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ORIGINAL ARTICLE

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Yoga for Tobacco Cessation: A Randomized Controlled Trial (QUIT-SMART)

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ABSTRACT

Background: Current tobacco cessation strategies, including pharmacological interventions and supportive therapies, have limitations related to adherence and relapse. Emerging evidence suggests that yoga plays a significant role in tobacco cessation through psycho-behavioral mechanisms. This study was conducted to evaluate the role of yoga among adults who used both smoking and smokeless forms (SLT) of tobacco.

Methods: A prospective, randomized, open-label, blinded endpoint trial was conducted among adult tobacco users. Participants were randomly assigned to either the yoga ($n=64$) or the exercise ($n=66$). The primary outcome was 7-day point prevalence abstinence (7-PPA) validated by salivary cotinine, at 6 months. Secondary outcomes included quality of life (QoL), assessed using WHOQOL-BREF, and psychological health was assessed using DASS-21.

Results: Between December 2021 and June 2023, 910 adult tobacco users were screened. A total of 130 participants (96.9% male) were enrolled, including 51 (39.3%) who used smoking tobacco and 79 (60.7%) who used smokeless tobacco. At 6 months, 14 (22%) participants in the yoga group achieved 7-PPA, compared to 6 (9.1%) in the exercise group ($p=0.043$) (OR: 2.8, 95% CI: 1.04–8.40). The yoga group demonstrated greater improvements in QoL ($p<0.05$), and psychological health outcomes, including stress and anxiety ($p<0.001$) and depression ($p=0.008$).

Conclusion: Yoga demonstrated a significantly higher rate of 7-PPA compared with exercise. The yoga group also showed greater improvements in QoL and psychological outcomes. These findings suggest that yoga may serve as a feasible complementary intervention for tobacco cessation among adult tobacco users.

Trial registration: Clinical Trial Registry India number; CTRI/2021/12/038745. Date of Registration – Dec 20, 2021

KEYWORDS

Tobacco cessation; smoking tobacco; smokeless tobacco; yoga; exercise

Introduction

Tobacco use is among the leading causes of preventable illness and mortality worldwide, accounting for over 8 million deaths each year (WHO, 2025). Low-and middle-income countries (LMICs) account for 80% of the 1.3 billion tobacco users worldwide, and bear a disproportionately high tobacco-related health burden (WHO, 2025). Tobacco poses a significant public health challenge in India, with more than one-third of its adult population consuming some form of tobacco products. It accounts for 27% of tobacco-related cancers and 14% of noncommunicable disease (NCD) deaths among those over 30 years of age (Singh et al., 2026). The prevalence of smokeless tobacco (SLT) use (21.4%) is nearly twice that of smoking tobacco (10.7%) (Tobacco Use Among Indian States, 2021). Smoking shows a greater gender gap, with 19% of men and only 2% of women reporting its use, while SLT is more widely used across genders (29.6% among men and 12.8% among women) (Tata Institute of Social Sciences, 2017).

Despite more than 60% of smokers expressing a desire to quit (Asma, 2015), nearly 70% still lack access to effective cessation services (WHO, 2025). Relapse rates remain high without support, with almost half of all the individuals relapsing despite the use of pharmacotherapy (Herd et al. 2009; Mills et al., 2010). Cognitive behavioral therapy (CBT), though helpful, often produces modest outcomes and suffers from poor adherence (Vinci, 2020). These challenges are amplified in LMICs, including India, where tobacco use is linked to male gender, rural residence, lower socioeconomic status, and limited education (Ministry of Health and Family Welfare Government of India, 2017).

Amidst the limitations, complementary and alternative therapies have gained recognition for addressing the behavioral and psychological components of addiction. (National Center for Complementary & Integrative Health, 2021). Yoga, a mind-body practice that incorporates pranayama, meditation, and asanas, has demonstrated potential in improving cessation outcomes (Kim et al., 2022) besides, it

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enhances self-regulation, emotional stability, and stress reduction, key psychological factors in preventing relapse (Marefat et al., 2011). The cognitive processing and sensory awareness, enhanced by mindful movement-based asanas, consequently build attention control and coping abilities, further supporting better craving management (Dick et al., 2014). While aerobic exercises have been reported to reduce cravings, withdrawal symptoms, and self-abstinence (Elibero et al., 2011; Ussher et al., 2006), they lack the mindfulness component central to yoga.

Although several studies have demonstrated the benefits of yoga for tobacco cessation, most have focused on smoking populations (Bock et al., 2012, 2019; Elibero et al., 2011). Its application to SLT users remains under explored (Siddiqi et al., 2020). Despite smoking and SLT being comparable in terms of nicotine dependence and health risks (Hecht & Hatsukami, 2023), smokeless use encounters added challenges from socio-cultural acceptance, lower risk perception, and limited support services. SLT being culturally ingrained in India further reduces the likelihood of quitting. Moreover, SLT-specific treatment options remain scarce (Chaffee & Cheng, 2018).

Addressing this gap, our study evaluates the effectiveness of yoga versus exercise-based interventions for tobacco cessation among both smoking and SLT users. Including both user groups allows for a more comprehensive and contextually relevant assessment. To our knowledge, this is the first randomized controlled trial directly comparing these two approaches across both forms of tobacco use.

Methods

Study design and participants

We conducted a prospective randomized open-label blinded end-point (PROBE) trial to evaluate the effect of yoga on tobacco cessation. The study was carried out at the Center for Integrative Medicine and Research (CIMR), All India Institute of Medical Sciences (AIIMS, New Delhi), India. Participants were recruited between December 2021 and June 2023 through the medical outpatient departments (OPDs) of AIIMS, ND, a tertiary care referral hospital. Recruitment involved advertisement hoardings and notices, and physicians were encouraged to refer individuals for screening. Ethical clearance for the trial was obtained from the institutional ethical Committee on Dec 03, 2021 (Reference no IEC-756/12.11.2021, RP-35/2021), and the trial has been registered with the Clinical Trials Registry of India on Dec 20, 2021: (CTRI no. CTRI/2021/12/038745). The trial protocol is in Appendix 1. Written informed consent was obtained from all the patients and a detailed patient information sheet (PIS) was completed for every participant before enrollment into the study. The primary objective was to evaluate the effectiveness of yoga therapy for tobacco cessation. The secondary objectives were to examine the effect of yoga on quality of life (QoL), anxiety, depression and stress. Following screening and baseline assessment, participants were randomized to the yoga or exercise group. The intervention was delivered over 8 weeks, comprising of four supervised contact sessions during the first week followed by one supervised session per week during weeks 2–8. Participants were encouraged to continue their assigned intervention at least three times a week thereafter. Outcome assessments were performed at baseline, 2, 3, and 6 months. The 6-month assessment is the primary endpoint.

