Original Article

Indian Journal of Ancient Medicine and Yoga
Volume 17 Number 2, April - June 2024
DOI: https://dx.doi.org/10.21088/ijamy.0974.6986.17224.2

Effect of Kapalabhati Pranayama (High Frequency Yoga Breathing) on Psychophysiological Variables: A PubMed Based Review

Dipak Chetry[1], Archana Chhetri[2], Ananya Gupta[3]

How to cite this article:
Dipak Chetry, Archana Chhetri, Ananya Gupta. Effect of Kapalabhati Pranayama (High Frequency Yoga Breathing) on Psychophysiological Variables: A PubMed Based Review. Ind J Anct Med Yoga. 2024;17(2):79–86.

Abstract

Kapalabhati pranayama is one of the most famous, frequently practiced and researched *pranayama* in yoga. Several studies have been conducted to determine whether *kapalabhati pranayama* has any potential health benefits. There were no reviews available that collected and summarized those experimental studies on potential health benefits. This PubMed based review was designed to examine all currently available experimental research on *kapalabhati pranayama* and psychophysiological variables. In the final review for qualitative synthesis, 22 experimental research – including one single arm clinical trial, twenty clinical controlled trials and one randomized control trial between 1991 and 2023 were included based on PubMed search conducted in February 2024. The findings showed that *kapalabhati pranayama* was found to be altered in cerebral activity, heart rate variability, attention, and anxiety. This *pranayama* has the beneficial effects of improving attention and reducing anxiety. This review of the literature looked at every experimental investigation on psychophysiological variables conducted on *kapalabhati pranayama*. To conduct more in-depth experiments on *kapalabhati pranayama* in the future, researchers can use the information found to identify gaps in the current literature.

Keywords: *Kapalbhati pranayama*; Skull shining breath; Yogic breathing; Yoga breathing; Breathing exercise.

INTRODUCTION

Yoga, which has been shown to have many beneficial effects on human physiology, is primarily known for its *pranayama*.[1-3] One such popular, frequently practiced and well studied pranayama in yoga is *kapalabhati pranayama*. The practice of *kapalabhati pranayama*, which is recommended by traditional yoga sources and said to reduce *kaphadoshas* (In Ayurveda, diseases resulting from an imbalance of water elements are referred to as *kaphadoshas*), involves inhaling and exhaling as rapid as the bellows of a blacksmith.[4]

Many experiments have been conducted to discover the potential health benefits of *kapalabhati pranayama*. Reviews that compiled those experimental investigations for *kapalabhati pranayama* were not yet available. With the intention of examining all currently available experimental

Author Affiliation: [1,3]Ph.D Scholar, [2]Post Graduate Student, Department of Yoga Science, University of Patanjali, Patanjali Yogpeeth, Haridwar 249405, Uttarakhand, India.

Corresponding Author: Dipak Chetry, Ph.D. Scholar, Department of Yoga Science, University of Patanjali, Patanjali Yogpeeth, Haridwar 249405, Uttarakhand, India.

E-mail: dipakchetry4u@gmail.com

Received on: 04.03.2024 **Accepted on:** 18.05.2024

research on the effects of *kapalabhati pranayama* on psychophysiological variables, a preliminary PubMed based review was planned.

METHODS

PubMed served as the basis for our literature review. The search strategy "keywords in title, abstract" technique was used to search PubMed in February 2024. Terms were searched that relate to or describe the *kapalabhati pranayama* practice (such as *kapalbhati, kapalabhati*, skull shining breath, and (High Frequency Yoga Breathing)). The electronic search strategy for PubMed was "(*kapalbhati* [Title/Abstract]) OR (*kapalabhati* [Title/Abstract]) OR (skull shining breath [Title/Abstract]) OR ((High Frequency Yoga Breathing) [Title/Abstract])".

For a study to be selected, it must meet the following eligibility requirements: ***(1) Type of study:*** All experimental trials were considered eligible, including single-arm clinical trials, controlled clinical trials and randomized control trials. However, review papers, case studies, research protocols and conference abstracts were not included. ***(2) Types of interventions:*** Trials examining the individual impact of the practice of *kapalabhati pranayama* were included. Trials that did not use *kapalabhati pranayamaas* an intervention or that combined it with other practices were excluded. ***(3) Types of participants:*** Trials on human subjects of any age group, whether healthy or sick, were included. ***(4) Types of outcomes:*** Trials assessing any psychophysiological outcome were included. Trials without any connection to psychophysiological outcomes were excluded.

