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Body Mass Index and Waist–Hip Ratio Responses to 16 Week Yoga in Female College Students

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Trial registration: CTRI/2025/11/097909 (Clinical Trials Registry–India), registered 24 November 2025.

ABSTRACT: Background: Indian women frequently carry excess and abdominal fat, and weight tends to climb during early adulthood. Whether yoga lowers body mass index (BMI) and waist–hip ratio (WHR) in young women is uncertain.

Objective: To test whether 16 weeks of supervised yoga changes BMI and WHR in female college students.

Methods: In this single-blind, two-arm, pragmatic, parallel-group randomized controlled trial (RCT) at two colleges in Telangana, India, 332 of 375 female D.Ed., B.Ed. and undergraduate degree students were randomized to a yoga group (YG; n = 164) or a control group (CG; n = 168). The YG practised loosening exercises, Surya Namaskar, asanas, pranayama, Jalandhara Bandha and relaxation for 60 min/day, 5 days/week; controls kept their usual routine. After 32 dropouts, 150 per group were analysed with paired and independent-samples t tests and analysis of covariance (ANCOVA).

Results: Post-test BMI was 24.24 ± 3.24 kg/m² in the YG versus 29.95 ± 5.22 kg/m² in the CG (mean difference [MD] −5.71 kg/m²; 95% CI −6.70 to −4.73; $p < .001$). Post-test WHR was 0.755 ± 0.032 versus 0.819 ± 0.048 (MD −0.065; 95% CI −0.074 to −0.055; $p < .001$). Within the YG, BMI dropped by 4.67 kg/m² and WHR by 0.052; within the CG, both rose slightly. Results held when dropouts were imputed.

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Conclusion: Sixteen weeks of supervised yoga was associated with lower BMI and WHR than usual routine. Effects exceeded earlier reports and diet was unrecorded, so replication with dietary assessment, longer follow-up and other populations is needed.

1. INTRODUCTION

In India, a large share of women carry excess weight, much of it around the abdomen. Data from the fifth National Family Health Survey (NFHS-5, 2019–2021) classed 40% of women as abdominally obese on waist circumference, against 12% of men (Chaudhary and Sharma, 2023). At any given body mass index (BMI), Asian people tend to carry more cardiometabolic risk than Europeans; many already face elevated risk of type 2 diabetes and cardiovascular disease while their BMI is still under 25 kg/m² (WHO Expert Consultation, 2004). For this reason, Indian consensus guidance lowers the thresholds to 23 kg/m² for overweight and 25 kg/m² for obesity, with a waist–hip ratio (WHR) cut-off of 0.80 for women (Misra et al., 2009).

The two indices capture different things. BMI scales weight to height, whereas WHR indicates how much fat is stored centrally. That difference has clinical weight: in INTERHEART, which compared roughly 27,000 people across 52 countries, the risk of myocardial infarction climbed steadily with WHR, and the gradient survived adjustment for BMI (Yusuf et al., 2005). For women, WHO treats a WHR ≥ 0.85 as a sign of considerably raised metabolic risk (World Health Organization, 2011). Trials that target adiposity are therefore more informative when they report both indices.

Weight gain is common in the years after school. Pooling 22 studies, Vadeboncoeur et al. (2015) found that first-year university students gained 1.36 kg on average over roughly five months, and that 61% of them gained weight. Trainee teachers on D.Ed. and B.Ed. courses deserve particular attention. Under Ayushman Bharat's School Health Programme, two teachers per school are trained as Health and Wellness Ambassadors and run weekly sessions whose topics include nutrition and yoga (Ministry of Health and Family Welfare and Ministry of Human Resource Development, 2018). Habits formed during training, and first-hand experience of yoga, may influence how these future teachers handle such content. The present trial drew its participants from an educational society that runs D.Ed. and B.Ed. courses together with undergraduate degree programmes.

Yoga brings together postures, regulated breathing and relaxation, needs no equipment and fits easily into a college day. Its effect on body size and fat distribution, however, appears modest:

- **Cardiovascular risk factors.** Across 44 randomized controlled trials (RCTs; 3,168 participants), yoga lowered waist circumference by 1.95 cm (95% confidence interval [CI] 0.89 to 3.01) and WHR by 0.02 (95% CI 0.00 to 0.03) relative to usual care, although risk of bias was high or unclear in most trials (Cramer et al., 2014).
- **Weight-related outcomes.** Pooling 30 RCTs (2,173 participants), Lauche et al. (2016) detected no overall change in weight, BMI, body fat or waist circumference with yoga. Reductions relative to usual care in two subgroups (WHR in healthy adults; BMI in adults with overweight or obesity) did not hold once selection bias was considered.
- **Metabolic syndrome.** In this population, waist circumference fell with yoga (standardized mean difference [SMD] −0.35; 95% CI −0.57 to −0.13) (Cramer et al., 2016).

Typical yoga sessions are of light-to-moderate intensity, about 3.3 metabolic equivalents (METs) on average, but Surya Namaskar reaches roughly 7.4 METs, i.e. moderate-to-vigorous effort (Larson-Meyer, 2016). Few RCTs have measured both BMI and WHR in young Indian women within educational institutions, and many existing yoga trials are small, brief or prone to bias.

We therefore tested whether 16 weeks of supervised yoga, scheduled on five days each week inside the college timetable, would alter BMI and WHR in female college students relative to their usual routine.

1.1 Objectives

Primary objectives

1. Compare post-test (week 16) BMI between the yoga group (YG) and the control group (CG).
2. Compare post-test WHR between the YG and the CG.

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Secondary objectives

1. Describe how BMI and WHR changed within each group between pre-test and post-test.
2. Count participants at or above the WHO and Asian-Indian BMI and WHR cut-offs before and after the programme.
3. Report dropouts in each group.

1.2 Earlier Evidence at a Glance

Table 1 places the present trial alongside the pooled and single-trial evidence cited above. In those sources, yoga's effects on WHR and BMI were small or inconsistent, and the trials were frequently brief or at risk of bias. None examined a sustained programme in young Indian women at college.