Eligible participants were adults aged 18–65 years who reported consuming at least five servings of tobacco per day, in either smoking or smokeless forms (but not concurrently), and had used tobacco at least 100 times in their lifetime. The Physical Activity Readiness Questionnaire (PAR-Q) was used to screen participants for safe participation in 45 min of moderate-intensity exercise or yoga.

Exclusion criteria included individuals already practicing regular exercise or yoga more than three times per week and those currently enrolled in any tobacco cessation program. Individuals using other substances (e.g., alcohol or opioids, etc.) or centrally acting medications (e.g., benzodiazepines, antidepressants, neuroleptics, anticonvulsants, major tranquillizers, etc.) were also excluded. Dual users of smoking and SLT were excluded because concurrent use reflects a distinct behavioral and dependence profile, which might be associated with higher nicotine dependence and lower quit rates (Tomar et al., 2010). Moreover, smoking and SLT users were assessed using different validated measures of nicotine dependence, the Fagerström Test for Nicotine Dependence (FTND) for smoking, and the Severson Smokeless Tobacco Dependence Scale (SSTDS) for SLT (Mushtaq & Beebe, 2012, 2021). Application of both tools to the same individual would not be appropriate, as each instrument is designed for a single primary mode of tobacco use. Including both could therefore introduce heterogeneity and compromise the comparability of outcomes, thereby affecting the internal validity of the study.

Randomization and masking

Eligible participants ($n = 130$) were stratified based on their mode of tobacco intake (smoking or smokeless) and randomly assigned in a 1:1 ratio to either yoga or exercise. Within each stratum, block randomization with a fixed block size of 20 (10 participants each to yoga and exercise groups) was used to minimize the potential imbalances in the number of participants at various enrollment stages. The randomization list was generated by an independent statistician who was not involved in the study, with the help of an online software www.sealedenvelope.com. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes, which were opened only after obtaining written informed consent and completing baseline assessments. Data interpretation and statistical analysis were conducted in a blinded manner by an independent statistician who was unaware of the group assignments. The outcome measures were assessed at baseline, 2, 3, and 6 months.

Interventions

Participants were randomly assigned to either the yoga or the exercise group.

Yoga (Intervention group): A specifically designed 45-min yoga protocol was developed by yoga experts at CIMR, AIIMS. The module was validated by 10 yoga experts of national repute using Lawshe's Content Validity Index (Appendix 2) and was delivered by institutionally certified yoga therapists. Participants completed an induction period comprising four supervised contact sessions in the first week. It was followed by one supervised session per week for the subsequent 7 weeks, conducted either online or in person, depending on participants' preference, resulting in a total of eleven contact sessions over 8 weeks. Following the induction phase, participants continued with their assigned intervention for at least three times per week until the final follow-up.

Exercise (Control group): The exercise module was in accordance with WHO (2020) recommendations for moderate-intensity physical activity, incorporating warm-up stretching, moderate-paced aerobic activity, and light strengthening exercises. The duration and session structure (30-45 min) were matched to those of the yoga intervention, and metabolic equivalents (METs) were calculated using the Compendium of Physical Activities 2011 to allow precise and meaningful comparisons between interventions. Exercise sessions were conducted at CIMR, AIIMS (Appendix 2) under comparable supervision. All procedures, including induction program, follow-ups, compliance and adherence monitoring, and overall session delivery, matched those implemented in the yoga group.

Outcomes

The primary outcome measure was self-reported 7-day abstinence measured by salivary cotinine levels <100 ng/mL/measured using Liquid Chromatography Mass Spectrometry (Appendix 3). 7-PPA and salivary cotinine were assessed at baseline and the 6-month endpoint. Secondary outcomes included health-related QoL measured using World Health Organization QoL-Brief version Questionnaire items (WHOQOL-BREF). Psychological outcomes were evaluated using the Depression Anxiety Stress Scale (DASS-21). Smoking-related behaviors were assessed using the Brief Wisconsin Inventory of Smoking Dependence Motives (Brief WISDM) (Smith et al., 2010), the Smoking Abstinence Self-Efficacy Questionnaire (SASEQ) (Spek et al., 2013), and the Smoking Situation Temptation Scale (SSTS) (Velicer et al., 1990).

Sample size

The planned sample size ($n = 260$) was calculated to detect a 20% difference in 7-PPA (Abrantes et al., 2014) with 80% power, accounting for 30% attrition. Due to slower than anticipated recruitment, primarily attributable to the high prevalence of dual tobacco use the trial was terminated early after enrolling 130 participants. In accordance with guidance from the Ethics Committee and Data Monitoring Committee, the final sample was deemed adequate for meaningful statistical inference, supported by the Central Limit Theorem, which allows reliable estimation of population parameters in samples of this size.

Statistical analysis

The normality distribution of continuous variables was assessed using the Shapiro–Wilk test. Data were presented as mean (SD) or median (Q1, Q3), and analyzed using either the t-test or Mann–Whitney U test, based on the data distribution. Categorical variables were reported as n (%) and analyzed using the Chi-square test or Fisher's exact test, depending on cell frequencies. For the primary outcome, the odds ratio with a 95% confidence interval (CI) was also reported. The hypothesis of no difference between the two groups for all the outcome variables was tested at follow-up. A p-value of less than 0.05 ($p < 0.05$) was considered statistically significant. Both intention-to-treat (ITT) and per-protocol (PP) analyses were performed. Missing data in ITT analysis were handled using the last observation carried forward (LOCF) method. The PP analysis included only those participants who complied with the intervention protocol and were assessed at the final follow-up. All analysis was conducted using R software (version 4.3.2).

Results

Baseline characteristics

A total of 910 individuals were screened for eligibility; 780 were excluded. The most common reasons for ineligibility ($n = 395$,79.7%) were concurrent use of both SLT forms of tobacco. The high proportion of dual users made it difficult to classify individuals into a single-use category, which significantly impacted the recruitment process and resulted in slower-than-expected enrollment despite screening a total of 910 individuals. Of these 130 participants met the inclusion criteria and were stratified accordingly to their primary mode of tobacco use: smoking (n = 57) or SLT (n = 73), and subsequently underwent baseline assessment and randomization to either the yoga group ($n = 64$) or the exercise group ($n = 66$). Patients were followed up for 6 months, during which 30 (23.08%) of the randomized individuals dropped out, with a dropout rate of 15 (23.44%) in the yoga group and 15 (22.72%) in the exercise group. An overview of the screening, enrollment, stratification, and follow-up processes according to CONSORT guidelines is provided in Figure 1.

The demographic and baseline descriptive characteristics of the participants are listed in Table 1. The groups were balanced in terms of socio-demographic characteristics and tobacco-related variables, such as daily tobacco consumption, types of tobacco products used, past attempts to quit, willingness to quit, and frequency of daily consumption of tobacco. Nearly three-quarters of the patients in both arms were strongly willing to quit tobacco. Willingness to quit tobacco was assessed using a Likert-type scale ranging from 1 to 5, where a score of 4–5 indicated being strongly willing to quit, and 1–3 indicated a moderate willingness to quit.