Essential data points from each included trial were extracted and condensed. Information about study design, participant characteristics (sample size and demographic information, such as age and gender), interventions, assessments and outcomes, and researchers' country of affiliation and year of publication were taken from all included studies. The extracted data was used in areas where it was needed.

RESULTS

Using the search terms in PubMed, 54 results were identified; After eliminating duplicate records, 48 studies were screened and evaluated to read the full text. For the following reasons, 26 studies were excluded: (i) eight studies were on *kapalabhati pranayama* combined with other practices,[5-12] (ii) eight studies were review papers or not related to *kapalabhati pranayama*,[13-20] (iii) seven studies assessed different outcome variables,[21-27] (iv) two were case studies,[28,29] and (v) a corrigendum.[30] Twenty-two studies were included in the final review for qualitative synthesis.[32–52] The detailed information about each included research trial is provided in Table 1.

Table 1: Summary of included eligible studies on *kapalabhati pranayama* and psychophysiological variables:

Citation	Participants; Study design; and conducted country	Duration of kapalabhati	Variables measured	Results
Kala, 2023[31]	38 Healthy male participants (mean age 24.1 years); Controlled clinical trial (pre-post design); India.	15 minutes	Heart rate variability, attention	An increase in P300 peak amplitude at Pz was recorded after the practice and no change in Heart rate variability compared to baseline.
Sharma, 2022[32]	38 Healthy male participants (mean age 24.1 years); Controlled clinical trial (pre-post design); India.	15 minutes	Attention, anxiety	Total attempted scoreand net attempted score increased as well as state anxiety score decreased after the practice compared to baseline.
Kumar, 2022[33]	16 Healthy male participants (mean age 23.7 years); Controlled clinical trial (pre-during-post design); India.	1 minute	Cerebral hemodynamics	End diastolic velocity and mean flow velocity decreased with increased pulsatility index in the middle cerebral artery during the practice compared to baseline.
Malhotra, 2022[34]	20 Healthy participants of both gender (mean age 44 years); Single arm clinical trial (pre-during-post design); India.	5 minutes	EEG brain waves, heart rate variability	SDNN, PNN50, RMSSD, HF decreased, and LF power (nu%) and LF/HF ratio increased during the practice. There was no significant changes in the EEG brain waves.

Table cont...

Nivethitha, 2021[35]	20 Healthy participants of both gender (mean age 23.4 years); Controlled clinical trial (pre-during-post design); India.	5 minutes	Blood pressure, cardiac output	Systolic blood pressure, diastolic blood pressure, mean blood pressure, heart rate, and cardiac output increased with a decrease in PI during the practice.
Telles, 2019[36]	61 Healthy participants of both gender (mean age 11.2 years); Controlled clinical trial (pre-post design); India.	15 minutes	Attention, anxiety	Total attempts and net scores increased as well as anxiety scores decreased after practice.
Gupta, 2019[37]	15 Healthy participants of both gender (mean age 20 years); Controlled clinical trial (pre-post design); India.	15 minutes	Spatial memory	There was no significant changes observed in spatial memory.
Nivethitha, 2018[38]	18 Healthy participants of both gender (mean age 23.8 years); Controlled clinical trial (pre-during-post design); India.	1 minute	Cerebral hemodynamics	End diastolic velocity and mean flow velocity decreased with increased pulsatility index in the middle cerebral artery during the practice compared to baseline.
Telles, 2016[39]	40 Healthy male participants (mean age 26.4 years); Controlled clinical trial (pre-during-post design); India.	15 minutes	Cerebral hemodynamics	Decreased in oxy-hemoglobin during and after practice compared to baseline.
Bhargav, 2014[40]	36 Participants of both gender (18 schizophrenia patients, and 18 healthy participants) (mean age 28.9 years); Controlled clinical trial (pre-during-post design); India.	1 minute	Cerebral hemodynamics	Bilateral oxy-hemoglobin and total-hemoglobin increased in healthy participants during the practice compared to baseline. On the other hand, a decrease in deoxy-hemoglobin was observed in the right pre-frontal cortex in schizophrenia patients.
Telles, 2014[41]	50 Healthy male participants (mean age 26.9 years); Controlled clinical trial (pre-post design); India.	15 minutes	Motor speed	The speed of both finger tapping and arm tapping increased after practice. Hand grip strength also increased after the practice.
Pradhan, 2013[42]	36 Healthy participants of both gender (mean age 25.7 years); Controlled clinical trial (pre-post design); India.	1 minute, and 5 minutes	Attention	Increase in errors in the digit-letter substitution task (DLST) after practice. In contrast, scores on the six-letter cancellation task (SLCT) remained completely unchanged.
Telles, 2012[43]	96 OPD patients of both gender (mean age 39.3 years); Controlled clinical trial (pre-post design); India.	10 minutes	Attention, motor skill	Finger dexterity increased and errors decreased after practice compared to baseline. A reduction in the time taken to complete shape and size discrimination tests was also observed.
Telles, 2012[44]	12 Healthy male participants (mean age 27.2 years); Controlled clinical trial (pre-during-post design); India.	15 minutes	Cerebral hemodynamics	Decreased in oxy-hemoglobin and increased in deoxy-hemoglobin during and after the practice compared to baseline.
Telles, 2011[45]	38 Healthy male participants (mean age 23.3 years); Controlled clinical trial (pre-during-post design); India.	15 minutes	Heart rate variability	Reduction in NN50, PNN50 and mean RR interval during and after the practice compared to baseline.
Telles, 2011[46]	30 Healthy male participants (mean age 26.9 years); Controlled clinical trial (pre-post design); India.	15 minutes	Optical Illusion	The degree of optical illusion decreased after practice.
Joshi, 2009[47]	30 Healthy male participants (mean age 26 years); Controlled clinical trial (pre-post design); India.	1 minute	Attention	P300 peak latency decreased after practice.