Table 1. Present study compared with earlier yoga research on anthropometric outcomes

Author and year	Design and population	Intervention and duration	Outcomes	Key findings and gaps
Cramer et al. (2014)	Meta-analysis of 44 RCTs (N = 3,168): healthy, high-risk and type 2 diabetic adults	Assorted yoga programmes	Cardiovascular risk factors, among them waist circumference and WHR	Against usual care, waist −1.95 cm (95% CI −3.01 to −0.89) and WHR −0.02 (−0.03 to −0.00); risk of bias high or unclear in most trials.
Lauche et al. (2016)	Meta-analysis of 30 RCTs (N = 2,173)	Assorted yoga programmes	Weight, BMI, body fat, waist circumference, WHR	No overall change in weight, BMI, body fat or waist. Subgroups vs usual care: WHR SMD −1.00 (healthy adults), BMI SMD −0.99 (overweight/obese adults); neither robust to selection bias.
Cramer et al. (2016)	Meta-analysis of 7 RCTs (N = 794) in adults with metabolic syndrome	Assorted yoga programmes	Waist circumference, blood pressure, lipid profile, fasting glucose	Waist SMD −0.35 (−0.57 to −0.13); triglycerides, HDL cholesterol and fasting glucose unchanged. Population not limited to young women.
Telles et al. (2014)	Controlled trial; 68 overweight or obese adults (35 women), mean age 36 years	Yoga or walking, 90 min/day for 15 days; both groups on the same calorie-restricted diet	BMI, waist and hip circumference, WHR and other measures	BMI fell in both groups. Very short duration, with a dietary co-intervention in both groups.
Present study	Single-blind, two-arm, parallel-group pragmatic RCT; 332 randomized, 300 analysed; female D.Ed., degree and B.Ed. students	Supervised yoga, 1 h on 5 days each week for 16 weeks; no diet advice	BMI and WHR	Post-test differences of −5.71 kg/m² (BMI) and −0.065 (WHR); dropout 9.6%.

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2. MATERIALS AND METHODS

2.1 Design, Approval and Registration

We ran a single-blind (outcome assessor–masked), two-arm, parallel-group, pragmatic RCT with students of the Madeena Educational Society, Vepalagadda, Telangana, India (Section 2.2). Sessions started on 5 January 2026 and ended on 25 April 2026.

A pragmatic design suited the question, which was whether structured yoga could shift BMI and WHR while students carried on with their normal academic and personal lives. In line with the protocol, which placed lifestyle and food habits outside the study's scope, nothing outside the sessions, including diet, daily routine, lifestyle and physical activity, was controlled or recorded; how these factors may have influenced the results is discussed in Section 3.10.

The Institutional Ethics Committee (IEC) of Meenakshi Academy of Higher Education and Research (MAHER), Chennai, approved the protocol on 24 June 2025 (Ref. No. MAHER/IEC/PhD/81/APRIL25). Registration with the Clinical Trials Registry–India (CTRI; CTRI/2025/11/097909) followed on 24 November 2025, ahead of the first session. The institutional authorities gave written permission for the study. The work conformed to the Declaration of Helsinki; this report follows CONSORT 2025 (Hopewell et al., 2025).

2.2 Study Setting and Population

The study was conducted under the auspices of the Madeena Educational Society, located at Vepalagadda, Bhadradri Kothagudem district, Telangana, India. The society encompasses multiple educational tracks, with a total enrolment of approximately 800 students across various streams. The target study population comprised female students drawn from the following programmes managed by the society:

- **Teacher education programmes:** Diploma in Education (D.Ed.) and Bachelor of Education (B.Ed.) at Madeena B.Ed. College.
- **Undergraduate degree programmes:** Bachelor of Arts (B.A.), Bachelor of Commerce (B.Com.) and Bachelor of Science (B.Sc.) at Madeena Degree College.

Prior to recruitment, the investigator visited the campus on three separate occasions. These preliminary visits served to familiarize the investigator with the campus environment, establish rapport with institutional staff, and brief the prospective student population regarding the purpose, procedures and participation requirements of the study.

2.3 Outcomes Covered Here

Flexibility, BMI, WHR, posture, balance and concentration were all assessed in the trial; only the two anthropometric indices, BMI and WHR, are reported in this paper.

2.4 Registration, Protocol and Data Access

Registration. CTRI/2025/11/097909, recorded on 24 November 2025, before the first session on 5 January 2026.

Protocol. Eligibility rules, the yoga programme and the outcomes are summarized in the CTRI record.

Data access. To safeguard privacy, the dataset is not public; the corresponding author will share de-identified data on reasonable request.

Funding and competing interests. No external grant was received; the authors met the costs themselves and have no competing interests (see the statements at the end).

2.5 Sample Size

Recruitment aimed at the sample size given in the CTRI record (CTRI/2025/11/097909), and all eligible female students who consented were taken in. With 150 participants analysed in each arm, the trial had 80% power (two-sided $\alpha = .05$) to detect a standardized difference of $d = 0.32$.

2.6 Recruitment

Of roughly 800 students across the society's programmes, 375 were women. The first author screened all 375, including a preliminary physical examination to check that each could safely perform the practices. Forty-three chose not to take part for personal reasons; the other 332 gave written informed consent before any baseline measurement and were enrolled (**Figure 1**).

