional well-being
- Dopamine: Boosts motivation and the sensation of pleasure
- Noradrenaline: Improves stress response and focus.[4]

In addition, *Kapalabhati* modulates the stress hormone cortisol, effectively reducing anxiety and depression. It enhances mental clarity and improves focus.[5] A study by Begum demonstrated its efficacy in alleviating psychological stress and mood disorders. Similarly, research by Deepeshwar *et al*. highlighted its role in promoting neurotransmitter release. Furthermore, Angiras emphasized the capacity to regulate neurotransmitter activity, aiding in the management of mental disorders.[5,21]

### 2.4. Hormonal Balance

*Kapalabhati* is a highly effective technique for maintaining hormonal balance, as it activates the endocrine system.[22] This practice stimulates the hypothalamus and pituitary gland, which in turn regulate the adrenal glands to secrete adrenaline and noradrenaline.[23] These hormones play a pivotal role in managing stress responses, enhancing energy production, and accelerating metabolic activities.[10]

In addition, *Kapalabhati* activates the pancreas to increase insulin secretion, aiding in blood sugar regulation and contributing to the management of diabetes.[24] It also stimulates the thyroid gland, promoting the release of thyroxine, a hormone essential for metabolic rate regulation.[25] The increased oxygen supply during rapid breathing enhances mitochondrial energy production, thereby improving cellular functionality.[26]

Studies have further validated that *Kapalabhati* improves insulin sensitivity and regulates stress hormones such as cortisol, thereby restoring hormonal equilibrium.[12] This not only aids in blood sugar control but also enhances overall health by improving metabolism and fostering endocrine system efficiency.[21]

### 2.5. Elimination of Metabolic Byproducts

*Kapalabhati*, an intense and dynamic breathing technique, plays a crucial role in expelling metabolic byproducts, particularly $CO_2$ and other toxins, from the body.[27] During this practice, oxygen flow to the lungs intensifies, enhancing oxygen delivery to cells. Concurrently, the respiratory process efficiently expels excess carbon dioxide and waste materials.[28] This mechanism accelerates cellular respiration in mitochondria, thereby boosting energy production and maintaining cellular health.[29]

The rapid breathing pattern in *Kapalabhati* improves blood circulation, facilitating the swift removal of metabolic byproducts. In addition, it optimizes oxygen-carbon dioxide exchange at the cellular level.[30] Research indicates that regular practice of *Kapalabhati* aids in detoxification and enhances the functional efficiency of internal organs.[27]

### 2.6. Anti-inflammatory Effect

*Kapalabhati*, a dynamic breathing technique, is instrumental in reducing inflammation within the body.[31] The enhanced oxygen supply during this practice lowers the levels of pro-inflammatory proteins such as C-reactive protein and cytokines like interleukin-6, while simultaneously increasing the production of anti-inflammatory cytokines like interleukin-10. This dual effect helps regulate inflammation and oxidative stress.[32]

Additionally, *Kapalabhati* improves mitochondrial efficiency and neutralizes free radicals, thereby promoting cellular health.[33] Studies have shown that this provides relief in conditions such as arthritis and other inflammatory disorders by modulating stress hormones such as cortisol and alleviating joint pain. Research by Thapa *et al*. substantiates that *Kapalabhati* stimulates anti-inflammatory processes, thereby enhancing the body's functional efficiency.[6,7]

### 2.7. Brain Oxygenation

*Kapalabhati*, a dynamic breathing technique, significantly enhances oxygen delivery to the brain, thereby improving its functions. The rapid and deep breathing involved in this practice increases oxygen flow to the lungs, elevating blood oxygen levels.[34] This oxygen is transported to brain cells, boosting neuronal activity and accelerating

blood flow in critical regions such as the prefrontal cortex. This leads to enhanced memory, focus, and cognitive performance.[11]

Additionally, *Kapalabhati* helps balance neurotransmitters such as dopamine and serotonin, which reduce stress and promote mental clarity.[8] Studies shows that this practice improves cerebral blood flow and neurochemical equilibrium, thereby supporting mental health and cognitive capabilities.[10,35]

### 2.8. Protein Synthesis

*Kapalabhati*, through its intense respiratory mechanism, enhances protein synthesis within the body. The increased oxygen flow during this practice activates cellular metabolism and improves mitochondrial efficiency.[36] This process enhances ribosomal efficiency, accelerating the conversion of amino acids into proteins. Regular practice of *Kapalabhati* stimulates metabolic enzymes such as mechanistic target of rapamycin, which play a pivotal role in protein synthesis and tissue regeneration.[37]

Furthermore, it reduces oxidative stress, promoting cellular repair and recovery.[12] Studies, including those by Bal and Arumugam *et al*., have validated that *Kapalabhati* not only boosts metabolic rates but also facilitates muscle growth and improves cellular health.[9,38,39]

