

“Pilot Investigation of the Effects of Yogic Vyāyāma on Pulmonary Function and Lumbar Flexibility in Defense Personnel”

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HOW TO CITE: ABSTRACT:

Rama Mishra, Nidheesh Kumar
Yadav, Satyaprakash Pathak
(2026).

Pilot Investigation of the Effects of
Yogic Vyāyāma on Pulmonary
Function and Lumbar Flexibility in
Defense Personnel
International Journal of Special
Education, 41(22s), 279-294

Background: Defense personnel are required to maintain high levels of physical fitness, respiratory efficiency, mobility, and functional readiness to meet the demands of military training and operational activities. Conventional physical training is an essential component of military preparedness; however, complementary practices that can improve physiological efficiency and flexibility with relatively low equipment requirements may have additional value. Yogic Vyāyāma, incorporating systematic physical movements, stretching, coordinated breathing, and selected yogic practices, may provide a practical approach for improving respiratory and musculoskeletal functions.

Objective: The present pilot investigation examined the effects of an 8-week Yogic Vyāyāma intervention on pulmonary function and lumbar flexibility among defense personnel.

Methods: A pilot randomized controlled design was adopted. One hundred defense personnel were allocated into an experimental group ($n = 50$) and a control group ($n = 50$). The experimental group participated in a structured 8-week Yogic Vyāyāma program, while the control group continued their routine physical activities without additional yogic training. Pulmonary function was assessed using Peak Expiratory Flow Rate (PEFR), while lumbar flexibility was assessed using the Sit-and-Reach test. Pre- and post-intervention measurements were obtained. Within-group changes were examined using paired statistical analysis, while between-group differences were assessed using appropriate independent-group analysis.

Results: The experimental group demonstrated an increase in PEFR from 470.36 ± 38.24 L/min at baseline to 526.14 ± 36.51 L/min after the intervention. The control group showed comparatively minimal change, from 472.08 ± 37.46 L/min to 475.86 ± 37.93 L/min. Lumbar flexibility in the experimental group increased from 23.82 ± 3.84 cm to 29.48 ± 3.42 cm, whereas the control group changed from 24.10 ± 3.71 cm to 24.58 ± 3.60 cm. Within-group changes in the experimental group were statistically significant ($p < 0.001$), with large standardized effects for both PEFR ($d = 2.12$) and

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flexibility ($d = 1.80$).

Conclusion: The findings of this pilot investigation suggest that an 8-week structured Yogic Vyāyāma program may improve pulmonary expiratory performance and lumbar flexibility among defense personnel. The results provide preliminary support for incorporating appropriately designed yogic practices as a complementary component of physical-conditioning programs for defense personnel. Larger randomized controlled studies with comprehensive pulmonary-function testing, longer follow-up, and objective measures of physical and operational readiness are warranted.

Keywords: Yogic Vyāyāma; Yoga; Defense Personnel; Pulmonary Function; Peak Expiratory Flow Rate; Lumbar Flexibility; Military Fitness; Pilot Study.

INTRODUCTION

1. Physical Readiness and Physiological Demands in Defense Personnel

Defense personnel operate in occupational environments characterized by substantial physical demands, including load carriage, prolonged movement, manual material handling, casualty evacuation, and activities requiring repeated changes in movement intensity. These occupational tasks place considerable demands on aerobic capacity, muscular strength and endurance, neuromuscular fitness, and the ability to sustain physical performance under fatigue. A comprehensive review of essential military tasks reported that successful load carriage performance is associated with aerobic and neuromuscular fitness, particularly maximal strength and maximal oxygen uptake, whereas manual material handling and casualty evacuation require combinations of strength, muscular endurance, aerobic fitness, and anaerobic capacity (Vaara et al., 2022).

Load carriage represents an important component of military activity because soldiers frequently carry weapons, protective equipment, communication devices, and other operational loads. Military load carriage can increase physiological cost and alter normal gait and movement mechanics. A systematic review by Walsh and Low (2021) found that carrying military loads consistently increased trunk, hip, and knee flexion and increased lower-limb and trunk muscle activation. Such biomechanical alterations may contribute to fatigue and musculoskeletal stress and may influence the efficiency and safety of military movement.

The physiological and biomechanical consequences of military load carriage indicate that physical readiness should not be considered solely in terms of muscular strength. Rather, military performance depends on the interaction of aerobic capacity, muscular fitness, movement efficiency, and the ability to tolerate repeated occupational stress. Reviews of soldier load carriage have demonstrated that external loads increase energy expenditure and physiological strain and can affect posture, gait, spinal loading, and mobility. These findings highlight the importance of maintaining adequate physical capacity and functional movement characteristics in military populations.

Among the physiological components relevant to military readiness, **pulmonary function is of particular interest** because effective ventilation and respiratory muscle function contribute to the ability to meet increased metabolic demands during physical activity. Evidence from systematic reviews indicates that yogic interventions incorporating breathing practices may positively influence several pulmonary parameters. Bhagel and Saha (2021), in a systematic literature review and meta-analysis involving healthy individuals, reported improvements in parameters including forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, peak expiratory flow rate (PEFR), maximum voluntary ventilation, and respiratory muscle strength following yogic interventions.

Population-specific evidence is also emerging from defense personnel. Singh et al. (2025) investigated a 20-day yogic training programme among 22 defense personnel deployed at high altitude. The 50-minute

sessions incorporated yogic practices involving postures with breath awareness, breathing techniques, and mindfulness. Significant pre–post improvements were reported in expiratory flow rate, breath-holding time, oxygen saturation, and heart rate. Although the findings are relevant to military populations, the single-group pre–post design and small sample size warrant cautious interpretation and emphasize the need for controlled studies with larger samples.

Functional mobility and flexibility are similarly relevant to military performance. Military activities frequently involve bending, lifting, squatting, climbing, running, load carriage, and rapid changes in body position. Evidence from military load-carriage research demonstrates that external loads modify trunk and lower-limb kinematics and increase muscular demands, suggesting that adequate mobility and movement capacity may be important for maintaining efficient movement under occupational load.

2. Pulmonary Function as a Component of Physical Performance

Pulmonary function represents an important physiological component of exercise capacity and physical performance. During physical activity, increased metabolic demand requires corresponding adjustments in ventilation to facilitate adequate oxygen uptake and carbon dioxide elimination. Measures such as forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), FEV₁/FVC ratio, and peak expiratory flow rate (PEFR) are commonly used indicators of pulmonary function and respiratory efficiency (Pellegrino et al., 2005; Graham et al., 2019).

PEFR, in particular, represents the maximum expiratory flow achieved during a forceful expiration following maximal inspiration. Although PEFR does not provide the comprehensive assessment offered by full spirometry, it is inexpensive, portable, easy to administer, and suitable for repeated field measurements, making it particularly useful in occupational populations such as defense personnel (Miller et al., 2005).