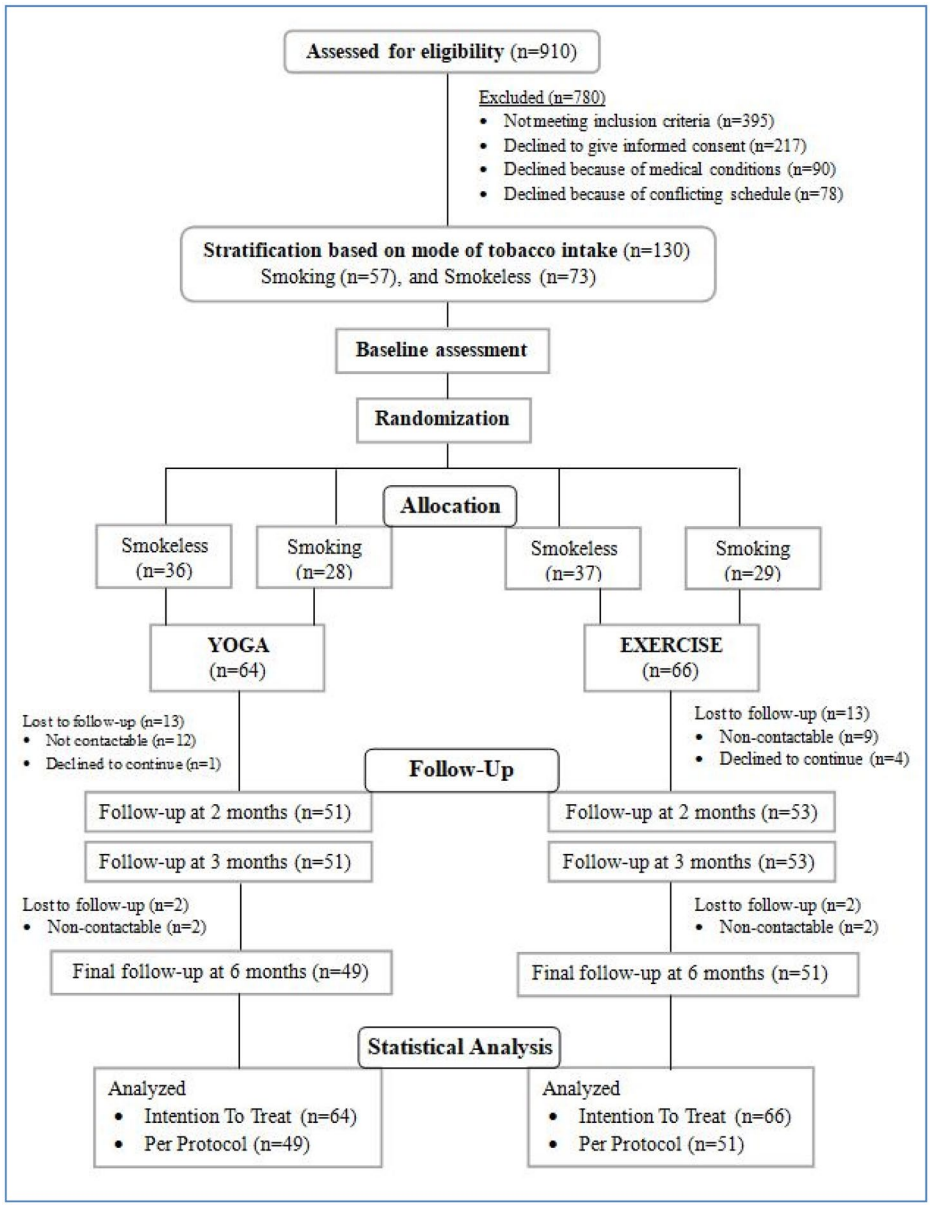


Figure 1. Consort diagram representing the flow of the trial.

Withdrawal symptoms were measured using The Minnesota Tobacco Withdrawal Scale-Revised (Behavior Rating Scale), with participants self-reporting their withdrawal-related behaviors.

Primary outcome

At the 6-month follow-up, a significantly greater proportion of participants in the yoga group achieved 7-PPA compared to those in the exercise group. Specifically, 14 participants (22%) in the yoga group reported 7-PPA, versus 6 participants (9.1%) in the exercise group ($p = 0.043$) (Figure 2(A)). The odds of achieving 7-PPA were 2.8 times higher in the yoga group (95% CI: 1.04–8.40), reflecting a 180% increase in the likelihoods of abstinence relative to exercise. There was a high degree of concordance between self-reported 7-PPA and biochemically verified abstinence. The overall agreement was 93.1%. Cohen's kappa indicated substantial agreement beyond chance ($\kappa = 0.749$, SE = 0.089, $p < 0.001$). Furthermore, there was an significant association between self-reported 7-PPA and cotinine-based abstinence ($p < 0.001$). In contrast at the 6-month follow-up, no statistically significant between-group differences were observed in salivary cotinine levels (median 256 ng/mL in the yoga group versus 298 ng/mL in the exercise group; $p = 0.697$). Specifically, 14 participants (22%) in the yoga group reported 7-PPA, versus 6 participants (9.1%) in the exercise group ($p = 0.043$) (Figure 2(A)). Yoga group showed a reduction in cotinine levels from baseline (311–256 ng/mL), whereas levels in the exercise group remained relatively stable (279–298 ng/mL). Non-abstinence was observed in 50 (78%) participants in the yoga group and 60 (90.9%) participants in the exercise group. Among participants who achieved abstinence in the yoga arm, equal proportions were from the smoking and SLT strata (7 participants each). A similar distribution was observed in the exercise group, where 3 abstinent

Table 1. Baseline characteristics of the study population.