Table cont...

Telles, 2008[48]	110 Healthy participants of both gender (46 medical students, 48 middle-aged adults, and 16 older adults) (mean age of medical students, middle-aged adults, and older adults was 20.1, 35, and over 60 years, respectively); Controlled clinical trial (pre-post design); India.	15 minutes	Attention	Total errors decreased in medical students, net scores increased in middle-aged and older adults after practice.
Raghuraj, 1998[49]	12 Healthy male participants (mean age 25.6 years); Controlled clinical trial (pre-post design); India.	1 minute	Heart rate variability	Increased in low frequency power and LF/HF ratio; whereas high frequency power decreased after practice compared to baseline.
StancÃ¡k, 1991[50]	17 Healthy participants of both gender (mean age not mentioned); Controlled clinical trial (pre-during-post design); Canada.	15 minutes	Heart rate variability, blood pressure	Increased in heart rate, systolic blood pressure, and diastolic blood pressure during practice. All frequency bands of R-R interval variability were reduced in kapalabhati practice.
StancÃ¡k, 1991[51]	11 Healthy participants of both gender (mean age not mentioned); Controlled clinical trial (pre-during-post design); Canada.	15 minutes	EEG brain waves	There was an increase in alpha activity during the initial 5 minutes of *kapalabhati* practice, with an increase in beta 1 activity during the first 10 minutes of *kapalabhati* practice in occipital and to a lesser extent in parietal regions; and theta activity was increased during the later stages of 15 minutes of *kapalabhati* practice mostly in the occipital region, compared to the baseline. Alpha and beta 1 activity decreased and theta activity was maintained on the level of the initial resting period after the practice.
StancÃ¡k, 1991[52]	24 Healthy participants of both gender (mean age 36.3 years); Controlled clinical trial (pre-during-post design); Canada.	15 minutes	Heart rate variability, blood pressure	Blood pressure increased during the practice. A 0.1 Hz rhythm was present in the R-R interval records.

Effect of kapalabhati pranayama on psychophysiological variables

The included researches showed the information on the effects of *kapalabhati pranayama* on EEG brain waves, cerebral hemodynamics, heart rate variability, attention, anxiety, finger tapping speed, shape and size discrimination, and optical illusion handling. Different durations of *kapalabhati pranayama* practice were associated with increases in alpha, beta 1 and theta activity.[51] There was less oxyhemoglobin and more deoxyhemoglobin during and after the practice of *kapalabhati pranayama*.[39,44] In the middle cerebral artery, end diastolic and mean flow velocities decreased with increased pulsatility index during *kapalabhati pranayama*.[33,38]

The heartrate variability results showed reduction in SDNN, PNN50, PNN50, mean RR interval, RMSSD, and HF; and increased in LF power and LF/HF ratio during and after the practice of *kapalabhati pranayama*.[35,45,49] There was also increased in cardiac output, systolic, diastolic and mean blood pressure during the practice.[35,50,52]