Physical training can positively influence respiratory performance; however, conventional exercise programs do not necessarily emphasize

diaphragmatic breathing, thoracic mobility, respiratory awareness, and conscious regulation of the breathing cycle to the same extent as yogic practices (Abel et al., 2013). This distinction provides a rationale for investigating yoga-based approaches as complementary interventions within physically trained populations.

3. Yoga and Pulmonary Function

Yoga integrates physical postures (*āsanas*), controlled movements, breathing regulation (*prāṇāyāma*), relaxation, and meditative practices. The combination of these components distinguishes yoga from many conventional exercise modalities and provides a potential mechanism through which it may influence respiratory function (Ross & Thomas, 2010).

Evidence accumulated over the past decade suggests that regular yogic practice can positively influence pulmonary-function parameters in healthy individuals. Abel et al. (2013), in a review of studies involving healthy populations, reported improvements in respiratory variables including FVC, FEV₁, vital capacity, and PEFR following yoga interventions. However, the authors also noted variability in outcomes due to differences in intervention duration, type of yoga practices, and participant characteristics.

More robust evidence has emerged from systematic reviews and meta-analyses. Bhagel and Saha (2021), in a systematic review and meta-analysis of healthy individuals, reported significant improvements in FVC, FEV₁, FEV₁/FVC ratio, PEFR, maximum voluntary ventilation (MVV), and respiratory-muscle strength following yogic interventions. The review concluded that yoga-based practices, particularly those incorporating breathing techniques, exert beneficial effects on pulmonary function and respiratory-muscle performance.

Similarly, Bandyopadhyay et al. (2026), in a systematic review and meta-analysis involving healthy adults, found significant improvements in FVC, FEV₁, FEV₁/FVC ratio, and PEFR following yogic breathing interventions. The review included practices such as *Nāḍī Śōdhana*, *Bhrāmārī*, *Kapālabhāti*, *Bhastrikā*, *Om* chanting, and slow breathing techniques, with intervention durations ranging from four weeks to four months. Meta-

analytic estimates demonstrated moderate effects of yogic breathing on pulmonary outcomes (Bandyopadhyay et al., 2026).

These findings suggest that respiratory-focused yogic practices may influence pulmonary function through mechanisms involving improved respiratory-muscle conditioning, thoracic expansion, enhanced chest-wall mobility, optimized breathing patterns, and improved coordination between respiration and movement (Jerath et al., 2006). Nevertheless, heterogeneity among yoga protocols and participant populations indicates the need for further research using standardized and reproducible interventions.

4. Yogic Breathing and Respiratory Regulation

One of the distinctive components of yoga is the deliberate regulation of respiration. Yogic breathing practices may involve slow breathing, alternate-nostril breathing, forceful expiratory techniques, breath awareness, and specific respiratory patterns. These practices have been proposed to influence respiratory mechanics, autonomic balance, and respiratory-muscle recruitment (Jerath et al., 2015).

Experimental research has demonstrated that specific yogic breathing techniques can influence pulmonary parameters. Studies involving Bhrāmārī Prāṇāyāma, Om chanting, and alternate-nostril breathing have reported improvements in pulmonary-function variables and respiratory efficiency (Kuppusamy et al., 2018; Telles et al., 2011).

Evidence from clinical populations also provides indirect support for the respiratory effects of yoga. A systematic review and meta-analysis by Wu et al. (2014) involving patients with chronic obstructive pulmonary disease (COPD) found that yoga interventions, particularly those emphasizing breathing techniques, improved pulmonary function, exercise capacity, and quality of life. Although these findings cannot be directly generalized to healthy defense personnel, they provide additional evidence that structured respiratory practices can influence respiratory performance.

More recently, evidence has emerged specifically in defense populations. Singh et al. (2025) investigated a 20-day yoga regimen among 22 defense personnel

deployed at approximately 3100 m altitude. The intervention included Sūkṣma Vyāyāma, Sthūla Vyāyāma, selected āsanās, sectional and complete yogic breathing, Kapālabhāti, Nāḍī Śodhana, Ujjāyī, Bhrāmārī, and relaxation techniques. Significant improvements were reported in expiratory flow rate, breath-holding time, oxygen saturation, and heart rate (Singh et al., 2025).

This study is noteworthy because it demonstrates the feasibility and physiological relevance of a structured yogic program within an operational defense setting. However, the single-group pre-post design and relatively small sample size limit causal interpretation and indicate the need for controlled studies involving larger samples of active-duty defense personnel.

5. Flexibility, Spinal Mobility, and Functional Readiness

Physical readiness in defense personnel extends beyond cardiovascular and pulmonary capacity and includes adequate mobility, flexibility, muscular strength, and movement coordination. Military occupational tasks frequently involve load carriage, running, marching, lifting, climbing, kneeling, crouching, and repeated transitions between different body positions. These tasks require the musculoskeletal system to maintain appropriate ranges of motion while simultaneously producing and controlling force. Reviews of military occupational performance indicate that essential military tasks depend on multiple interacting physical capacities, including muscular strength, aerobic fitness, muscular endurance, and movement efficiency (Vaara et al., 2022).

The spine and surrounding musculature play an important role in trunk movement, postural control, and transfer of mechanical loads between the upper and lower body. Military load carriage can alter trunk and lower-limb movement patterns and increase muscular demands. A systematic review by Walsh and Low (2021) demonstrated that military load carriage is associated with changes in trunk, hip, and knee kinematics and increased muscular activation. These findings indicate that adequate mobility and movement capacity may be relevant to maintaining efficient movement during occupationally demanding military activities.

Flexibility is generally defined as the ability of a joint or series of joints to move through an available range

of motion, whereas mobility represents the functional capacity to actively and effectively control movement through that range. In military settings, these characteristics may contribute to the performance of activities requiring bending, lifting, squatting, running, climbing, and changes in body position. Therefore, flexibility and spinal mobility can reasonably be considered components of comprehensive physical conditioning rather than isolated musculoskeletal outcomes.

Yoga provides a potentially relevant approach because many yogic practices involve controlled movement through different ranges of motion, sustained postures, stretching, spinal movements, and postural alignment. A systematic review by Rathore, Singh, and Katiyar (2024) specifically examined the effects of yoga interventions on spine and shoulder mobility. The review included eight studies comprising five randomized controlled trials, two quasi-experimental studies, and one study of unspecified design. The included populations consisted of individuals with chronic low-back pain, healthy adults, and older adults. Overall, the authors reported that yoga had the potential to improve spinal flexibility and mobility, particularly among individuals with chronic low-back pain; however, the magnitude of the effects varied according to population and intervention characteristics.