Characteristic	Yoga ($n=64$)	Exercise ($n=66$)
Age (years)*	37.80 (11.22)	40.58 (11.71)
BMI*	24.3 (5)	24.3 (3.7)
Male#	62 (96.9%)	66 (100%)
Socio-economic class#		
Lower	1 (1.5%)	0 (0%)
Lower middle	33 (50%)	34 (53%)
Upper lower	18 (27%)	12 (19%)
Upper middle	14 (21%)	18 (28%)
Frequency of daily tobacco consumption#	14 (7%)	13 (7%)
Past attempts to quit#	1.98 (1.77)	2.06 (1.60)
Willingness to quit#		
Moderately	14 (22%)	15 (23%)
Strongly	50 (78%)	51 (77%)
Types#		
Bidi (SG)	7 (11%)	5 (7.8%)
Cigarettes (SG)	15 (23%)	18 (28%)
Cigarettes and Bidi (SG)	0 (0%)	2 (3.1%)
Gutka (SL)	17 (26%)	17 (27%)
Hookah (SG)	3 (4.5%)	1 (1.6%)
Khaini (SL)	18 (27%)	12 (19%)
Khaini and Gutka (SL)	1 (1.5%)	0 (0%)
Kuber (SL)	0 (0%)	2 (3.1%)
Tambakhu (SL)	3 (4.5%)	4 (6.3%)
Tambakhu and Khaini (SL)	1 (1.5%)	1 (1.6%)
Zarda (SL)	1 (1.5%)	2 (3.1%)
Salivary cotinine (ng/mL)	311 (194, 484)	279 (151, 393)
WHO-BREF QoL scores		
Domain 1 (physical health)	14 (12, 15)	14 (13, 16)
Domain 2 (psychological health)	13 (11, 15)	13 (11, 15)
Domain 3 (social relationships)	15 (12, 16)	15 (12, 16)
Domain 4 (environmental health)	14 (12, 15)	14 (12, 15)
DASS scores		
Stress score	16 (12, 25)	16 (10, 26)
Anxiety score	12 (8, 18)	12 (8, 18)
Depression score	12 (4, 18)	11 (3, 22)
MTWS-R (BRS) - Total	16 (10, 21)	15 (8, 21)
Smokeless tobacco users	**Yoga ($n=36$)**	**Exercise ($n=37$)**
SSTDS	6 (5, 7)	6 (5, 7)
Smoking tobacco users	**Yoga, $n=28$**	**Exercise, $n=29$**
FTND	6 (4, 7)	4 (4, 6)
Mean brief WISDM score	5.65 (4.69, 6.15)	5.47 (4.58, 6.09)
PDM	6.11 (4.76, 6.66)	6 (4.90, 6.50)
SDM*	5.26 (1.04)	5.07 (1.26)
Average score—SSTS	5.00 (4.28, 5)	4.55 (4, 5)
Average SASEO	0 (0, 1.20)	0 (0, 0.66)

Values are presented as median (Q1, Q3), #*n* (%,) and *mean (SD).

SD: standard deviation; *n* (%): number (percentage); Q_1: quartile 1; Q_3: quartile 3; SG: smoking, SL: smokeless; WHOQOL–BREF: World Health Organization Quality of Life Brief; MTWS-R(BRS)-Total: Minnesota Nicotine Withdrawal Scale-Revised (Behavior Rating Scale)-Total, SSTDS: Severson Smokeless Tobacco Dependence Scale, FTND: Fagerström Test for Tobacco Nicotine Dependence; WISDM: Wisconsin Inventory of Smoking Dependence Motives; PDM: Primary Dependence Motive; SDM: Secondary Dependence Motive); SSTS: Smoking Situation Temptation Scale; SASEQ: Smoking Abstinence Self-Efficacy Questionnaire, ng/mL: nanograms per milliliter.

participants (50%) were from each stratum. Given the high baseline cotinine concentrations, inclusion of both SLT users, and the modest sample size at follow-up, cotinine levels demonstrated limited sensitivity for distinguishing abstinence status at the group level.

Secondary outcomes

At the final follow-up, all domains of QoL demonstrated a significant difference between the groups, indicating greater improvement in the yoga group (Figure 3). The median scores of stress, anxiety and depression were also significantly lower in the yoga group compared to the exercise group (Figure 4). MTWS-R (BRS) score showed a reduction in withdrawal symptoms in both groups compared to baseline values, with a statistically significant difference favoring the yoga group ($p=0.035$) (Table 2). The median nicotine dependence as measured by FTND in the Smoking group did not differ significantly between groups at the final follow-up ($p=0.069$), although the yoga group showed a favorable reduction from baseline. For the Smokeless group, nicotine dependence assessed using the SSTDS indicated a significant difference between the groups ($p=0.013$). The mean scores for smoking dependence motives, including both primary and secondary motives based on the brief WISDM, indicate no significant difference between groups ($p=0.300$). Similar findings were observed for temptation to smoke based on mean SSTS scores. The mean SASEQ scores showed an improvement in smoking abstinence self-efficacy scores from baseline, with a greater increase in the yoga group, though the intergroup differences did not reach statistical significance ($p=0.200$) (Table 2).

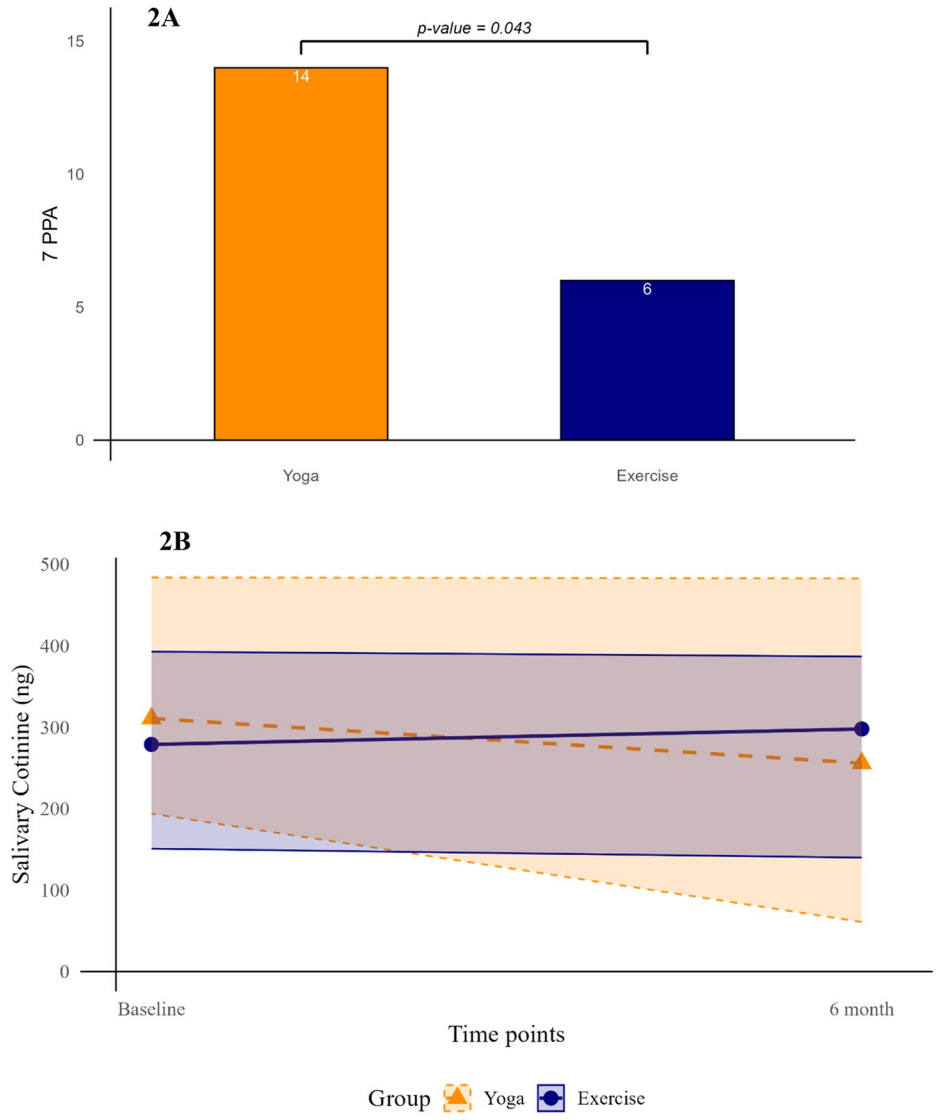


Figure 2. (A) 7-Day point prevalence abstinence at 6-month follow-up. (B) Salivary cotinine (ng/mL) at baseline and 6-month follow-up.