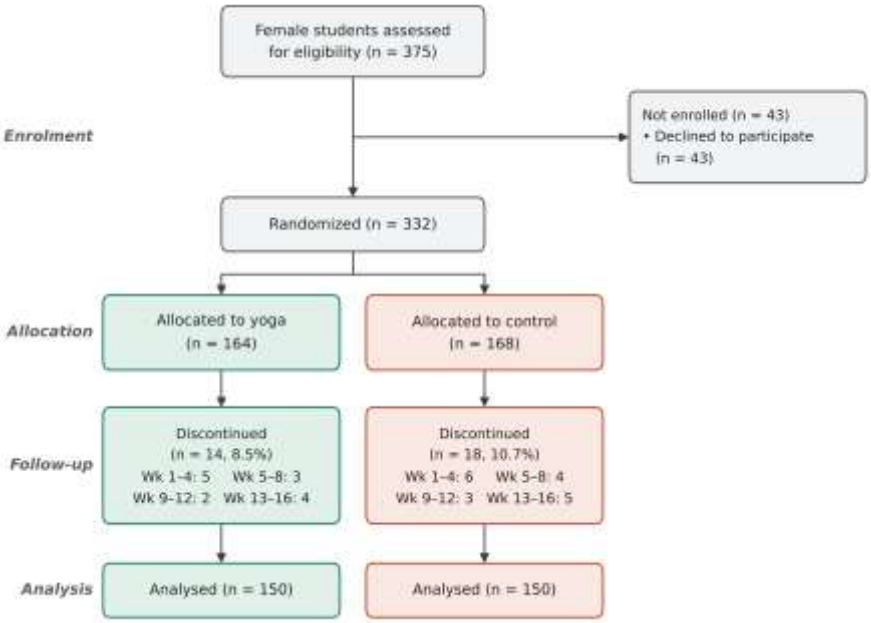


Figure 1. Flow of participants through the trial (CONSORT 2025): screening, enrolment, allocation, dropouts by group and four-week phase, and analysis.

2.7 Inclusion and Exclusion

A student was included if she:

- was aged 18–22 years;
- volunteered and gave written informed consent;
- was found fit for the practices at the first author's preliminary physical examination;
- could attend the scheduled sessions.

A student was excluded if she:

- took part in organized sports or structured athletic training;
- had a medical or physical condition that ruled out the prescribed practices;
- did not give written informed consent.

Enrolment required every inclusion condition and no exclusion condition.

2.8 Random Allocation and Masking

After enrolment, the 332 students were allocated to the YG or the CG by simple (unrestricted) 1:1 randomization. The first author generated the random sequence with statistical software, without blocks or strata, and assigned each enrolled student to the group given by the sequence. Because simple randomization does not guarantee equal arms, the sequence produced 164 YG and 168 CG allocations. Allocation was not concealed; this is listed among the limitations (Section 3.15). Pre-test BMI and WHR were measured after allocation and before the first session. Masking of participants and the instructor was impossible

given the nature of yoga, but the assessors who recorded weight, height, waist and hip at both time points did not know each student's group. The trial was therefore single-blind, with only the outcome assessors masked.

2.9 Yoga Programme

The YG met for 60-minute supervised sessions on five days each week for 16 weeks (80 sessions in all). Classes took place on the campus and were taught by the first author (G.D.), a Ph.D. scholar in yoga science with over 10 years of yoga teaching experience. The sequence in Table 2 was followed in every session, and the programme was purely practical, with no theory classes.

Table 2. Sequence of practices in each session (60 min/day, 5 days/week, 16 weeks)

Order	Component	Practices
1	Loosening exercises	Sukshma Vyayama
2	Surya Namaskar	Sun salutation
3	Standing asanas	Tadasana, Vrikshasana, Utkatasana, Natarajasana, Padahastasana, Parshva Uttanasana, Trikonasana
4	Kneeling, prone and supine asanas	Adho Mukha Svanasana, Eka Pada Rajakapotasana, Marjariasana, Ushtrasana, Bhujangasana, Dhanurasana, Shashankasana, Setu Bandhasana
5	Pranayama	Anuloma Viloma, Bhramari
6	Bandha	Jalandhara Bandha
7	Relaxation	Quick Relaxation Technique (QRT), Shavasana

Control group. CG students kept to their normal academic and daily activities and received neither yoga nor any other study intervention.

Adherence. Attendance was taken at all 80 sessions; YG members attended 94.3% of them on average (about 75 sessions). Attendance did not determine inclusion in the analysis, which depended only on completing the post-test (Section 2.13).

2.10 Safety

Over the 80 supervised sessions no injury or adverse effect was reported, and no student left the study because of the yoga.

2.11 Dropouts

Before the post-test, 32 of the 332 students (9.6%) dropped out: 14 from the YG (8.5%) and 18 from the CG (10.7%). A student counted as a dropout if she left before the week-16 assessment and therefore had no post-test values; no student who stayed to the post-test was excluded, whatever her attendance. Dropouts were logged in four-week phases (Table 3), and how they were handled in the analysis is described in Section 2.13.

Reasons were logged by programme. New D.Ed. entrants found it hard to cope with academic demands. B.Ed. students cited personal circumstances, and some were not available on the post-test day. Employment commitments and preparation for competitive examinations also took B.Ed. and undergraduate degree (B.A., B.Com. and B.Sc.) students away. None of the dropouts was linked to the yoga programme.

Table 3. Dropouts by four-week phase and group

Phase	Weeks	Yoga	Control	Total
I	1–4	5	6	11
II	5–8	3	4	7
III	9–12	2	3	5
IV	13–16	4	5	9
Total	1–16	14 (8.5%)	18 (10.7%)	32 (9.6%)

Percentages use the number allocated to each group (164 Yoga, 168 Control; 332 overall).

2.12 Measurements

Each outcome was measured on two occasions only: at pre-test, after allocation and before the first session, and at post-test, at the end of week 16. Nothing was measured in between, and both groups were measured the same way each time.

Body mass index. Weight and height were recorded, and BMI was computed in kg/m² (weight in kilograms divided by height in metres squared).

Waist–hip ratio. Waist and hip girths were taken with a measuring tape, and WHR was obtained by dividing the waist value by the hip value.

2.13 Data Analysis

Analyses used Python 3.13 with SciPy 1.18 and NumPy 2.5, and figures were produced with Matplotlib 3.11. Continuous data are given as mean ± standard deviation (SD), and a two-sided $p < .05$ denoted significance.

Analysis set and handling of dropouts. The main analysis included the 300 completers (150 per group) with both pre-test and post-test values. The 32 dropouts (14 YG, 18 CG) had no post-test values and were excluded from the main analysis without imputation, so the analysis is per-protocol (PP). Because a PP analysis can be biased if those who leave differ from those who stay, two intention-to-treat (ITT)-style sensitivity analyses compared change scores (post-test minus pre-test) in all 332 randomized students, with each dropout's change imputed (i) as zero, i.e. no change from pre-test, and (ii) as the mean change of CG completers, i.e. assuming yoga had no effect in dropouts. These comparisons, and the same change-score comparison in completers for reference, used Welch *t* tests. Single imputation understates uncertainty, so these analyses show whether the conclusions depend on how dropouts are handled rather than replacing the PP estimates. Dropout proportions were compared with Fisher's exact test.