Evidence from broader systematic reviews also supports the potential musculoskeletal benefits of yoga. Wieland et al. (2022), in a Cochrane systematic review including 21 randomized trials and 2,223 participants, found low- to moderate-certainty evidence that yoga produced small improvements in back-related function and pain compared with no exercise. However, the review also indicated that yoga did not clearly outperform other forms of back-focused exercise. This finding is important because it suggests that yoga should be considered a form of complementary physical exercise rather than assumed to be superior to conventional exercise or physiotherapy.

Similarly, a systematic review and meta-analysis of randomized controlled trials involving 2,702 participants found that yoga improved pain and functional disability in people with chronic low-back pain compared with non-exercise interventions, while its effects were generally

comparable to other physical therapy exercises (Wang et al., 2020).

The existing evidence therefore provides a plausible physiological and functional basis for investigating whether structured Yogic Vyāyāma can influence flexibility and spinal mobility. However, an important limitation of the current literature is that most research has been conducted in clinical populations, healthy adults, older adults, or individuals with musculoskeletal complaints rather than active-duty defense personnel. Rathore et al. (2024) similarly highlighted the need for further research to strengthen the evidence concerning yoga and spinal mobility.

Accordingly, investigating lumbar flexibility in defense personnel may provide population-specific evidence that is currently limited in the literature. In the present context, lumbar flexibility can be assessed using an objective functional measure such as the **sit-and-reach test**, provided that its limitations and its relationship to isolated lumbar mobility are appropriately acknowledged.

6. Yogic Vyāyāma as an Integrated Physical-Conditioning Approach

Yogic Vyāyāma may be conceptualized as a structured system of yogic physical exercises involving systematic movements intended to develop mobility, flexibility, coordination, body awareness, and physical efficiency. Depending on the protocol, it may include Sūkṣma Vyāyāma, Sthūla Vyāyāma, joint-mobility exercises, dynamic movements, spinal movements, selected āsanās, and coordinated breathing practices.

A potentially important characteristic of Yogic Vyāyāma is the integration of movement and respiration. In contrast to interventions that target flexibility or cardiorespiratory function independently, a structured yogic program can combine controlled movement, postural regulation, stretching, and conscious breathing within the same session. Reviews comparing yoga with conventional exercise have suggested that yoga can produce improvements in several physical and psychological outcomes, although the magnitude and consistency of these effects vary according to the intervention and population studied (Ross & Thomas, 2010).

From a physiological perspective, the combination of movement and breathing may be particularly relevant to defense personnel because military activities frequently require simultaneous control of posture, movement, breathing, and physical effort. However, this proposed mechanism should be regarded as a **plausible rationale rather than an established causal mechanism in military populations**, because direct experimental evidence remains limited.

Another potential advantage of Yogic Vyāyāma is its relatively low equipment requirement. Many yogic movement and breathing practices can be performed in institutional or field environments with minimal equipment. This characteristic may facilitate integration into training environments where access to specialized equipment is limited.

Nevertheless, Yogic Vyāyāma should be regarded as a **complementary component of military physical conditioning rather than a replacement for conventional strength, endurance, running, load-carriage, or combat training**. Military physical readiness requires task-specific development of multiple physical capacities, and current evidence does not justify replacing established military conditioning with yoga (Vaara et al., 2022).

7. Current Evidence and Research Gap in Defense Populations

Although research on yoga and physical fitness has expanded substantially, direct evidence involving active-duty defense personnel remains comparatively limited. Most published studies examining yoga and flexibility or spinal mobility have been conducted in healthy adults, older adults, or individuals with chronic musculoskeletal conditions. For example, the systematic review by Rathore et al. (2024) included studies involving chronic low-back-pain populations, healthy adults, and older adults, but did not establish the effectiveness of yoga specifically among active military personnel.

The distinction between general health populations and defense personnel is important. Defense personnel are exposed to occupational requirements involving load carriage, prolonged standing or marching, repetitive movement, constrained postures, and physically demanding

tasks. Consequently, changes in flexibility or mobility in this population should ideally be evaluated using outcomes that have functional relevance to military physical performance.

Evidence from military research demonstrates that load carriage can substantially modify movement mechanics and increase physiological and muscular demands (Walsh & Low, 2021). At the same time, systematic reviews of yoga indicate potential benefits for spinal mobility and musculoskeletal function (Rathore et al., 2024; Wieland et al., 2022). However, these two bodies of evidence have rarely been brought together experimentally in active-duty military populations.

The recent study by Singh et al. (2025) provides particularly relevant population-specific evidence. The investigators examined a 20-day yoga regimen among defense personnel deployed at high altitude and reported improvements in respiratory and cardiovascular-related outcomes. However, the study focused primarily on pulmonary and physiological parameters and did not establish the effects of the intervention on lumbar flexibility. Furthermore, its single-group pre-test–post-test design and small sample size limit causal inference.

Therefore, an important research gap remains regarding whether a **structured Yogic Vyāyāma intervention can simultaneously influence pulmonary function and functional flexibility in defense personnel**. Investigating these outcomes within the same experimental framework may provide a more integrated understanding of the potential contribution of Yogic Vyāyāma to military physical readiness.

The proposed investigation is consequently justified not by an assumption that yoga has already been proven superior to conventional military conditioning, but by the need to determine whether a standardized Yogic Vyāyāma protocol can produce measurable changes in **pulmonary function and lumbar flexibility among physically trained defense personnel**. Such evidence could help clarify whether Yogic Vyāyāma has value as an adjunct to existing military physical-conditioning programs.

8. Research Gap and Rationale

Although existing literature provides encouraging evidence regarding the effects of yoga on pulmonary

function and spinal mobility, several gaps remain.

First, studies investigating pulmonary outcomes have used diverse yoga and pranayama protocols, making it difficult to determine whether a broader, structured Yogic Vyāyāma program can produce comparable effects.

Second, respiratory and flexibility outcomes have frequently been examined separately. Fewer studies have investigated both **pulmonary expiratory performance and functional flexibility simultaneously** within the same intervention.

Third, evidence specifically involving active defense personnel remains limited. The recent study among high-altitude defense personnel provides valuable preliminary evidence, but its single-group design and specialized environmental context limit generalization.

Fourth, there is a need for interventions that are practical, structured, reproducible, and compatible with existing military training schedules.

The present study addresses these gaps by examining the effects of a structured 8-week Yogic Vyāyāma intervention on two practical indicators of physical readiness: **Peak Expiratory Flow Rate as an indicator of expiratory pulmonary performance and Sit-and-Reach performance as an indicator of functional flexibility involving the lower back and posterior chain.**

RESEARCH GAP → PILOT RESPONSE

Limited defense-specific evidence + heterogeneous yoga protocols + separate respiratory/flexibility outcomes → standardized 8-week Yogic Vyāyāma protocol + controlled comparison + two practical field outcomes.