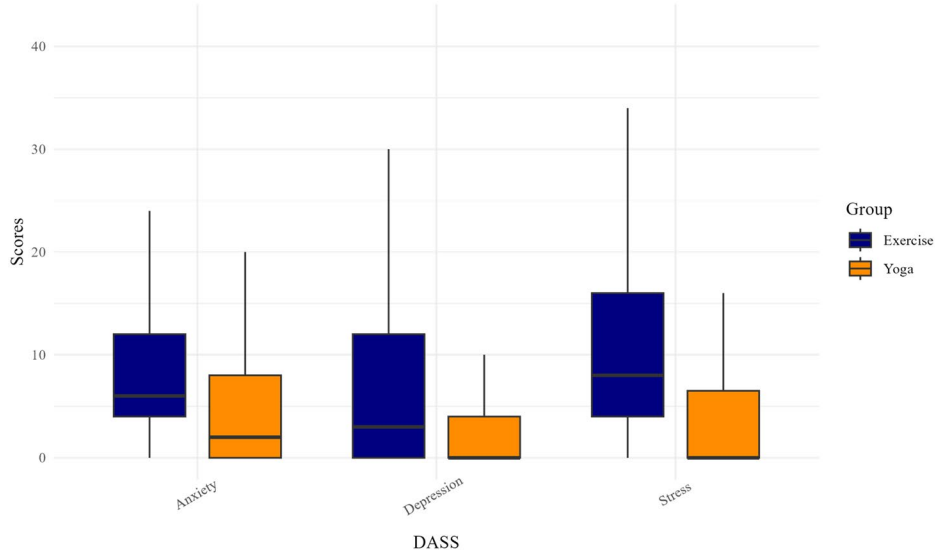


Figure 3. Box and whisker plot DASS-21.

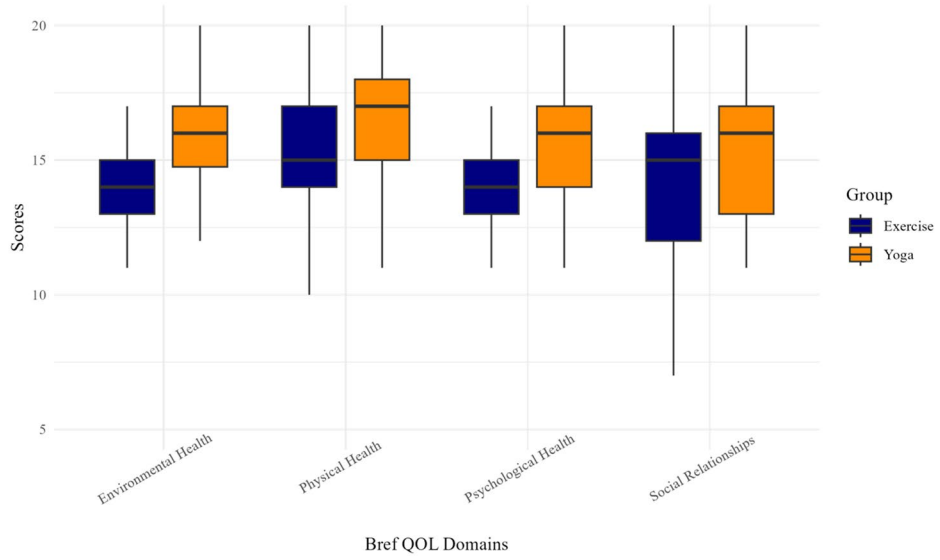


Figure 4. Box and whisker plot WHOQOL-BREF.

Table 2. Outcome measures at follow-up.

Characteristic	Yoga, $n=64$	Exercise, $n=66$	p-Value
7PPA[#]	14 (22%)	6 (9.1%)	0.043
Salivary cotinine (ng/mL)	256 (61, 483)	298 (140, 387)	0.697
WHO-BREF QoL scores			
Domain 1 (physical health)	17 (15, 18)	15 (14, 17)	0.002
Domain 2 (psychological health)	16 (14, 17)	14 (13, 15)	<0.001
Domain 3 (social relationships)	16 (13, 17)	15 (12, 16)	0.008
Domain 4 (environmental health)	16 (14.8, 17)	14 (13, 15)	<0.001
DASS scores			
Stress score	0 (0, 7)	8 (4, 16)	<0.001
Anxiety score	2 (0, 8)	6 (4, 12)	<0.001
Depression score	0 (0, 3)	2 (0, 9)	0.008
MTWS-R (BRS)-total	5 (2, 11)	8 (4, 13)	0.035
Smokeless tobacco group	**Yoga, $n=36$**	**Exercise, $n=37$**	***p*-Value**
SSTDS	4 (1.75, 5)	5 (4, 7)	0.014
Smoking tobacco group	**Yoga, $n=28$**	**Exercise, $n=29$**	***p*-value**
FTND	1 (0,5)	4 (1,5)	0.069
Brief WISDM score (Mean)	2.84 (1, 4.76)	3.56 (3.23,5.04)	0.300
PDM	2.82 (1, 4.94)	3.70 (2.50, 5.63)	0.200
SDM	2.95 (1, 4.97)	3.50 (2.21, 4.18)	0.400
Mean score of SSTS	3.00 (1, 4.51)	3.11 (2.44, 4.00)	0.600
Mean SASEQ	2.33 (0.5, 3.87)	1.83 (0.66, 2)	0.200

Values are Median (Q1, Q3), [#]n (%,).