After practice, a decrease in total errors in attention tasks, an increase in total attempted score, and an increase in net attempted score in the six-letter cancellation task (SLCT) were observed. These results were confirmed by objective measurements of the P300, which showed a reduction in P300 peak latency and an increase in peak amplitude.[31,32,36,47,48] However, after practice, errors in the digit-letter substitution task (DLST) increased according to one study.[42] There was also decreased in state anxiety score following the practice of *kapalabhati pranayama*.[32,36]

The speed of tapping hands and fingers increased, finger dexterity increased and errors were reducedafter the practice.[41] It was also noted that the duration of time taken to complete shape and size discrimination tests was reduced.[43] The optical illusion was also reduced after the practice.[46]

Adverse events

No complaints or adverse events were observed in any of the included studies of *kapalabhati pranayama*. However, the emergency department received a report of pneumothorax caused by kapalbhati pranayama from a 29-year-old healthy woman in a case study.[29]

DISCUSSION

The overall results of the effect of *kapalabhati pranayama* on psychophysiological variables indicated that the practice affected brain wave activity, decreased cerebral blood flow, and decreased oxyhemoglobin in the cerebral cortex. In accordance with the heart rate variability findings, there was a decrease in parasympathetic activity and an increase in sympathetic activity during and after the practice of *kapalabhati pranayama*. Additionally, following *kapalabhati pranayama*, there was a reduction in anxiety and improvement in attention.

An increase in theta, alpha and beta 1 activity was found with different lengths of *kapalabhati pranayama* practice; On the other hand, decreased in the alpha and beta 1 and theta activity remained maintained after the practice.[51] These findings from *kapalabhati pranayama* suggest a relative increase in slow EEG frequencies and an increase in subjective relaxation after practice. A decrease in oxyhemoglobin and an increase in deoxyhemoglobin suggest that there was no frontal activation during and after *kapalabhati pranayama*.[39,44] In the middle cerebral artery, end diastolic and mean flow velocity, which decreased with increase in pulsatility index suggested decreased cerebrovascular blood flow and higher flow resistance during *kapalabhati pranayama*.[33,38]

The results of heart rate variability demonstrated an increase in LF power and LF/HF ratio and a decrease in SDNN, PNN50, HF, mean RR interval, RMSSD and PNN50 during and after the practice of *kapalabhati pranayama*.[35,45,49] The findings showed that parasympathetic modulation was reduced during and after *kapalabhati pranayama practice* by reducing vagal activity and increasing sympathetic activity.

After the practice of *kapalabhati pranayama*, anxiety levels decreased and attention levels increased.[31,32,36,47,48] These results imply that *kapalabhati pranayama*, improves selective attention for an auditory oddball task, increases attentional brain resources and reduces the time required for this task. Sustained attention was also found increased after this practice. The findings suggest that *kapalabhati pranayama* may be a simple, quick and effective technique to increase attention and reduce anxiety.

CONCLUSION

In conclusion, the overall findings showed that *kapalabhati pranayama* altered cerebral activity, heart rate variability, attention, and anxiety. This pranayama has the beneficial effects of improving attention and reducing anxiety. In this evaluation of the literature each experimental study on psychophysiological variables conducted on *kapalabhati pranayama* was examined. Researchers can identify gaps in the current literature and use the information to conduct more rigorous experiments on *kapalabhati pranayama* for future experiments.

LIMITATIONS

The quality of the included studies was not assessed, and the wide range of clinical trials included in this review may have influenced the findings. None of the included studies indicated that *kapaalbhati pranayama* had any long-term effects; Instead, the studies assessed the short-term effects (follow-up periods ranging from one minute to fifteen minutes). Most of the included studies used designs for clinically controlled trials, with RCTs making up a very small proportion of the investigations.