9. Present Study

Considering the physiological demands placed on defense personnel and the growing evidence supporting yoga-based interventions for respiratory and musculoskeletal outcomes, a structured Yogic Vyāyāma program may represent a useful complementary strategy for military physical conditioning.

The present pilot investigation was therefore designed to examine the effects of an **8-week structured Yogic Vyāyāma intervention on pulmonary function and lumbar flexibility in**

defense personnel.

The study specifically sought to determine whether participation in the intervention would result in measurable improvements in **Peak Expiratory Flow Rate (PEFR)** and **Sit-and-Reach performance** compared with routine physical training.

It was hypothesized that defense personnel participating in the structured Yogic Vyāyāma program would demonstrate greater improvements in pulmonary expiratory performance and lumbar flexibility than those continuing routine physical training alone.

2. Aim

The primary aim of the study was to investigate the effects of an 8-week structured Yogic Vyāyāma intervention on pulmonary function and lumbar flexibility among defense personnel.

3. Objectives

The study was undertaken with the following objectives:

1. To assess baseline pulmonary function in defense personnel using Peak Expiratory Flow Rate.
2. To assess baseline lumbar flexibility using the Sit-and-Reach test.
3. To determine the effect of an 8-week Yogic Vyāyāma intervention on PEFR.
4. To determine the effect of an 8-week Yogic Vyāyāma intervention on lumbar flexibility.
5. To compare changes in pulmonary function and lumbar flexibility between the experimental and control groups.

4. Hypotheses

H₁

An 8-week structured Yogic Vyāyāma intervention will significantly improve pulmonary function among defense personnel.

H₂

An 8-week structured Yogic Vyāyāma intervention will significantly improve lumbar flexibility among defense personnel.

H₃

The experimental group will demonstrate greater improvements in pulmonary function and lumbar

flexibility than the control group.

5. Materials and Methods

5.1 Study Design

A **pilot randomized controlled pre-test–post-test design** was employed.

Participants were divided into two groups:

Study population	Allocation	Intervention	Post-test
Defense personnel (N=100)	Experimental n=50	8-week Yogic Vyāyāma	PEFR + Sit-and-Reach
Defense personnel (N=100)	Control n=50	Routine physical training	PEFR + Sit-and-Reach

The experimental group received the structured Yogic Vyāyāma intervention for eight weeks, whereas the control group continued their routine physical-training activities.

5.2 Participants

The study included defense personnel who fulfilled the predetermined eligibility criteria.

Inclusion Criteria

Participants were eligible when they:

- were active defense personnel;
- were within the predetermined age range for the study;
- were medically fit to participate in physical activity;
- were willing to participate voluntarily;
- provided written informed consent; and
- were able to attend the scheduled intervention sessions.

Exclusion Criteria

Participants were excluded if they:

- had a diagnosed respiratory disorder that could substantially influence pulmonary-function measurements;
- had an acute musculoskeletal injury;
- had a medical contraindication to physical exercise;

- were undergoing another structured yoga intervention;
- were unable to attend the required intervention sessions; or
- withdrew consent during the study.

6. Intervention

The experimental group participated in a structured **Yogic Vyāyāma program for 8 weeks**.

The intervention emphasized:

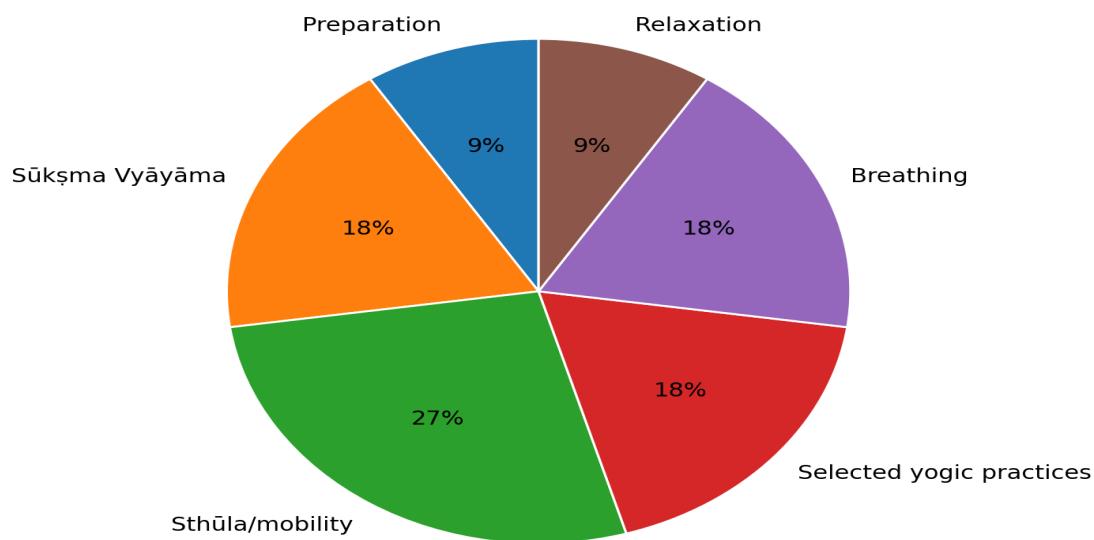
1. Preparatory practices;
2. Sūkṣma Vyāyāma;
3. Selected Sthūla Vyāyāma;
4. Dynamic and controlled movements;
5. Practices promoting spinal and lumbar mobility;
6. Coordinated movement with respiration;
7. Selected breathing practices;
8. Relaxation following practice.

The intervention was conducted under supervision to ensure appropriate technique, consistency, and participant safety.

The program was designed to progressively expose participants to controlled movements involving the trunk, spine, thoracic region, limbs, and respiratory musculature.

Proposed Session Structure

Component	Approx. duration	Primary emphasis
Centering and preparation	5 min	Preparation / awareness
Sūkṣma Vyāyāma	10 min	Joint mobility / preparation
Sthūla Vyāyāma / mobility	15 min	Dynamic movement / mobility
Selected yogic practices	10 min	Posture / movement
Breathing practices	10 min	Respiratory regulation
Relaxation	5 min	Recovery
Total	~55 min	Integrated session

Session Composition (~55 min)**Figure 1. Relative distribution of the proposed session components based on the durations reported in the manuscript.**

The exact frequency and session schedule should be reported according to the intervention actually delivered.

7. Outcome Measures

7.1 Pulmonary Function

Peak Expiratory Flow Rate

Peak Expiratory Flow Rate (PEFR) was selected as the primary pulmonary outcome measure.

PEFR represents the maximum expiratory flow achieved during a forceful expiration following maximal inspiration. It provides an accessible measure of expiratory airflow and can be particularly useful in field-based or occupational

settings.