SD: standard deviation; n (%): number (percentage); Q_1: quartile 1; Q_3: quartile 3; 7PPA: 7-day point prevalence abstinence; SG: smoking, SL: smokeless; WHOQOL-BREF: World Health Organization Quality of Life Brief; MTWS-R(BRS)-Total: Minnesota Nicotine Withdrawal Scale-Revised (Behavior Rating Scale)-Total, SSTDS: Severson Smokeless Tobacco Dependence Scale, FTND: Fagerström Test for Tobacco Nicotine Dependence; WISDM: Wisconsin Inventory of Smoking Dependence Motives; PDM: Primary Dependence Motive; SDM: Secondary Dependence Motive); SSTS: Smoking Situation Temptation Scale; SASEQ: Smoking Abstinence Self-Efficacy Questionnaire, ng/mL: nanogram per milliliter

The results of PP analysis demonstrated that 14 (29%) participants in the yoga group achieved 7PPA, as compared to 6 (12%) in the exercise group ($p=0.036$). The median salivary cotinine levels at six months follow-up were 256 ng/mL and 284 ng/mL, respectively ($p=0.851$) (Appendix 4).

Adherence and compliance monitoring

To support adherence, a bilingual (Hindi and English) yoga booklet containing a structured module with clear step-by-step instructions and illustrative images of yoga poses supported home practice. Compliance was monitored through telephonic follow-ups and participants logbooks documenting the date and duration of each practice session. Logbooks were reviewed during follow-up visits. Participants were classified as complaint if they attended at least two of the four supervised sessions in the first week, completed one supervised session per week during weeks 2–8, and reported at least one home practice session per week from week 2 to the six-month follow-up. In total, 49 of 64 participants in the yoga group (76.5%) and 51 of 66 participants in the exercise group (77.3%) were considered compliant, indicating strong engagement and supporting the feasibility and acceptability of both interventions.

Discussion

Our findings modestly favor yoga over exercise for 7-PPA, validated by cotinine levels despite comparable drop out rates between the two groups. The self-reported 7PPA favored the yoga intervention among tobacco users, including those who use smokeless tobacco, a sub-population that remains underrepresented in tobacco cessation research align with previous studies that have used adjunct yoga therapy on the smoking population (Bock et al., 2012, 2019 ; Piper et al., 2020). The between-group difference in the cotinine levels was not statistically significant. Cotinine concentrations vary substantially across tobacco users due to differences in product type and nicotine content, frequency and intensity of use, inhalation depth, ingestion of juices, and exposure to second-hand or even third-hand smoke (Ferketich et al. 2007;Patel et al., 2017; Association of Second-Hand Smoke Exposure, 2023). Additionally, given cotinine's half-life of 16–20 h, levels can decline from smoker to non-smoker ranges within 2–4 days. Therefore, if sample collection is not standardized relative to the timing of last tobacco

use, substantial intra-individual variability can occur, potentially obscuring true between-group differences (Benowitz et al., 2009). Thus, while cotinine is an objective biochemical marker, its interpretation must be contextualized with behavioral outcomes.

Significant improvements in stress, anxiety and depression, and Qol were observed in both SLT tobacco users. These findings are consistent with the earlier studies (Bock et al., 2012; Lotfalian et al., 2020). Given that psychological factors strongly influence relapse risk in tobacco cessation, our results support the premise that breath-focused yoga practices may modulate parasympathetic activity and regulate emotional states (Streeter et al., 2012), an effect distinct from that of physical exercise.

None of the participants was receiving cessation treatment at enrollment, underscoring persistent barriers to the uptake of formal cessation services among tobacco users (specifically SLT) in LMICs such as India (Chhabra et al., 2021). Although evidence-based strategies exist, long-term abstinence remains low (Centers for Disease Control and Prevention, 2024). Integrating yoga, delivered through in-person and online sessions, offers a cost-effective, accessible option, as evidenced by the high compliance rate (76.5%) observed in our study intervention arm.

The physiological pathways through which yoga may influence tobacco addiction remain insufficiently explored. Nicotine dependence arises from activation of nicotinic cholinergic receptors, which trigger neurotransmitter release and reinforce reward pathways (Dajas-Bailador & Wonnacott, 2004), while withdrawal increases stress through the activation of corticotropin-releasing factor and adrenocorticotropic hormone.

Yoga may mitigate these effects by promoting a shift from sympathetic to parasympathetic dominance, thereby attenuating hypothalamic–pituitary–adrenal (HPA) axis activation, consequently elevating GABA levels and reducing stress reactivity (Streeter et al., 2012).

The proportion achieving abstinence, although modest in our study, is noteworthy given the high-risk nature of the population, many of whom had long-standing tobacco use despite a strong wiliness to quit. The comparable representation of smoking and SLT users among those who achieved abstinence within each intervention arm further suggests that yoga may have broad applicability across different patterns of tobacco dependence. This is particularly relevant for regions like India, where smokeless tobacco is highly prevalent and requires tailored cessation strategies.

Although yoga and exercise have each been examined independently or as adjuncts, relatively few studies have directly compared the two in tobacco users and those that exist have focused on acute outcomes such as craving and affect rather than cessation outcomes (Elibero et al., 2011; Kim et al., 2022). Moreover, most previous studies were conducted in Western settings, predominantly focusing on smoking populations and employing standardized yoga protocols such as Vinyasa or Hatha Yoga, often with short or immediate follow-up periods (Bock et al., 2019, Jeffries et al., 2020; 2012; Elibero et al., 2011; Lotfalian et al., 2020). In contrast, recognizing the diverse cultural and socioeconomic landscape of India, our study utilized a tailored and validated yoga intervention delivered over 8 weeks, with a six-month follow-up. This customized approach for both smoking and SLT suggests that a culturally relevant yoga-based intervention may serve as a scalable adjunct to conventional cessation strategies (Woodyard, 2011).

There are multiple limitations of the study. First, considering the socioeconomic context of India, where lower education levels may contribute to reduced long-term willingness to participate in tobacco cessation trials, sustained engagement of participants in our study posed significant challenges. Consequently, early termination of recruitment led to a small sample size, limiting statistical power and widening confidence intervals around the estimated treatment effect particularly for biochemically verified cotinine levels. In addition, only two female participants enrolled in the study, limiting generalizability of findings across genders. This underrepresentation also reflects the broader social barriers and stigma in low-income settings, where women are less likely to come forward for tobacco cessation programs. Moreover, exclusion of dual users and multiple product users further limits the external validity of the findings. Second, the abstinence rates overall remained relatively low (22% in yoga and 9.1% in exercise), highlighting the challenge of achieving long-term cessation in this population and suggesting that yoga, while beneficial, may need to be combined with other behavioral counseling or pharmacological therapy to maximize effectiveness. Third, reliance on self-reported 7-PPA may have overestimated cessation outcomes, particularly in the absence of significant biochemical verification. Discrepancies between self-reported abstinence and cotinine measures highlight the need to better account for constructs such as dependence severity, self-efficacy, dependence motives, and situational temptation, which are known to influence cessation behaviors (Rajani et al., 2021). However, the lack of equivalent validated tools to measure these variables in smokeless tobacco users limited meaningful comparisons between modes of tobacco consumption despite observable trends favoring the yoga group. Lastly, patients using e-cigarettes, vaping products, were not included, as their prevalence remains low in the study setting, thereby limiting the applicability of findings to these emerging forms of nicotine users.