## 3. PHYSIOLOGICAL EFFECTS OF *KAPALABHATI*

### 3.1. Lung Capacity

*Kapalabhati*, a vital yogic breathing technique, significantly enhances lung capacity and purifies the respiratory system. Its positive impact on lung function has been substantiated by numerous studies. In 2024, Tomar and Verma investigated the effects of *Kapalabhati* on adults recovering from COVID-19 and observed improved lung capacity and respiratory efficiency.[40] Similarly, Singh and Sharma studied its impact on football players, reporting enhanced ventilatory function and airflow dynamics. In the same year, Sharma found a substantial increase in vital capacity among physical education students after seven weeks of *Kapalabhati* practice.[41]

In 2016, Sachan *et al*. measured the effects of *Kapalabhati* and Anulom-Vilom on high school students, noting improvements in lung capacity and concentration levels.[42] Panwar *et al*. highlighted that *Kapalabhati* enhanced blood flow in the upper lungs and improved various respiratory parameters.[43] Further, Malhotra *et al*. identified its role in promoting heart rate variability and balancing the autonomic nervous system, thereby fortifying the respiratory system while enhancing physical energy and mental tranquility.[44] Kumar explored the combined effects of *Kapalabhati* and Nadi Shodhana on lung strength and ventilation efficiency, reporting significant improvements in airflow dynamics.[45]

### 3.2. Blood Circulation and Oxygenation

Numerous studies have highlighted the profound impact of *Kapalabhati* on physical and mental health through improved respiratory function. Malhotra *et al*. identified *Kapalabhati* as a practice that enhances heart rate variability and cerebral activity, leading to improved blood circulation.[34] Beniwal and Chaudhary evaluated its effects on school children, reporting significant improvements in lung function, oxygen levels, and blood pressure regulation.[46]

In 2021, Vaid and Verma demonstrated the efficacy in supplying oxygen-rich blood to the brain and body, thereby enhancing both mental and physical health.[27] Tyagi and Cohen noted that *Kapalabhati* optimizes oxygen consumption, boosting physical endurance.[47] Nivethitha *et al*. observed that it improves blood flow to the brain and lungs while reducing stress levels.[48] Gusain found it effective in enhancing blood circulation and oxygen delivery to tissues.[49] Similarly, Gokhale *et al*. highlighted its ability to increase blood pressure regulation and oxygen saturation.[50]

These findings collectively affirm that *Kapalabhati* effectively promotes smooth blood circulation and elevates oxygen levels in the body, contributing to enhanced overall vitality and resilience.

### 3.3. Digestive System

*Kapalabhati* has a profound positive impact on the digestive system, as evidenced by various studies. Gusain found that the repetitive practice of *Kapalabhati* enhances blood circulation to the stomach and intestines, improving digestive efficiency and alleviating stress-induced digestive disorders.[49] Yadav and Pathak highlighted its role in boosting digestive strength and reducing acidity.[51]

*Kapalabhati* effectively cleanses the stomach of toxins and regulates hyperacidity.[51] Similarly, digestive organs and enhances internal functionality.[52] Nathani *et al*. emphasized its ability to tone digestive organs and improve overall digestive capacity.[53] Furthermore, Arumugam explored the combined effects of *Kapalabhati* and Jal Neti, finding them effective in mitigating digestive disorders and enhancing digestive system efficiency.[11]

These findings collectively establish that *Kapalabhati* stimulates abdominal muscles, increases blood flow to digestive organs, and significantly improves overall digestive health.

## 4. CONCLUSION

*Kapalabhati*, an ancient yogic breathing technique, has proven to be a scientifically validated practice for enhancing holistic health. By employing rapid breathing cycles, it effectively improves lung capacity, optimizes blood circulation and oxygenation, and activates fat and glucose oxidation. Consequently, it boosts mitochondrial processes and metabolic rates, contributing to enhanced energy production.

From a biochemical perspective, *Kapalabhati* promotes protein synthesis and cellular regeneration. It activates antioxidant enzymes such as SOD and GPx, reducing oxidative stress and strengthening cellular health. Additionally, it regulates the secretion of key hormones such as adrenaline, noradrenaline, and insulin, thereby maintaining hormonal equilibrium and aiding in the management of metabolism and blood pressure.

The effects of *Kapalabhati* on mental and emotional health are particularly noteworthy. By elevating levels of neurotransmitters such as dopamine, serotonin, and noradrenaline, it enhances mental clarity, focus, and memory. Moreover, it alleviates stress and depression, fostering mental balance and emotional stability.

Thus, *Kapalabhati* stands as an effective and scientifically substantiated technique for addressing health challenges associated with modern lifestyles. Its practice not only aids in maintaining health but also serves as a powerful tool for its enhancement, making it an indispensable component of a comprehensive wellness routine.

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All the authors contributed equally to the design and execution of the article.

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## 8. ETHICAL APPROVALS

This study does not require ethical approval as it is a review study.

## 9. CONFLICTS OF INTEREST

Nil.

## 10. DATA AVAILABILITY

This is an original manuscript, and all data are available for review purposes only from the principal investigators.

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