Measurements were recorded in **litres per minute (L/min)**.

To improve measurement reliability, participants were instructed regarding the correct testing procedure and were provided with appropriate familiarization before assessment.

7.2 Lumbar Flexibility

Sit-and-Reach Test

The Sit-and-Reach test was used to assess flexibility involving the lower back and posterior chain.

Participants performed the standardized test following appropriate instructions and warm-up

procedures. The best valid performance was recorded in centimetres.

The Sit-and-Reach test was selected because it is inexpensive, practical, easy to administer, and suitable for field-based physical-fitness assessment.

8. Data Collection Procedure

Stage 1	Stage 2	Stage 3	Stage 4
Recruitment Screening →	Consent → Baseline	Allocation Intervention →	Post-test → Analysis

Operational sequence: Recruitment → Screening → Informed consent → Baseline assessment → Group allocation → 8-week intervention → Post-intervention assessment → Statistical analysis.

9. Statistical Analysis

Data were organized and analyzed using appropriate statistical procedures.

Descriptive statistics were expressed as **mean $\pm$ standard deviation (SD)**.

Within-group pre- and post-intervention differences were assessed using paired statistical analysis.

Between-group differences were examined using

appropriate independent-group analysis.

The level of statistical significance was set at:

$p < 0.05$

Effect sizes were calculated to determine the magnitude of intervention-related changes.

Because this was a pilot investigation, emphasis was placed not only on statistical significance but also on the magnitude and direction of changes and the feasibility of conducting a larger controlled study.

10. Results

10.1 Participant Characteristics

A total of 100 defense personnel participated in the pilot investigation, with 50 allocated to the experimental group and 50 to the control group.

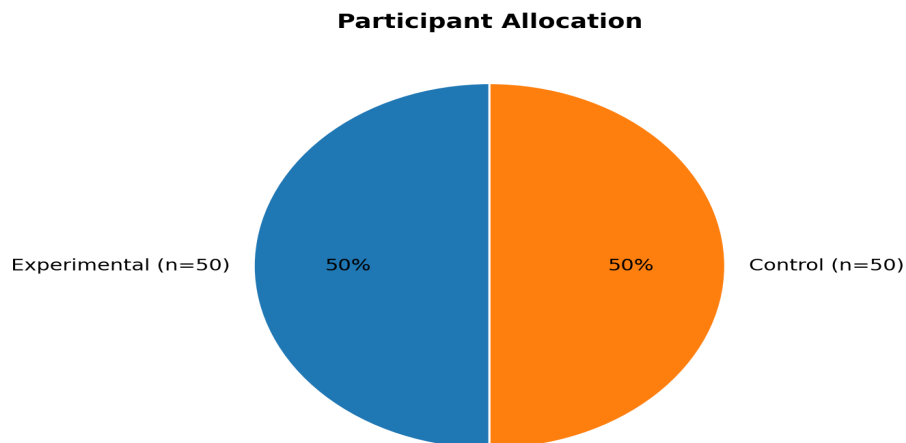


Figure 2. Equal allocation of participants across the two study groups.

10.2 Changes in Pulmonary Function

The experimental group demonstrated an increase in PEFR from **470.36 $\pm$ 38.24 L/min** at baseline to **526.14 $\pm$ 36.51 L/min** following the

intervention.

The control group demonstrated only a small change from **472.08 $\pm$ 37.46 L/min** to **475.86 $\pm$ 37.93 L/min**.

Group	Pre-test, mean $\pm$ SD (L/min)	Post-test, mean $\pm$ SD (L/min)	Mean change
Experimental	470.36 $\pm$ 38.24	526.14 $\pm$ 36.51	+55.78
Control	472.08 $\pm$ 37.46	475.86 $\pm$ 37.93	+3.78

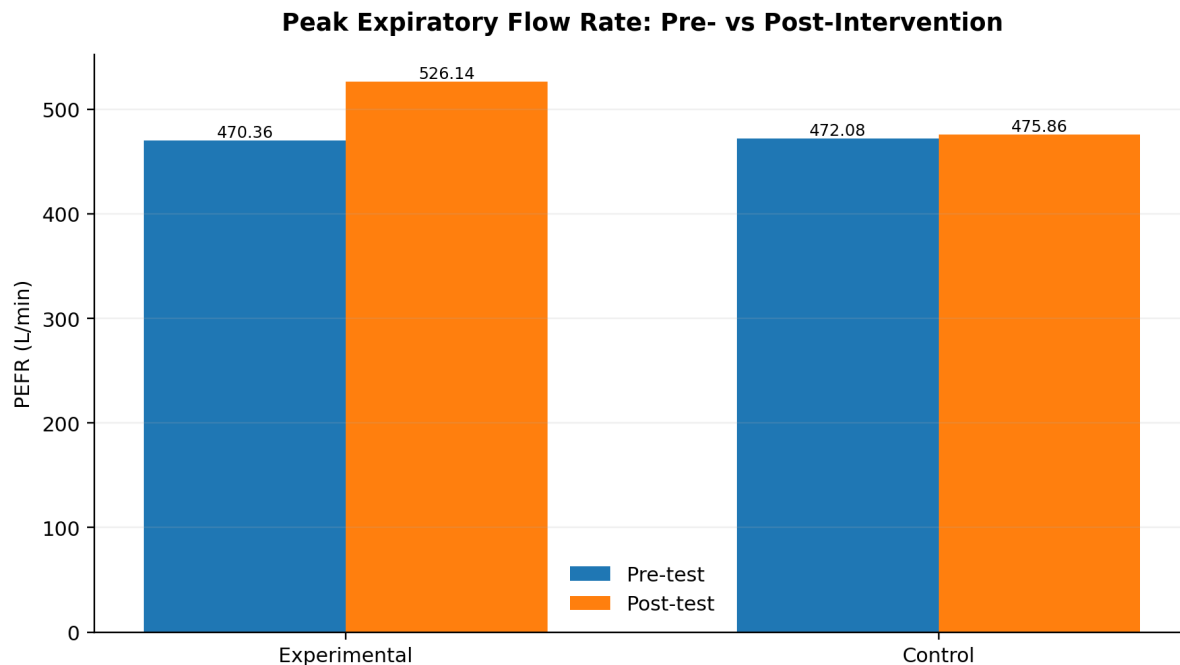


Figure 3. PEFR before and after the 8-week intervention.