Baseline. Independent-samples *t* tests compared pre-test BMI and WHR between arms. These tests show how alike the analysed groups were at entry; they were not used to judge whether randomization had worked, and no analysis was adjusted because of them.

Within-group change. As planned, paired-samples *t* tests compared pre-test with post-test values inside each arm. Change was defined as post-test minus pre-test (negative = reduction) and is reported as mean change, 95% confidence interval (CI), *t* (df = 149) and *p*.

Between-group comparison. Student's (pooled-variance) independent-samples *t* tests compared post-test values (df = 298). We report the mean difference (MD; YG minus CG) with its 95% CI, *t*, *p* and Cohen's *d* (MD divided by the pooled SD). With arms of equal size, the pooled and Welch *t* statistics coincide. BMI and WHR were co-primary outcomes; *p* values were not adjusted for multiplicity but were also checked against a Bonferroni threshold of .025.

Adjustment for baseline values. A within-group test is not a comparison between arms (Bland and Altman, 2011), and an unadjusted post-test comparison ignores chance imbalance at baseline. Post-test values were therefore also analysed by analysis of covariance (ANCOVA; Vickers and Altman, 2001): post-test value = $\beta_0 + \beta_1 \times$ group $+ \beta_2 \times$ pre-test value, with group

coded 1 for the YG and 0 for the CG. The pre-test value of the same outcome was the only covariate; no other variable was adjusted for. β_1 is the adjusted MD, reported with its 95% CI, $F(1, 297)$ and partial η^2, and adjusted means were computed at the overall pre-test mean. Model assumptions were checked: homogeneity of regression slopes by adding a group × pre-test term, normality of residuals with the Shapiro–Wilk test and equality of residual variances with Levene's test. Where slopes differed between arms, the model was refitted with the interaction term and the pre-test value centred at its overall mean, so that the group coefficient gives the effect at the mean pre-test value, and effects were also estimated at selected pre-test values. To guard against non-normal and unequal residual variances, ANCOVA CIs were also computed with heteroscedasticity-consistent (HC3) standard errors.

Non-parametric checks. As change scores were not normally distributed (Shapiro–Wilk $p < .001$), every comparison was repeated with Wilcoxon signed-rank and Mann–Whitney U tests.

Clinical categories. Each participant was classed against the WHO cut-offs (BMI 25 and 30 kg/m²; WHR 0.85 in women) (World Health Organization, 2000, 2011) and the Asian-Indian cut-offs (BMI 23 and 25 kg/m²; WHR 0.80 in women) (Misra et al., 2009). Within-group shifts in the count at or above each cut-off were tested with the exact McNemar test, and post-test counts were compared between arms with Yates-corrected χ^2 tests.

3. RESULTS AND DISCUSSION

3.1 Flow of Participants and Baseline Values

All 375 female students were screened; 43 declined, and 332 were randomized (YG 164, CG 168). With 32 (9.6%) dropping out before the post-test, 150 per group entered the analysis (**Figure 1**; Table 3). The proportion dropping out did not differ significantly between arms (8.5% vs 10.7%; Fisher's exact $p = .578$). No further exclusions were made, and no outcome value was missing among those analysed.

Pre-test BMI averaged 28.91 ± 5.14 kg/m² in the YG and 29.66 ± 5.19 kg/m² in the CG (MD −0.75 kg/m², 95% CI −1.93 to 0.42; $t(298) = -1.26$, $p = .207$). WHR averaged 0.807 in each group ($t(298) = -0.06$, $p = .952$) (Tables 4 and 5).

Table 4. BMI and WHR at pre-test and post-test in each group (n = 150 per group)

Outcome	Group	Pre-test, mean ± SD	Post-test, mean ± SD	Mean change (95% CI)	Change (%)	*t* (df = 149)	*P*
BMI (kg/m²)	Yoga	28.91 ± 5.14	24.24 ± 3.24	−4.67 (−5.34 to −4.00)	−16.2	−13.79	< .001
BMI (kg/m²)	Control	29.66 ± 5.19	29.95 ± 5.22	+0.29 (0.16 to 0.42)	+1.0	4.42	< .001
WHR	Yoga	0.807 ± 0.052	0.755 ± 0.032	−0.052 (−0.058 to −0.046)	−6.4	−15.92	< .001
WHR	Control	0.807 ± 0.044	0.819 ± 0.048	+0.012 (0.010 to 0.015)	+1.5	9.87	< .001

Change: post-test minus pre-test. p from paired-samples t tests.

3.2 Body Mass Index

In the YG, mean BMI dropped from 28.91 ± 5.14 to 24.24 ± 3.24 kg/m² (**Figure 2A**), a mean change of −4.67 kg/m² (95% CI −5.34 to −4.00; $t(149) = -13.79$, $p < .001$), i.e. 16.2% below the pre-test mean. BMI decreased in 135 of 150 YG participants, stayed the same in 9 and increased in 6 (**Figure 3A**). In the CG, BMI went up from 29.66 ± 5.19 to 29.95 ± 5.22 kg/m² (mean change +0.29 kg/m², 95% CI 0.16 to 0.42; $t(149) = 4.42$, $p < .001$; +1.0%).

At post-test the YG mean sat 5.71 kg/m² below the CG mean (95% CI −6.70 to −4.73; $t(298) = -11.39$, $p < .001$), a gap equal to 1.31 pooled SDs (Cohen's $d = -1.31$) (Table 5; **Figure 4A**).