REFERENCES

1. Chetry D, Chhetri A, Rajak DK, Rathore V, Gupta A. Exploring the Health Benefits of Bhramari Pranayama (Humming Bee Breathing): A Comprehensive Literature Review. Indian Journal of Physiology and Pharmacology, 2024; 68(1), 1-15.doi: 10.25259/IJPP_325_2023
2. Chetry D, Chhetri A, Yadav K. Effects of Bhastrika Pranayama (Yoga Bellows-Type Breathing) on Pulmonary, Cardiovascular and Psychological Variables: A Systematic Review. Yoga Mimamsa, 2023; 55(1), 1-10. doi: 10.4103/ym.ym_9_23
3. Chetry D, Rawat P, Rajak D, Chhetri A. General features, types, techniques, benefits, safety and adverse effects related to Pranayamas

mentioned in traditional Hatha Yoga texts: A review on Pranayama chapters. Yoga Mimamsa, 2022; 54(2), 140-146. doi: 10.4103/ym.ym_56_22

4. Muktibodhananda S. Hatha Yoga Pradipika. Munger, Bihar, India: Yoga Publications Trust; 1998.
5. Dinesh T, Gaur G, Sharma V, Madanmohan T, Harichandra Kumar K, Bhavanani A. Comparative effect of 12 weeks of slow and fast pranayama training on pulmonary function in young, healthy volunteers: A randomized controlled trial. Int J Yoga. 2015 Jan;8(1):22-6. doi: 10.4103/0973-6131.146051. PMID: 25558130; PMCID: PMC4278131.
6. Sharma VK, M R, S V, Subramanian SK, Bhavanani AB, Madanmohan, Sahai A, Thangavel D. Effect of fast and slow pranayama practice on cognitive functions in healthy volunteers. J ClinDiagn Res. 2014 Jan;8(1):10-3. doi: 10.7860/JCDR/2014/7256.3668. Epub 2013 Nov 18. PMID: 24596711; PMCID: PMC3939514.
7. Thangavel D, Gaur GS, Sharma VK, Bhavanani AB, Rajajeyakumar M, Syam SA. Effect of slow and fast pranayama training on handgrip strength and endurance in healthy volunteers. J ClinDiagn Res. 2014 May;8(5):BC01-3. doi: 10.7860/JCDR/2014/7452.4390. Epub 2014 May 15. PMID: 24995168; PMCID: PMC4079989.
8. Sharma VK, Trakroo M, Subramaniam V, Rajajeyakumar M, Bhavanani AB, Sahai A. Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students. Int J Yoga. 2013 Jul;6(2):104-10. doi: 10.4103/0973-6131.113400. PMID: 23930028; PMCID: PMC3734635.
9. Gosewade NB, Shende VS, Kashalikar SJ. Effect of Various Eye Exercise Techniques along with Pranayama on Visual Reaction Time: A Case Control Study. J ClinDiagn Res. 2013 Sep;7(9):1870-3. doi: 10.7860/JCDR/2013/6324.3338. Epub 2013 Sep 10. PMID: 24179885; PMCID: PMC3809624.
10. Patil NJ, Nagaratna R, Garner C, Raghuram NV, Crisan R. Effect of integrated Yoga on neurogenic bladder dysfunction in patients with multiple sclerosis-A prospective observational case series. Complement Ther Med. 2012 Dec;20(6):424-30. doi: 10.1016/j.ctim.2012.08.003. Epub 2012 Oct 9. PMID: 23131373.
11. Morya AK, Shrivastava AK, Janti SS, Tejaswini A, Gupta R, Gurnani B, Venkatesh D, Prasad R. Effect of Asanas in Yoga on Intraocular Pressure of Practicing Healthy Individuals: a Prospective Observational Study. Maedica (Bucur). 2023 Jun;18(2):238-245. doi: 10.26574/maedica.2023.18.2.238. PMID: 37588839; PMCID: PMC10427079.
12. Bhargav H, Vidyasagar PD, Venugopal S, Arsappa R, Narasimha VL, Varshney P, Sharma P, A V, Venkatasubramanian G, Varambally S, Gangadhar BN, Murthy P. Development, Validation, and Feasibility Testing of a Yoga Module for Opioid Use Disorder. Adv Mind Body Med. 2021 Summer;35(3):20-30. PMID: 34237026.
13. Telles S, Vishwakarma B, Gupta RK, Balkrishna A. Changes in Shape and Size Discrimination and State Anxiety After Alternate-Nostril Yoga Breathing and Breath Awareness in One Session Each. Med SciMonit Basic Res. 2019 Apr 22;25:121-127. doi: 10.12659/MSMBR.914956. PMID: 31006767; PMCID: PMC6496972.
14. Puranik A, Kanthi M, Nayak AV. Wearable Device for Yogic Breathing with Real-Time Heart Rate and Posture Monitoring. J Med Signals Sens. 2021 Oct 20;11(4):253-261. doi: 10.4103/jmss.JMSS_54_20. PMID: 34820297; PMCID: PMC8588879.
15. Sharma H, Swetanshu, Singh P. Role of Yoga in Cardiovascular Diseases. Curr Probl Cardiol. 2024 Jan;49(1 Pt A):102032. doi: 10.1016/j.cpcardiol.2023.102032. Epub 2023 Aug 13. PMID: 37582455.
16. Ansari RM. Kapalabhati pranayama: An answer to modern day polycystic ovarian syndrome and coexisting metabolic syndrome? Int J Yoga. 2016 Jul-Dec;9(2):163-7. doi: 10.4103/0973-6131.183705. PMID: 27512324; PMCID: PMC4959327.
17. Chetry D, Telles S, Mahadevan J, Prasoon K, Gandharva K, Agrawal M, Balkrishna A. A Comparison of Practice Guidelines for Yoga Breathing from the Traditional Texts and PubMed-Indexed Research. Int J Yoga Therap. 2022 Jan 1;32(2022):Article 17. doi: 10.17761/2022-D-22-00024. PMID: 36669770.
18. Telles S, Sayal N, Nacht C, Chopra A, Patel K, Wnuk A, Dalvi P, Bhatia K, Miranpuri G, Anand A. Yoga: Can it be integrated with treatment of neuropathic pain? Ann Neurosci. 2019 Apr;26(2):82-91. doi: 10.5214/ans.0972.7531.260208. Epub 2019 Apr 1. PMID: 31975778; PMCID: PMC6894618.
19. Swathi PS, Raghavendra BR, Saoji AA. Health and therapeutic benefits of Shatkarma: A narrative review of scientific studies. J Ayurveda Integr Med. 2021 Jan-Mar;12(1):206-212. doi: 10.1016/j.jaim.2020.11.008. Epub 2021 Jan 13. PMID: 33454186; PMCID: PMC8039332.
20. Nivethitha L, Mooventhan A, Manjunath NK. Effects of Various Prāāyāma on Cardiovascular and Autonomic Variables. AncSci Life. 2016 Oct-Dec;36(2):72-77. doi: 10.4103/asl.ASL_178_16. PMID: 28446827; PMCID: PMC5382821.