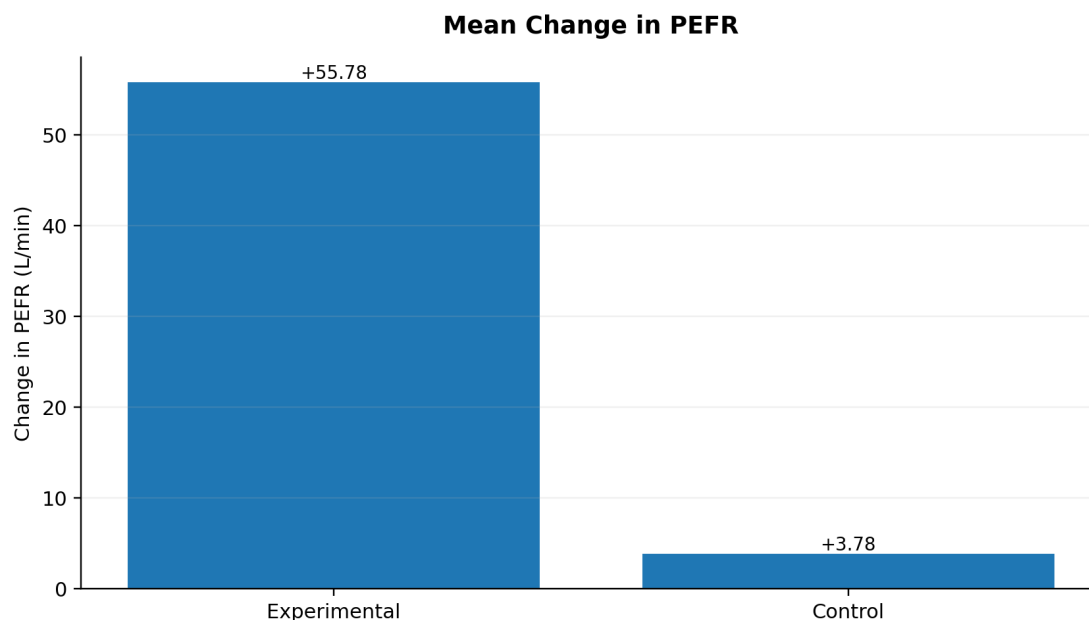


Figure 4. Mean change in PEFR by group.

The experimental group showed a much larger increase in PEFR than the control group. The manuscript reports a statistically significant within-

group change for the experimental group ($p < 0.001$) with a large standardized effect ($d = 2.12$).

10.3 Changes in Lumbar Flexibility

Lumbar flexibility improved from 23.82 ± 3.84 cm at baseline to 29.48 ± 3.42 cm following the intervention in the experimental group.

In comparison, the control group changed only from 24.10 ± 3.71 cm to 24.58 ± 3.60 cm.

Group	Pre-test, mean $\pm$ SD (cm)	Post-test, mean $\pm$ SD (cm)	Mean change
Experimental	23.82 ± 3.84	29.48 ± 3.42	+5.66
Control	24.10 ± 3.71	24.58 ± 3.60	+0.48

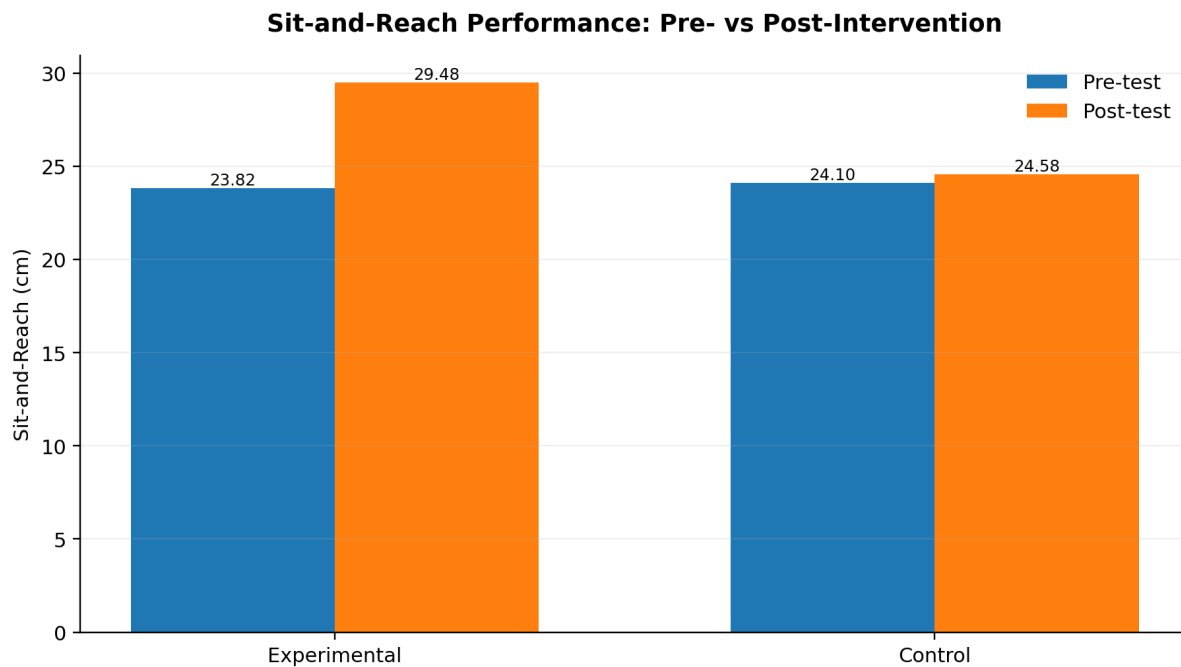


Figure 5. Sit-and-Reach performance before and after the 8-week intervention.

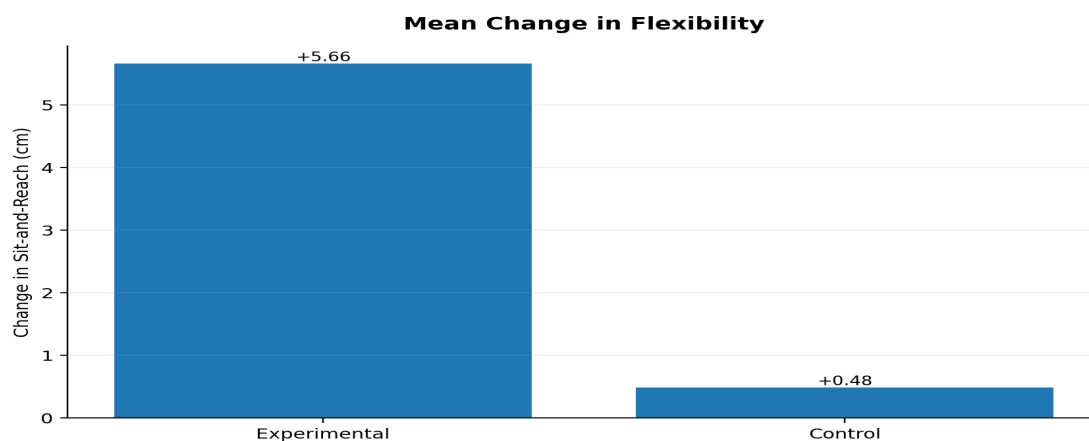


Figure 6. Mean change in Sit-and-Reach performance by group.