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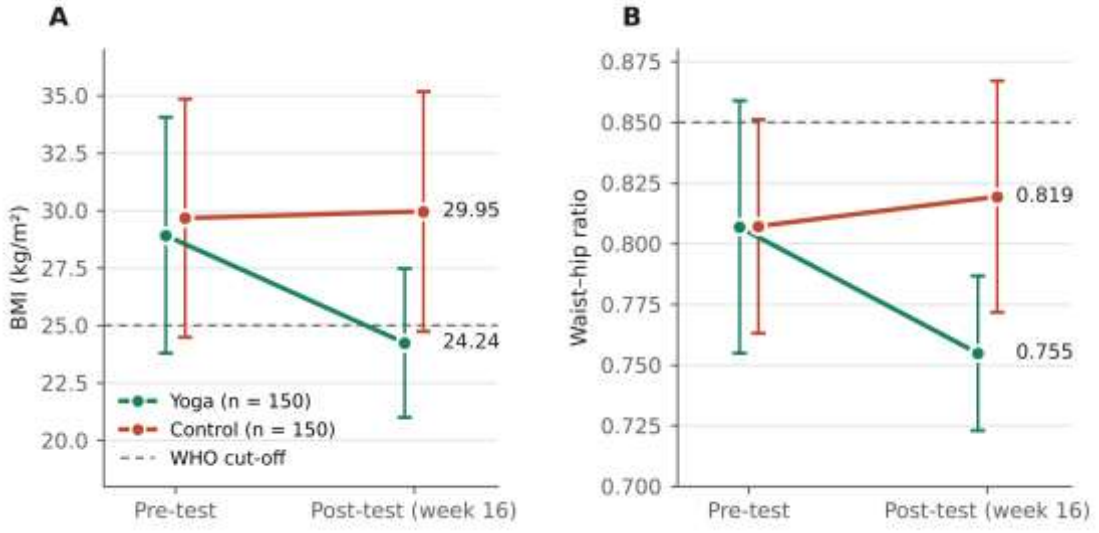


Figure 2. Group means of body mass index (A) and waist–hip ratio (B) before and after the programme (n = 150 per group). Error bars are ±1 SD, and the value printed beside each post-test point is its mean. Dashed lines show the WHO cut-offs (BMI 25 kg/m²; WHR 0.85 in women).

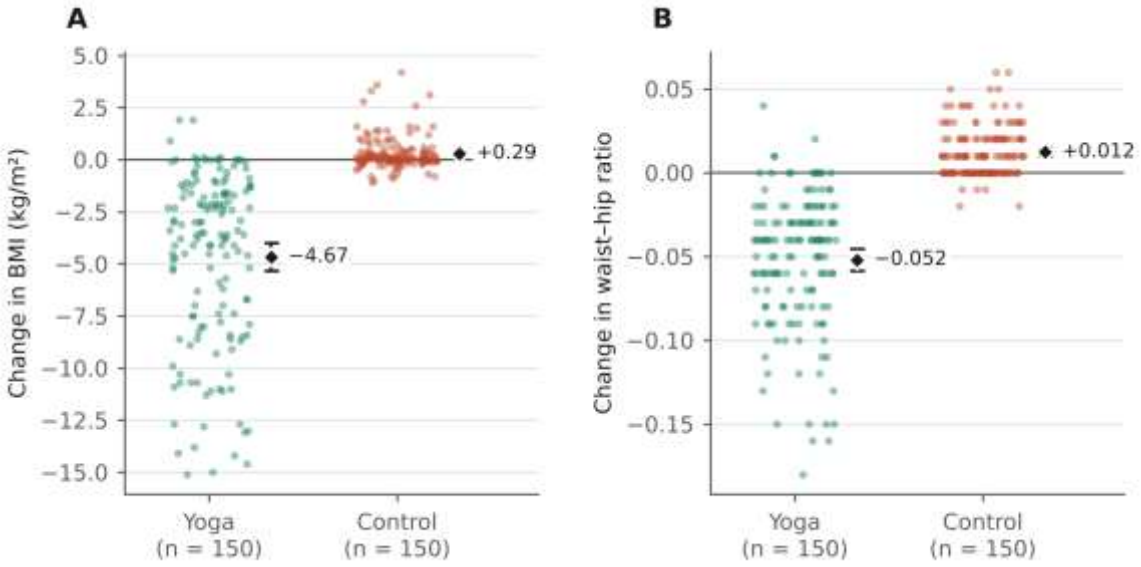


Figure 3. Change from pre-test to post-test for every participant in body mass index (A) and waist–hip ratio (B). Dots are jittered sideways so that they overlap less, and darker dots mark coincident values; diamonds give each group's mean change and 95% CI.

3.3 Waist–Hip Ratio

WHR in the YG declined from 0.807 ± 0.052 to 0.755 ± 0.032 (**Figure 2B**): a mean change of −0.052 (95% CI −0.058 to −0.046; $t(149) = -15.92$, $p < .001$), or −6.4%. It decreased in 135 YG participants, stayed the same in 11 and increased in 4 (**Figure 3B**). CG values climbed from 0.807 ± 0.044 to 0.819 ± 0.048 (mean change +0.012, 95% CI 0.010 to 0.015; $t(149) = 9.87$, $p < .001$; +1.5%), increasing in 87, unchanged in 58 and decreasing in 5 participants.

Post-test WHR in the YG was 0.065 below that of the CG (95% CI −0.074 to −0.055; $t(298) = -13.80$, $p < .001$; $d = -1.59$; **Figure 4B**).

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Table 5. BMI and WHR compared between groups (YG minus CG; n = 150 per group)

Outcome	Comparison	Mean difference (95% CI)	Test statistic	*p*	Effect size
BMI (kg/m²)	Pre-test	−0.75 (−1.93 to 0.42)	$t(298) = -1.26$	.207	$d = -0.15$
BMI (kg/m²)	Post-test	−5.71 (−6.70 to −4.73)	$t(298) = -11.39$	< .001	$d = -1.31$
BMI (kg/m²)	Post-test, adjusted for pre-test (ANCOVA)	−5.20 (−5.77 to −4.62)	$F(1, 297) = 317.7$	< .001	partial $\eta^2 = 0.52$
WHR	Pre-test	0.000 (−0.011 to 0.011)	$t(298) = -0.06$	.952	$d = -0.01$
WHR	Post-test	−0.065 (−0.074 to −0.055)	$t(298) = -13.80$	< .001	$d = -1.59$
WHR	Post-test, adjusted for pre-test (ANCOVA)	−0.064 (−0.070 to −0.059)	$F(1, 297) = 483.4$	< .001	partial $\eta^2 = 0.62$

t: independent-samples test with pooled variance. ANCOVA: post-test value modelled on group (factor) and pre-test value (covariate).