21. Pandit UN, Pakhale H, Bellare B. Protective Role of Moolabandha While Practicing Bhastrika and Kapalabhati by Women Vulnerable to Bladder Dysfunction: A Preliminary Ultrasound Study. Int J Yoga. 2020 Jan-Apr;13(1):80-83. doi: 10.4103/ijoy.IJOY_38_18. PMID: 32030027; PMCID: PMC6937871.

22. Wooten SV, Cherup N, Mazzei N, Patel S, Mooney K, Rafiq A, Signorile JF. Yoga Breathing Techniques Have No Impact on Isokinetic and Isoinertial Power. J Strength Cond Res. 2020 Feb;34(2):430-439. doi: 10.1519/JSC.0000000000002771. PMID: 30142133.

23. Telles S, Singh N. (High Frequency Yoga Breathing) increases energy-expenditure from carbohydrates. Comment to: Assessment of sleep patterns, energy expenditure and circadian rhythms of skin temperature in patients with acute coronary syndrome Hadil Al Otair, Mustafa Al-shamiri, Mohammed Bahobail, Munir M. Sharif, Ahmed S. BaHammam Med SciMonit, 2011; 17(7): CR397-403. Med SciMonit. 2011 Sep;17(9):LE7-8. doi: 10.12659/msm.881916. PMID: 21873954.

24. Singh N, Telles S. (High Frequency Yoga Breathing) can increase alveolar dead space. Comment to: Gastroesophageal reflux disease and pulmonary function: a potential role of the dead space extension, DamirBonacin, DamirFabijanić, MislavRadić, ŽeljkoPuljiz, GoranaTrgo, Andre Bratanić, IzetHozo, JadrankaTocilj, Med SciMonit, 2012; 18(5): CR271-275. Med SciMonit. 2012 Jul;18(7):LE5-6; author reply LE6-7. doi: 10.12659/msm.883189. PMID: 22739742.

25. Telles S, Singh N, Balkrishna A. Metabolic and Ventilatory Changes During and After High-Frequency Yoga Breathing. Med SciMonit Basic Res. 2015 Aug 13;21:161-71. doi: 10.12659/MSMBR.894945. PMID: 26270968; PMCID: PMC4547545.