The experimental group demonstrated a substantially greater improvement in flexibility than the control group. The manuscript reports a

statistically significant within-group change ($p < 0.001$) with a large standardized effect ($d = 1.80$).

Outcome	Experimental change	Control change
PEFR	+11.9%	+0.8%
Sit-and-Reach	+23.8%	+2.0%

Table 3. Changes in Sit-and-Reach Performance

Group	Pre-test Mean $\pm$ SD (cm)	Post-test Mean $\pm$ SD (cm)	Mean Change
Experimental	23.82 $\pm$ 3.84	29.48 $\pm$ 3.42	+5.66
Control	24.10 $\pm$ 3.71	24.58 $\pm$ 3.60	+0.48

The experimental group demonstrated a substantially greater improvement in flexibility than the control group.

The within-group improvement was statistically significant ($p < 0.001$), with a large standardized effect ($d = 1.80$).

11. Discussion

The present pilot investigation examined whether a structured eight-week Yogic Vyāyāma intervention could improve pulmonary function and lumbar flexibility among defense personnel.

The findings indicate substantial improvements in both outcomes in the experimental group, whereas only minimal changes were observed in the control group.

The improvement in PEFR may be associated with several components of the intervention. Yogic practices frequently combine controlled respiratory patterns with coordinated trunk and thoracic movements. Regular practice may improve respiratory-muscle coordination, expiratory control, thoracic mobility, and awareness of breathing mechanics. The recent systematic review and meta-analysis by Bandyopadhyay et al. reported a moderate pooled effect of yogic breathing practices on PEFR, providing contemporary support for the potential

respiratory benefits of structured yogic breathing.

Previous literature has also reported improvements in pulmonary-function parameters following regular yoga practice. A review of nine studies found that yoga was generally associated with

improvements in measures such as forced vital capacity, FEV₁, maximum voluntary ventilation, and PEFR, although the magnitude of response varied according to intervention duration and participant characteristics.

The observed improvement in lumbar flexibility may be explained by the repeated controlled movements, stretching, spinal mobility practices, and sustained postures included in Yogic Vyāyāma. Regular exposure to these movements may increase tolerance to muscle lengthening and improve functional range of motion.

This interpretation is consistent with broader evidence that structured stretching and movement interventions can increase range of motion. In addition, a recent systematic review specifically examining yoga's effects on spinal and shoulder mobility identified evidence from randomized and quasi-experimental studies supporting potential improvements in spinal mobility.

An important feature of the present study is its focus on defense personnel. Military personnel generally undertake substantial amounts of physical training, meaning that the additional value of a complementary intervention should be considered in relation to existing training rather than in isolation. The observed differences between the intervention and control groups suggest that Yogic Vyāyāma may complement conventional physical conditioning rather than simply replace it.

The large observed effect sizes for both PEFR and flexibility are encouraging from a pilot-study perspective. Nevertheless, these findings should be interpreted cautiously because pilot studies primarily

provide preliminary evidence and information for the design of larger definitive trials.

12. Possible Mechanisms

Several mechanisms may potentially explain the observed improvements.

12.1 Respiratory Mechanisms

Yogic breathing and coordinated movement may:

- improve respiratory-muscle recruitment;
- enhance expiratory control;
- increase thoracic mobility;
- improve breathing awareness;

- facilitate more efficient respiratory patterns; and
- contribute to improved expiratory flow.

12.2 Musculoskeletal Mechanisms

Yogic Vyāyāma incorporates repeated spinal flexion, extension, rotation, and controlled stretching. These movements may contribute to:

- improved lumbar mobility;
- increased flexibility of the posterior kinetic chain;
- improved trunk movement;
- enhanced neuromuscular coordination; and
- improved functional movement capacity.

12.3 Integrated Mechanistic Model

Yogic Vyāyāma component	Potential physiological/functional pathway	Measured outcome
Coordinated breathing	Respiratory-muscle recruitment / expiratory control	PEFR
Thoracic and trunk movement	Thoracic mobility / breathing mechanics	PEFR
Spinal movements	Lumbar movement capacity	Sit-and-Reach
Controlled stretching	Posterior-chain flexibility	Sit-and-Reach
Movement + breathing + awareness	Integrated neuromuscular and respiratory regulation	Both outcomes

13. Strengths of the Study

The study has several strengths:

1. It focuses specifically on defense personnel.
2. It employed an experimental-control group design.
3. The intervention was structured and supervised.
4. Both respiratory and musculoskeletal outcomes were assessed.
5. The selected measures are relatively inexpensive and practical for field settings.
6. The study provides preliminary effect-size estimates for planning a larger trial.

14. Limitations

The findings should be interpreted in light of

several limitations.

First, this was a pilot investigation with a relatively limited sample size. Second, PEFR provides an important measure of expiratory airflow but does not provide the comprehensive information obtained through full spirometry. Future studies should therefore include FVC, FEV₁, FEV₁/FVC, and other relevant pulmonary parameters.

Third, the present study assessed outcomes immediately following the intervention period; therefore, the long-term persistence of the observed improvements remains uncertain.

Fourth, adherence to the intervention and other physical-training activities should be carefully documented in future trials.

Finally, defense personnel constitute a relatively

specialized population, and therefore the findings may not be directly generalizable to civilian

populations.

15. Conclusion

The findings of this pilot investigation suggest that an **8-week structured Yogic Vyāyāma intervention may substantially improve pulmonary expiratory performance and lumbar flexibility among defense personnel.**

The experimental group demonstrated marked improvements in PEFr and Sit-and-Reach performance compared with the control group. The large observed effect sizes indicate that the intervention warrants further investigation using a larger, adequately powered randomized controlled trial.

Yogic Vyāyāma may therefore have potential as a complementary component of military physical-conditioning programs, particularly where the objectives include respiratory efficiency, spinal mobility, flexibility, and overall functional preparedness.

However, definitive conclusions regarding efficacy should be based on larger trials incorporating comprehensive pulmonary-function testing, objective measures of physical fitness, intervention adherence, and longer-term follow-up.

16. Practical Implications

The findings have potential implications for military physical-conditioning programs.

A structured Yogic Vyāyāma program may be incorporated alongside conventional physical training to target physiological domains that are important for occupational readiness. Because many yogic practices require minimal equipment, they may also be feasible in field or institutional settings.