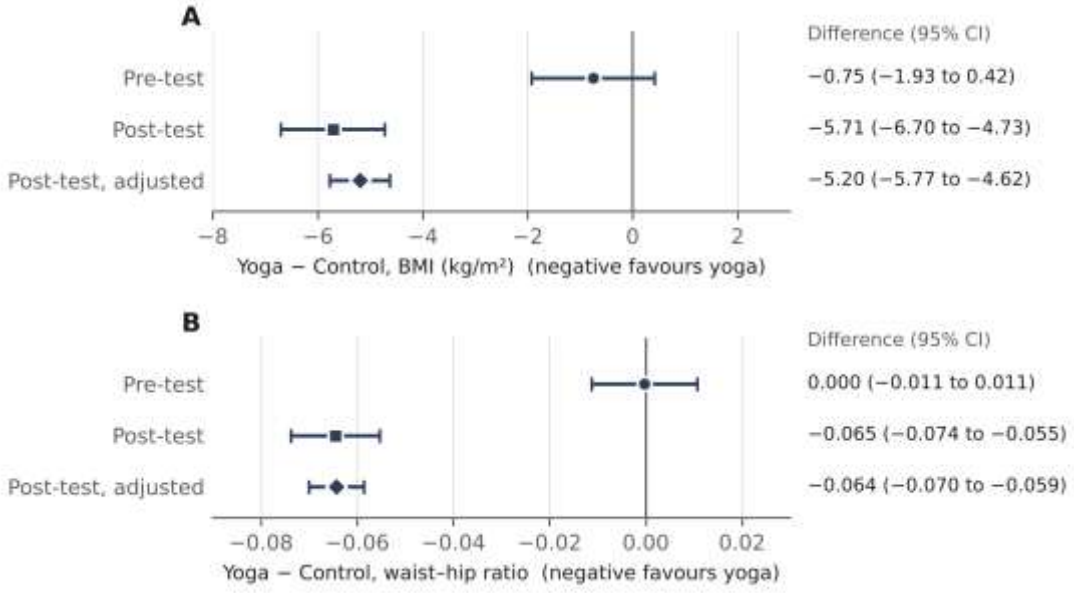


Figure 4. Differences between groups (YG minus CG), with 95% CIs, in body mass index (A) and waist–hip ratio (B): at pre-test, at post-test, and at post-test after ANCOVA adjustment for the pre-test value. Values below zero favour yoga.

3.4 Participants Above Clinical Cut-Offs

Before the programme the two groups had similar counts at or above every cut-off (all $p > .29$). In the YG, BMI ≥ 30 kg/m² dropped from 62 to 5 participants and WHR ≥ 0.85 from 35 to 0 (both $p < .001$). In the CG, both counts increased: BMI ≥ 30 kg/m² from 72 to 78 ($p = .031$) and WHR ≥ 0.85 from 30 to 43 ($p = .004$) (Table 6). At post-test three YG participants had BMI under 18.5 kg/m², against four at pre-test.

Table 6. Counts at or above the WHO and Asian-Indian cut-offs before and after the programme (n = 150 per group)

Cut-off	Yoga: pre-test → post-test	Control: pre-test → post-test	Between groups at post-test
BMI ≥ 23 kg/m² (Asian-Indian overweight)	129 → 99 ($p < .001$)	128 → 129 ($p = 1.000$)	$\chi^2(1) = 15.4$, $p < .001$
BMI ≥ 25 kg/m² (WHO overweight; Asian-Indian obesity)	121 → 74 ($p < .001$)	116 → 118 ($p = .500$)	$\chi^2(1) = 26.8$, $p < .001$
BMI ≥ 30 kg/m² (WHO obesity)	62 → 5 ($p < .001$)	72 → 78 ($p = .031$)	$\chi^2(1) = 86.3$, $p < .001$
WHR ≥ 0.80 (Asian-Indian, women)	95 → 17 ($p < .001$)	97 → 104 ($p = .016$)	$\chi^2(1) = 102.4$, $p < .001$
WHR ≥ 0.85 (WHO, women)	35 → 0 ($p < .001$)	30 → 43 ($p = .004$)	$\chi^2(1) = 47.9$, $p < .001$

Within groups: exact McNemar test. Between groups: Yates-corrected χ^2 test.

3.5 Adjusted, Sensitivity and Non-Parametric Results

With pre-test values as covariate (ANCOVA), the post-test MD was −5.20 kg/m² for BMI (95% CI −5.77 to −4.62; $F(1, 297) = 317.7$, $p < .001$; partial $\eta^2 = 0.52$) and −0.064 for WHR (95% CI −0.070 to −0.059; $F(1, 297) = 483.4$, $p < .001$; partial $\eta^2 = 0.62$) (Tables 5 and 7; **Figure 4**). Adjusted means were 24.50 kg/m² in the YG and 29.69 kg/m² in the CG for BMI, and 0.755 and 0.819 for WHR. The adjusted BMI gap is narrower than the unadjusted 5.71 kg/m² because the CG began 0.75 kg/m² higher. HC3 standard errors gave almost the same intervals (BMI −5.79 to −4.60 kg/m²; WHR −0.070 to −0.059).

The regression slopes were not homogeneous: the group × pre-test interaction was significant for both outcomes ($p < .001$), with larger YG–CG differences at higher pre-test values. At the mean pre-test value, the interaction model gave −5.20 kg/m² (95% CI −5.64 to −4.76) for BMI and −0.064 (95% CI −0.069 to −0.060) for WHR, the same as the main ANCOVA. Estimated differences were −2.53, −5.64 and −8.75 kg/m² at pre-test BMI values of 25, 30 and 35 kg/m², and −0.028, −0.060 and −0.092 at pre-test WHR values of 0.75, 0.80 and 0.85. These estimates are exploratory.

In completers, the between-group difference in change scores was −4.96 kg/m² for BMI and −0.064 for WHR. With all 332 randomized students included, the difference was −4.53 kg/m² and −0.058 when dropouts were assigned no change, and −4.54 kg/m² and −0.059 when they were assigned the mean change of CG completers (all $p < .001$; Table 7). Handling dropouts in these ways therefore reduced the estimates slightly but did not change the conclusions.