26. Desai BP, Gharote ML. Effect of Kapalabhati on blood urea, creatinine and tyrosine. Act Nerv Super (Praha). 1990 Jun;32(2):95-8. PMID: 2399804.

27. Raghavendra P, Shetty P, Shetty S, Manjunath NK, Saoji AA. Effect of high-frequency yoga breathing on pulmonary functions in patients with asthma: A randomized clinical trial. Ann Allergy Asthma Immunol. 2016 Nov;117(5):550-551. doi: 10.1016/j.anai.2016.08.009. Epub 2016 Sep 14. PMID: 27640077.

28. Kaswala D, Shah S, Mishra A, Patel H, Patel N, Sangwan P, Chodos A, Brelvi Z. Can yoga be used to treat gastroesophageal reflux disease? Int J Yoga. 2013 Jul;6(2):131-3. doi: 10.4103/0973-6131.113416. PMID: 23930033; PMCID: PMC3734640.

29. Johnson DB, Tierney MJ, Sadighi PJ. Kapalabhati pranayama: breath of fire or cause of pneumothorax? A case report. Chest. 2004 May;125(5):1951-2. doi: 10.1378/chest.125.5.1951. PMID: 15136413.

30. Bhargav H, Nagendra HR, Gangadhar BN, Nagarathna R. Corrigendum: frontal hemodynamic responses to (High Frequency Yoga Breathing) in schizophrenia: a functional near-infrared spectroscopy study. Front Psychiatry. 2014 May 20;5:55. doi: 10.3389/fpsyt.2014.00055. PMID: 24904438; PMCID: PMC4032994.

31. Kala N, Telles S, Sharma SK, Balkrishna A. P300 Following Four Voluntarily Regulated Yoga Breathing Practices and Breath Awareness. Clin EEG Neurosci. 2023 Mar; 54(2):117-129. doi: 10.1177/15500594221089369. Epub 2022 Mar 23. PMID: 35317637.

32. Sharma SK, Kala N, Telles S. Volitional Yoga Breathing Influences Attention and Anxiety: An Exploratory Randomized Crossover Study. Complement Med Res. 2022;29(2):120-126. English. doi: 10.1159/000519715. Epub 2021 Nov 16. PMID: 34784592.

33. Kumar A, Kala N, Telles S. Cerebrovascular dynamics associated with yoga breathing and breath awareness. International Journal of Yoga. 2022 Jan;15(1):19.

34. Malhotra V, Javed D, Wakode S, Bharshankar R, Soni N, Porter PK. Study of immediate neurological and autonomic changes during kapalbhati pranayama in yoga practitioners. J Family Med Prim Care. 2022 Feb;11(2):720-727. doi: 10.4103/jfmpc.jfmpc_1662_21. Epub 2022 Feb 16. PMID: 35360798; PMCID: PMC8963645.

35. Nivethitha L, Mooventhan A, Manjunath NK. Evaluation of Cardiovascular Functions during the Practice of Different Types of Yogic Breathing Techniques. Int J Yoga. 2021 May-Aug; 14(2):158-162. doi: 10.4103/ijoy.IJOY_61_20. Epub 2021 May 10. PMID: 34188389; PMCID: PMC8191218.

36. Telles S, Gupta RK, Gandharva K, Vishwakarma B, Kala N, Balkrishna A. Immediate Effect of a Yoga Breathing Practice on Attention and Anxiety in Pre-Teen Children. Children (Basel). 2019 Jul 22;6(7):84. doi: 10.3390/children6070084. PMID: 31336661; PMCID: PMC6678429.

37. Gupta RK, Agnihotri S, Telles S, Balkrishna A. Performance in a Corsi Block-tapping Task following High-frequency Yoga Breathing or Breath Awareness. Int J Yoga. 2019 Sep-Dec;12(3):247-251. doi: 10.4103/ijoy.IJOY_55_18. PMID: 31543634; PMCID: PMC6746049.

38. Nivethitha L, Mooventhan A, Manjunath NK, Bathala L, Sharma VK. Cerebrovascular Hemodynamics During the Practice of Bhramari Pranayama, Kapalbhati and Bahir-Kumbhaka: An Exploratory Study. ApplPsychophysiol Biofeedback. 2018 Mar;43(1):87-92. doi: 10.1007/s10484-017-9387-8. PMID: 29188396.