Conclusion

This trial suggests that yoga may be a feasible and acceptable therapy for tobacco cessation. Although only modest between-group differences were observed in salivary cotinine levels, the yoga intervention demonstrated a significantly higher rate of 7-PPA and was associated with greater improvements in psychological outcomes and health-related QoL. These findings indicate that yoga intervention may influence factors relevant to cessation, such as stress regulation and emotional well-being, which could support behavior change. However, the results should be interpreted cautiously in light of the limited sample size, attrition at

follow-up, and limitations in the use of biochemical verification. Future trials should be adequately powered, include longer intervention and follow-up periods, and employ biomarker analyses that explicitly verify abstinence and distinguish between tobacco products. Incorporating structured maintenance phases and recruiting more diverse populations, including individuals with comorbid health conditions, will be important for evaluating sustained abstinence and generalizability. Further research is also needed to elucidate the biological mechanisms through which yoga may influence craving and addiction-related neurochemistry.

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Author contributions

CRediT: **Sudha Lama**: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Shruti Singh**: Methodology, Writing – review & editing; **Partha Haldar**: Formal analysis, Methodology, Supervision, Validation; **Asmita Shukla**: Data curation, Formal analysis, Methodology, Software; **Varun Chhabra**: Data curation, Formal analysis, Investigation, Resources; **Akriti Shukla**: Methodology, Supervision, Validation; **Man Singh Jat**: Investigation, Resources; **Dhanlika Dhanlika**: Data curation, Formal analysis, Software; **Rajesh Sagar**: Conceptualization, Methodology, Supervision; **Udisha Singh**: Formal analysis; **Gautam Sharma**: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing.

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Data statement

The data will be available from the corresponding author upon reasonable request.

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References

Abrantes, A. M., Bloom, E. L., Strong, D. R., Riebe, D., Marcus, B. H., Desaulniers, J., Fokas, K., & Brown, R. A. (2014). A preliminary randomized controlled trial of a behavioral exercise intervention smoking cessation. *Nicotine & Tobacco Research*, *16*(8), 1094–1103. https://doi.org/10.1093/ntr/ntu036

Asma, S. (2015). *The GATS atlas: Global adult tobacco survey.* World Health Organization. https://www.who.int/publications/i/item/9789241509305

Association of Second-Hand Smoke Exposure. (2023). *Association of Second-Hand Smoke Exposure, quantified by salivary cotinine, with dental caries in Japanese adolescents*. PubMed. https://pubmed.ncbi.nlm.nih.gov/36990753/

Bagalad, B., Mohankumar, K. P., Madhushankari, G. S., Donoghue, M., Kuberappa, P., Patel, V. D., Jadhav, K. B., Shah, V. S., & Gupta, N. D. (2017). Comparative assessment of salivary cotinine level and psychological dependence among tobacco users. *Dental Research Journal*, *14*(1), 44–130. https://doi.org/10.4103/1735-3327.201138

Benowitz, N. L., Schultz, K. E., Haller, C. A., Wu, A. H. B., Dains, K. M., & Jacob, P.III (2009). Prevalence of smoking assessed biochemically in an urban public hospital: A rationale for routine cotinine screening. *American Journal of Epidemiology*, *170*(7), 885–891. https://doi.org/10.1093/aje/kwp215

Bock, B. C., Dunsiger, S. I., Rosen, R. K., Thind, H., Jennings, E., Fava, J. L., Becker, B. M., Carmody, J., & Marcus, B. H. (2019). Yoga as a complementary therapy for smoking cessation: Results from breath easy, a randomized clinical trial. *Nicotine & Tobacco Research*, *21*(11), 1517–1523. https://doi.org/10.1093/ntr/nty212

Bock, B. C., Fava, J. L., Gaskins, R., Morrow, K. M., Williams, D. M., Jennings, E., Becker, B. M., Tremont, G., & Marcus, B. H. (2012). Yoga as a complementary treatment for smoking cessation in women. *Journal of Women's Health (2002)*, *21*(2), 240–248. https://doi.org/10.1089/jwh.2011.2963

Centers for Disease Control and Prevention. (2024). Benefits of quitting smoking. https://www.cdc.gov/tobacco/about/benefits-of-quitting.html

Chaffee, B. W., & Cheng, J. (2018). Cigarette and smokeless tobacco perception differences of rural male youth. *Tobacco Regulatory Science*, *4*(4), 73–90. https://doi.org/10.18001/TRS.4.4.8

Chhabra, A., Hussain, S., & Rashid, S. (2021). Recent trends of tobacco use in India. *Journal of Public Health*, *29*(1), 27–36. https://doi.org/10.1007/s10389-019-01091-3

Dajas-Bailador, F., & Wonnacott, S. (2004). Nicotinic acetylcholine receptors and the regulation of neuronal signalling. *Trends in Pharmacological Sciences*, *25*(6), 317–324. https://doi.org/10.1016/j.tips.2004.04.006

Dick, A. M., Niles, B. L., Street, A. E., DiMartino, D. M., & Mitchell, K. S. (2014). Examining mechanisms of change in a yoga intervention for women: The influence of mindfulness, psychological flexibility, and emotion regulation on PTSD symptoms. *Journal of Clinical Psychology*, *70*(12), 1170–1182. https://doi.org/10.1002/jclp.22104

Elibero, A., Janse Van Rensburg, K., & Drobes, D. J. (2011). Acute effects of aerobic exercise and Hatha yoga on craving to smoke. *Nicotine & Tobacco Research*, *13*(11), 1140–1148. https://doi.org/10.1093/ntr/ntr163

Ferketich, A. K., Wee, A. G., Shultz, J., & Wewers, M. E. (2007). Smokeless tobacco use and salivary cotinine concentration. *Addictive Behaviors*, *32*(12), 2953–2962. https://doi.org/10.1016/j.addbeh.2007.06.012

Herd, N., Borland, R., & Hyland, A. (2009). Predictors of smoking relapse by duration of abstinence: Findings from the International Tobacco Control (ITC) Four Country Survey. *Addiction (Abingdon, England)*, *104*(12), 2088–2099. https://doi.org/10.1111/j.1360-0443.2009.02732.x

Hecht, S. S., & Hatsukami, D. K. (2023). Smokeless tobacco and cigarette smoking: Chemical mechanisms and cancer prevention. *Nature Reviews Cancer*, *22*, 143–155. https://pmc.ncbi.nlm.nih.gov/articles/PMC9308447/