Every within-group change was significant on the Wilcoxon signed-rank test ($p < .001$), and both post-test between-group comparisons were significant on the Mann–Whitney U test ($p < .001$). All post-test and ANCOVA p values fell below the Bonferroni threshold of .025.

Table 7. Between-group differences under alternative analyses (YG minus CG)

Analysis	n (YG/CG)	BMI, MD (95% CI), kg/m²	WHR, MD (95% CI)
Post-test, unadjusted (main analysis)	150/150	−5.71 (−6.70 to −4.73)	−0.065 (−0.074 to −0.055)
ANCOVA, adjusted for pre-test value	150/150	−5.20 (−5.77 to −4.62)	−0.064 (−0.070 to −0.059)
ANCOVA with HC3 standard errors	150/150	−5.20 (−5.79 to −4.60)	−0.064 (−0.070 to −0.059)
ANCOVA with group × pre-test interaction, effect at mean pre-test value	150/150	−5.20 (−5.64 to −4.76)	−0.064 (−0.069 to −0.060)
Change score, completers	150/150	−4.96 (−5.64 to −4.28)	−0.064 (−0.071 to −0.057)

Change score, all randomized; dropouts assigned no change	164/168	−4.53 (−5.19 to −3.88)	−0.058 (−0.065 to −0.052)
Change score, all randomized; dropouts assigned CG mean change	164/168	−4.54 (−5.20 to −3.88)	−0.059 (−0.066 to −0.052)

MD: mean difference. HC3: heteroscedasticity-consistent standard errors. Change scores (post-test minus pre-test) were compared with Welch t tests. All $p < .001$.

3.6 Main Results in Brief

In this single-blind, two-arm trial, after 16 weeks the 150 YG participants had lower BMI and WHR than the 150 CG participants.

- **Unadjusted post-test gap:** BMI 5.71 kg/m² lower (95% CI 4.73 to 6.70) and WHR 0.065 lower (95% CI 0.055 to 0.074); both $p < .001$.
- **ANCOVA-adjusted gap:** 5.20 kg/m² for BMI and 0.064 for WHR.
- **Change in the YG:** BMI −4.67 kg/m² (16.2%); WHR −0.052 (6.4%).
- **Change in the CG:** small rises in both indices.
- **Cut-offs:** YG participants with BMI ≥ 30 kg/m² fell from 62 to 5, and none stayed at or above the WHO WHR cut-off of 0.85.

3.7 How the Findings Compare with Earlier Studies

Our WHR effect exceeds the pooled estimates. Across 44 RCTs, yoga lowered WHR by 0.02 and waist circumference by 1.95 cm relative to usual care (Cramer et al., 2014); the 0.065 post-test WHR gap seen here is roughly three times as large. For BMI, the 30-trial synthesis by Lauche et al. (2016) showed no overall yoga effect, only a fragile subgroup effect in adults with overweight or obesity.

Sizeable short-term falls in BMI have been seen when yoga was paired with caloric restriction: in a 15-day trial where the yoga and walking arms followed an identical low-calorie diet, BMI decreased in both (Telles et al., 2014). Our programme gave no dietary advice, but because food intake was not recorded, dietary change during the study cannot be ruled out.

Two characteristics of this trial may partly explain why its effects exceed earlier ones. Participants began with high BMI (121 of 150 YG members were at or above the Asian-Indian obesity cut-off of 25 kg/m² at pre-test), and the programme was intensive and supervised, with 80 sessions in 16 weeks.

3.8 Change in the Control Group

Over 16 weeks, CG means rose by 0.29 kg/m² (1.0%) for BMI and by 0.012 (1.5%) for WHR, and the count at or above the WHO WHR cut-off went from 30 to 43. Students commonly gain weight: one meta-analysis put the gain among first-year university students at 1.36 kg over about five months (Vadeboncoeur et al., 2015). Term-time academic pressure and lower physical activity may have contributed.

Even so, the CG's WHR change was strikingly uniform, rising in 87 of 150 participants and falling in just 5. As WHR was recorded to two decimals, a slight shift in measuring technique between the two assessments could move many values by 0.01, so a measurement effect is possible. The CG's rise explains only a minority of the between-group gap; most of it comes from change in the YG.

3.9 How Large Are the Effects?

The standardized effects are large, with post-test means separated by 1.31 pooled SDs for BMI and 1.59 for WHR. Behavioural interventions rarely produce differences of this size.

A 4.67 kg/m² fall in mean BMI equals roughly 10–12 kg for a woman 1.50–1.60 m tall. Individual changes ranged widely, from −15.1 to +1.9 kg/m² (**Figure 3A**), and 22 YG participants lost more than 10 kg/m². Since most yoga is of light to moderate

intensity (Larson-Meyer, 2016), the energy spent in 80 sessions probably cannot explain reductions this large by itself; unrecorded changes in eating or other habits, and measurement factors, may also have played a part (Section 3.10).

Every adjusted, robust, non-parametric and ITT-style analysis agreed on the direction and significance of the effects (Table 7). Their size, though, should be treated as provisional until it is reproduced in other settings with recorded diet and physical activity (Section 3.10).

3.10 Diet and Other Lifestyle Factors

In keeping with the pragmatic design, food intake, physical activity outside the sessions, sleep and other daily habits were neither controlled nor recorded. These factors could have shaped the results in several ways:

- **Changes prompted by the programme.** Taking part in a structured, supervised programme may have led YG members to eat less, choose different foods or be more active outside class. Such changes would form part of the effect of offering the programme, they would mean that the reductions can be credited to the yoga practices. Given the size of the BMI change (Section 3.9), a contribution of this kind is plausible.
- **Changes in the control group.** CG students' habits may also have shifted over the 16 weeks, in either direction, as study load, meal routines and activity changed across the term. The small rise in CG BMI and WHR (Section 3.8) fits such drift but cannot be traced to a particular cause.
- **Living and eating arrangements.** Where students lived and ate, which can shape meal patterns and daily activity, was not recorded. Randomization should balance such characteristics between arms on average, but this could not be checked.
- **Contamination.** CG students shared the campus with YG students and may have tried some of the practices. Any such contamination would tend to shrink, not enlarge, the between-group difference.
- **Measurement conditions.** Short-term factors such as recent meals, fluid status, time of day and menstrual-cycle phase can shift single readings of weight and waist girth. They could not be accounted for and add noise to individual values, but they are unlikely to differ systematically between arms when assessors do not know group membership.