39. Telles S, Gupta RK, Singh N, Balkrishna A. A Functional Near-Infrared Spectroscopy Study of High-Frequency Yoga Breathing Compared to Breath Awareness. Med SciMonit Basic Res. 2016 Jun 28;22:58-66. doi: 10.12659/msmbr.899516. PMID: 27351626; PMCID: PMC4946388.

40. Bhargav H, Nagendra HR, Gangadhar BN, Nagarathna R. Frontal hemodynamic responses to (High Frequency Yoga Breathing) in schizophrenia: a functional near-infrared spectroscopy study. Front Psychiatry. 2014 Mar 24;5:29. doi: 10.3389/fpsyt.2014.00029. PMID: 24715879; PMCID: PMC3970016.

41. Telles S, Sharma SK, Yadav A, Singh N, Balkrishna A. Immediate changes in muscle strength and motor speed following yoga breathing. Indian J PhysiolPharmacol. 2014 Jan-Mar;58(1):22-9. PMID: 25464673.

42. Pradhan B. Effect of kapalabhati on performance of six-letter cancellation and digit letter substitution task in adults. Int J Yoga. 2013 Jul;6(2):128-30. doi: 10.4103/0973-6131.113415. PMID: 23930032; PMCID: PMC3734639.

43. Telles S, Singh N, Balkrishna A. Finger dexterity and visual discrimination following two yoga breathing practices. Int J Yoga. 2012 Jan;5(1):37-41. doi: 10.4103/0973-6131.91710. PMID: 22346064; PMCID: PMC3276931.

44. Telles S, Singh N, Gupta RK, Balkrishna A. Optical topography recording of cortical activity during (High Frequency Yoga Breathing) and breath awareness. Comment to: Non-invasive assessment of hemispheric language dominance by optical topography during a brief passive listening test: a pilot study. Stefano Bembich, Sergio Demarini, Andrea Clarici, Stefano Massaccesi, Domenico Grasso. Med SciMonit 2011; 17(12): CR692-697. Med SciMonit. 2012 Jan;18(1):LE3-4. doi: 10.12659/msm.882189. PMID: 22207124.

45. Telles S, Singh N, Balkrishna A. Heart rate variability changes during (High Frequency Yoga Breathing) and breath awareness. Biopsychosoc Med. 2011 Apr 13;5:4. doi: 10.1186/1751-0759-5-4. PMID: 21486495; PMCID: PMC3088536.

46. Telles S, Maharana K, Balrana B, Balkrishna A. Effects of high-frequency yoga breathing called kapalabhati compared with breath awareness on the degree of optical illusion perceived. Percept Mot Skills. 2011 Jun;112(3):981-90. doi: 10.2466/02.20.22.PMS.112.3.981-990. PMID: 21853784.

47. Joshi M, Telles S. A nonrandomized non-naive comparative study of the effects of kapalabhati and breath awareness on event-related potentials in trained yoga practitioners. J Altern Complement Med. 2009 Mar; 15(3):281-5. doi: 10.1089/acm.2008.0250. PMID: 19243275.

48. Telles S, Raghuraj P, Arankalle D, Naveen KV. Immediate effect of high-frequency yoga breathing on attention. Indian J Med Sci. 2008 Jan; 62(1):20-2. PMID: 18239268.

49. Raghuraj P, Ramakrishnan AG, Nagendra HR, Telles S. Effect of two selected yogic breathing techniques of heart rate variability. Indian J PhysiolPharmacol. 1998 Oct; 42(4):467-72. PMID: 10874345.

50. Stancák A Jr, Kuna M, Srinivasan, Vishnudevananda S, Dostálek C. Kapalabhati--yogic cleansing exercise. I. Cardiovascular and respiratory changes. Homeost Health Dis. 1991; 33(3):126-34. PMID: 1818666.

51. Stancák A Jr, Kuna M, Srinivasan, Dostálek C, Vishnudevananda S. Kapalabhati--yogic cleansing exercise. II. EEG topography analysis. Homeost Health Dis. 1991; 33(4):182-9. PMID: 1818698.

52. Stancák A Jr, Kuna M, Novák P, Srinivasan MA, Dostálek C, Vishnudevananda S. Observations on respiratory and cardiovascular rhythmicities during yogic high-frequency respiration. Physiol Res. 1991;40(3):345-54. PMID: 1751482.