References

- Abel, A. N., Lloyd, L. K., & Williams, J. S. (2013). The effects of regular yoga practice on pulmonary function in healthy individuals: A literature review. *Journal of Alternative and Complementary Medicine*, 19(3), 185–190. <https://doi.org/10.1089/acm.2011.0516>
- Anshu, Singh, N., Deka, S., Saraswati, P., Sindhwani, G., Goel, A., & Kumari, R. (2023). The effect of yoga on pulmonary function in patients with asthma: A meta-analysis. *Complementary Therapies in Clinical Practice*, 50, 101682. <https://doi.org/10.1016/j.ctcp.2022.101682>
- Bandyopadhyay, N., Das, T., & Biswas, A. (2026). Yogic breathing practices as a non-pharmacological alternative medicine for managing pulmonary functions of healthy adults: A systematic review and meta-analysis. *Indian Journal of Community Medicine*, 51(Suppl. 1), S27–S38. https://doi.org/10.4103/ijcm.ijcm_929_24
- Bhagel, P., & Saha, M. (2021). Effects of yogic intervention on pulmonary function and respiratory muscle strength

Future military-focused yoga interventions could investigate combined outcomes including:

- pulmonary function;
- flexibility;
- muscular strength;
- cardiovascular endurance;
- reaction time;
- sleep quality;
- perceived stress;
- recovery;
- balance and coordination; and
- combat-readiness measures.

18. Declarations

Ethical Approval

The study should be conducted following approval from the appropriate Institutional Ethics Committee and in accordance with applicable ethical standards for research involving human participants.

Ethics Approval Number: [SU/IEC/25/01]

Informed Consent

Written informed consent should be obtained from all participants before their inclusion in the study.

Conflict of Interest

The authors declare that there is no conflict of interest associated with this study.

Data Availability

The data generated during the present study should be made available from the corresponding author upon reasonable request, subject to applicable institutional and ethical restrictions.

- parameters: A systematic literature review and meta-analysis. *Journal of Biosciences*, 46, 76.
<https://doi.org/10.1007/s1279-295-0279-295>
- Graham, B. L., Steenbruggen, I., Miller, M. R., Barjaktarevic, I. Z., Cooper, B. G., Hall, G. L., Hallstrand, T. S., Kaminsky, D. A., McCarthy, K., McCormack, M. C., Oropez, C. E., Rosenfeld, M., Stanojevic, S., Swanney, M. P., & Thompson, B. R. (2019). Standardization of spirometry 2019 update: An official American Thoracic Society and European Respiratory Society technical statement. *American Journal of Respiratory and Critical Care Medicine*, 200(8), e70–e88. <https://doi.org/10.1164/rccm.20279-295ST>
- Jerath, R., Edry, J. W., Barnes, V. A., & Jerath, V. (2006). Physiology of long pranayamic breathing. *Medical Hypotheses*, 67(3), 566–571. <https://doi.org/10.1016/j.mehy.2006.02.042>
- Knapik, J. J., Reynolds, K. L., & Harman, E. (2004). Soldier load carriage: Historical, physiological, biomechanical, and medical aspects. *Military Medicine*, 169(1), 45–56. <https://doi.org/10.7205/MILMED.169.1.45>
- Kuppusamy, M., Kamaldeen, D., Pitani, R., et al. (2018). Immediate effects of Bhramari Pranayama on resting cardiovascular parameters. *Journal of Clinical and Diagnostic Research*, 12(5), CC17–CC19.
- Miller, M. R., Hankinson, J., Brusasco, V., et al. (2005). Standardisation of spirometry. *European Respiratory Journal*, 26(2), 319–338. <https://doi.org/10.1183/09031936.05.00034805>
- Mooventhan, A., & Khode, V. (2014). Effect of Bhramari Pranayama and OM chanting on pulmonary function in healthy individuals: A prospective randomized control trial. *International Journal of Yoga*, 7(2), 104–110. <https://doi.org/10.4103/279-295.133875>
- Orr, R. M., Pope, R., Johnston, V., & Coyle, J. (2013). Soldier occupational load carriage: A narrative review of associated injuries. *International Journal of Injury Control and Safety Promotion*, 20(1), 1–15. <https://doi.org/10.1080/17457300.2013.833944>
- Pellegrino, R., Viegi, G., Brusasco, V., et al. (2005). Interpretative strategies for lung function tests. *European Respiratory Journal*, 26(5), 948–968.
- Rathore, V., Singh, S., & Katiyar, V. K. (2024). Exploring the therapeutic effects of yoga on spine and shoulder mobility: A systematic review. *Journal of Bodywork and Movement Therapies*, 40, 586–596. <https://doi.org/10.1016/j.jbmt.2024.04.029>
- Raub, J. A. (2002). Psychophysiologic effects of Hatha Yoga on musculoskeletal and cardiopulmonary function: A literature review. *Journal of Alternative and Complementary Medicine*, 8(6), 797–812.
- Ross, A., & Thomas, S. (2010). The health benefits of yoga and exercise: A review of comparison studies. *Journal of Alternative and Complementary Medicine*, 16(1), 3–12. <https://doi.org/10.1089/acm.2009.0044>
- Singh, L., Keshav, R., Pandey, M., & Babu, N. (2025). Effect of yoga regimen on the lung capacity of defence personnel deployed at high altitude area. *Journal of Ayurveda and Integrative Medicine*, 16(6), 101223. <https://doi.org/10.1016/j.jaim.2025.101223>
- Telles, S., Singh, N., & Balkrishna, A. (2011). Managing mental health disorders resulting from trauma through yoga. *Depression Research and Treatment*, 2012, 401513.
- Vaara, J. P., Groeller, H., Drain, J., Kyröläinen, H., Pihlainen, K., Ojanen, T., Connaboy, C., Santtila, M., Agostinelli, P., & Nindl, B. C. (2022). Physical training considerations for optimizing performance in essential military tasks. *European Journal of Sport Science*, 22(1), 43–57. <https://doi.org/10.1080/17461391.2021.1930193>
- Walsh, G. S., & Low, D. C. (2021). Military load carriage effects on the gait of military personnel: A systematic review. *Applied Ergonomics*, 93, 103376. <https://doi.org/10.1016/j.apergo.2021.103376>
- Wang, X., et al. (2020). Yoga compared to non-exercise or physical therapy exercise on pain, disability, and quality of life for patients with chronic low back pain: A systematic review and meta-analysis of randomized controlled trials. *PLoS ONE*, 15(9), e0238902.
- Wieland, L. S., Skoetz, N., Pilkington, K., Harbin, S., Vempati, R., & Berman, B. M. (2022). Yoga for chronic non-specific low back pain. *Cochrane Database of Systematic Reviews*, 11, CD010671. <https://doi.org/10.1002/14651858.CD010671.pub3>
- Wu, W., Liu, X., Wang, L., et al. (2014). Effects of yoga on exercise capacity in patients with chronic obstructive pulmonary disease: A systematic review and meta-analysis. *International Journal of Chronic Obstructive Pulmonary Disease*, 9, 1197–1205.