Jeffries, E. R., Zvolensky, M. J., & Buckner, J. D. (2020). The acute impact of Hatha yoga on craving among smokers attempting to reduce or quit. *Nicotine & Tobacco Research*, *22*(3), 446–451. https://doi.org/10.1093/ntr/nty263

Kim, H., Kim, J., Woo, M., & Kim, T. (2022). Changes in inhibitory control, craving, and affect after yoga vs. aerobic exercise among smokers with nicotine dependence. *Frontiers in Psychiatry*, *13*, 940415. https://doi.org/10.3389/fpsyt.2022.940415

Lotfalian, S., Spears, C. A., & Juliano, L. M. (2020). The effects of mindfulness-based yogic breathing on craving, affect, and smoking behavior. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors*, *34*(2), 351–359. https://doi.org/10.1037/adb0000536

Marefat, M., Peymanzad, H., & Alikhajeh, Y. (2011). The study of the effects of yoga exercises on addicts' depression and anxiety in rehabilitation period. *Procedia - Social and Behavioral Sciences*, *30*, 1494–1498. https://doi.org/10.1016/j.sbspro.2011.10.289

Mills, E. J., Wu, P., Lockhart, I., Wilson, K., & Ebbert, J. O. (2010). Adverse events associated with nicotine replacement therapy (NRT) for smoking cessation: A systematic review and meta-analysis of one hundred and twenty studies involving 177,390 individuals. *Tobacco Induced Diseases*, *8*(1), 8. https://doi.org/10.1186/1617-9625-8-8

Ministry of Health and Family Welfare, Government of India. (. (2017). *Global adult tobacco survey – Second round India 2016–2017*. https://ntcp.mohfw.gov.in/assets/document/surveys-reports-publications/Global-Adult-Tobacco-Survey-Second-Round-India-2016-2017.pdf

Mushtaq, N., & Beebe, L. A. (2021). Evaluating the psychometric properties of the Severson 7-item Smokeless Tobacco Dependence Scale (SSTDS). *Nicotine & Tobacco Research*, *23*(7), 1224–1229. https://doi.org/10.1093/ntr/ntaa269

Mushtaq, N., Beebe, L. A., & Vesely, S. K. (2012). Determinants of salivary cotinine concentrations among smokeless tobacco users. *Nicotine & Tobacco Research*, *14*(10), 1229–1234. https://doi.org/10.1093/ntr/ntr279

National Center for Complementary and Integrative Health. (2021). *NCCIH clinical digest: Complementary health approaches for smoking cessation*. US Department of Health and Human Services, National Institutes of Health. https://www.nccih.nih.gov/health/providers/digest/complementary-health-approaches-for-smoking-cessation

Piper, M. E., Bullen, C., Krishnan-Sarin, S., Rigotti, N. A., Steinberg, M. L., Streck, J. M., & Joseph, A. M. (2020). Defining and measuring abstinence in clinical trials of smoking cessation interventions: An updated review. *Nicotine & Tobacco Research*, *22*(7), 1098–1106. https://doi.org/10.1093/ntr/ntz110

Rajani, N. B., Mastellos, N., & Filippidis, F. T. (2021). Self-efficacy and motivation to quit of smokers seeking to quit: Quantitative assessment of smoking cessation mobile apps. *JMIR mHealth and uHealth*, *9*(4), e25030. https://doi.org/10.2196/25030

Siddiqi, K., Husain, S., Vidyasagaran, A., Readshaw, A., Mishu, M. P., & Sheikh, A. (2020). Global burden of disease due to smokeless tobacco consumption in adults: An updated analysis of data from 127 countries. *BMC Medicine*, *18*(1), 222. https://doi.org/10.1186/s12916-020-01677-9

Singh, S., Dhanlika, D., Haldar, P., & Sharma, G. (2026). Efficacy of yoga on tobacco cessation: A systematic review and meta-analysis. *Nicotine and Tobacco Research*, *28*(7), 1094–1102. https://doi.org/10.1093/ntr/ntaf236

Smith, S. S., Piper, M. E., Bolt, D. M., Fiore, M. C., Wetter, D. W., Cinciripini, P. M., & Baker, T. B. (2010). Development of the brief Wisconsin inventory of smoking dependence motives. *Nicotine & Tobacco Research*, *12*(5), 489–499. https://doi.org/10.1093/ntr/ntq032

Spek, V., Lemmens, F., Chatrou, M., van Kempen, S., Pouwer, F., & Pop, V. (2013). Development of a smoking abstinence self-efficacy questionnaire. *International Journal of Behavioral Medicine*, *20*(3), 444–449. https://doi.org/10.1007/s12529-012-9229-2

Streeter, C. C., Gerbarg, P. L., Saper, R. B., Ciraulo, D. A., & Brown, R. P. (2012). Effects of yoga on the autonomic nervous system, gamma-aminobutyric-acid, and allostasis in epilepsy, depression, and post-traumatic stress disorder. *Medical Hypotheses*, *78*(5), 571–579. https://doi.org/10.1016/j.mehy.2012.01.021

Tata Institute of Social Sciences. (2017). *Global adult tobacco survey 2 (GATS-2), India 2016–17*. https://www.tiss.edu/projects/global-adult-tobacco-survey-round-2-for-india-2016/

Tobacco Use Among Indian States. (2021). *Tobacco use among Indian states: Key findings from the latest demographic health survey 2019–2020*. Tobacco Prevention & Cessation. https://www.tobaccopreventioncessation.com/Tobacco-use-among-Indian-states-Key-findings-from-the-latest-demographic-health-survey,132466,0,2.html

Tomar, S. L., Alpert, H. R., & Connolly, G. N. (2010). Patterns of dual use of cigarettes and smokeless tobacco among US males: Findings from national surveys. *Tobacco Control*, *19*(2), 104–109. https://doi.org/10.1136/tc.2009.031070

Ussher, M., West, R., Doshi, R., & Sampuran, A. K. (2006). Acute effect of isometric exercise on desire to smoke and tobacco withdrawal symptoms. *Human Psychopharmacology*, *21*(1), 39–46. https://doi.org/10.1002/hup.744

Velicer, W. F. DiClemente, C. C. Rossi, J. S. & Prochaska, J. O. (1990). Relapse situations and self-efficacy: An integrative model. Addictive Behaviors, 15(3), 271–283. 10.1016/0306-4603(90)90070-e 2378287

Vinci, C. (2020). Cognitive behavioral and mindfulness-based interventions for smoking cessation: A review of the recent literature. *Current Oncology Reports*, *22*(6), 58. https://doi.org/10.1007/s11912-020-00915-w

Woodyard, C. (2011). Exploring the therapeutic effects of yoga and its ability to increase quality of life. International Journal of Yoga, 4(2), 49–54. https://doi.org/10.4103/0973-6131.85485 22022122

World Health Organization. (2025, June 25). *Tobacco*. https://www.who.int/news-room/fact-sheets/detail/tobacco