Because none of these influences was measured, their contribution cannot be estimated from the present data. Recording diet and physical activity is therefore a priority for replication (Section 3.16).

3.11 Possible Explanations

Mechanisms were not measured; the pathways below are plausible rather than proven:

- **Energy expenditure.** Surya Namaskar can reach moderate-to-vigorous intensity (Larson-Meyer, 2016), and sessions ran on five days each week.
- **Stress and eating.** Pranayama and relaxation may lower stress and stress-driven eating. Stress hormones are associated with central fat storage, but cortisol and eating behaviour were not assessed.
- **Posture and trunk muscle tone.** Postures that work the trunk may alter waist measurements without any loss of fat, so part of the WHR change could be postural.
- **Health awareness.** Joining a structured programme may have led to other, unrecorded changes in diet or activity (Section 3.10).

As the programme bundled several practices, the contribution of any single component cannot be isolated.

3.12 What the 16-Week Period Does and Does Not Show

The programme ran for 16 weeks (80 sessions), roughly one academic term. This allowed the whole programme to be delivered within the timetable with high attendance, and it is long compared with very short trials such as the 15-day programme of Telles et al. (2014). Its implications are nonetheless limited:

- **Effect at one time point.** The results describe the difference at the end of week 16. As nothing was measured in between, the time course is unknown: the reductions may have built steadily, levelled off after some weeks, or still been continuing at week 16.
- **Maintenance.** There was no follow-up after the sessions ended, so it is not known whether the lower BMI and WHR persisted once supervised practice stopped; changes achieved under supervision may fade when that support is withdrawn.
- **Dose.** Whether a shorter, less frequent or longer programme would give a smaller or larger effect cannot be judged, because only one schedule was tested and attendance was not analysed against outcome.
- **Practicality.** A 16-week block fits a semester calendar and could be repeated each term, but sustaining practice across vacations and between academic years would need planning.

Trials with intermediate measurements and follow-up after the programme ends are needed to show how quickly changes occur and how long they last.

3.13 To Whom Do the Findings Apply?

Several features of the sample limit how far the results can be generalized:

- **Sex and age.** All participants were women aged 18–22 years. Men store fat differently and are judged against a different WHR cut-off (0.90 rather than 0.85; World Health Organization, 2011), so the findings cannot be assumed to apply to men. Adolescents, older adults and postmenopausal women were not studied.
- **Starting weight.** Pre-test BMI was high (mean about 29 kg/m²; 121 of 150 YG members at or above 25 kg/m²), and the effect was larger at higher pre-test values (Section 3.5). Smaller absolute changes might be expected in women of normal weight.
- **Setting.** Participants came from the teacher-education and undergraduate programmes of a single educational society in Bhadradri Kothagudem district, Telangana. Students elsewhere, with different diets, routines and facilities, and non-student or urban populations may respond differently.
- **Health and activity status.** Students with conditions that ruled out the practices, and those already in organized sports or athletic training, were excluded, so the results do not describe people with chronic disease or those who are already trained.
- **Delivery.** One experienced instructor taught every session on campus, and attendance averaged 94.3%. In community settings or with less experienced instructors, attendance, and therefore effects, may be lower.

The findings are therefore most relevant to young women in Indian colleges and teacher-education institutions where a supervised daily yoga session can be built into the timetable. Trials in men, in other age groups and regions, and outside educational institutions are needed before wider claims are made.

3.14 Feasibility

All 80 supervised sessions fitted within the college timetable; mean attendance was 94.3%, and no injuries or adverse effects occurred. Dropout was 9.6% overall and comparable between arms (8.5% YG, 10.7% CG). Colleges could therefore add a practice-based yoga programme to their timetable. For D.Ed. and B.Ed. students, it would also provide first-hand experience of a practice they may later teach under the School Health Programme (Ministry of Health and Family Welfare and Ministry of Human Resource Development, 2018).

3.15 Strengths and Weaknesses

Strengths.

- Randomization and a large sample (332 allocated; 300 analysed).
- CTRI registration.

- Eighty supervised sessions following a fixed sequence.
- High attendance (mean 94.3%).
- Single-blind design, with assessors who did not know group membership.
- Dropouts reported by arm and by four-week phase.
- Two complementary anthropometric indices.
- Between-group estimates with CIs and effect sizes.
- Individual-level classification against clinical cut-offs.
- Consistent results across adjusted, robust, non-parametric and ITT-style sensitivity analyses.

Weaknesses.

1. The main analysis was PP. Dropouts had no post-test values, so a true ITT analysis was impossible; ITT-style imputation gave similar results (Table 7), but single imputation cannot rule out bias if dropouts differed from completers.
2. The first author generated the random sequence with statistical software and also enrolled and assigned the students. Allocation was not concealed (for example, with sequentially numbered, sealed, opaque envelopes), so selection bias at allocation cannot be excluded.
3. Neither students nor the instructor could be masked, and the first author also screened participants and taught the sessions; the outcome assessors, however, did not know group membership.
4. Diet, physical activity outside the sessions, sleep and other behaviours were not recorded and may have changed during the trial (Section 3.10).
5. All participants were women aged 18–22 years from one educational society, most with high BMI, so the results may not apply to other groups (Section 3.13).
6. With a passive control, the trial cannot show whether yoga outperforms another programme of equal time and attention.
7. Delivery was documented through attendance records and a fixed session sequence, but session content, duration and intensity were not independently monitored.
8. BMI and WHR estimate adiposity only indirectly; fat mass and its distribution were not measured, and WHR was recorded to two decimals.
9. Baseline characteristics beyond BMI and WHR (e.g. age, height, weight) are not reported.
10. Outcomes were measured only at pre-test and week 16, with no follow-up afterwards, so the time course and durability of the changes are unknown (Section 3.12).
11. Several outcomes were measured in the trial, and only two are reported here.

3.16 Next Steps for Research

The findings need replication before they guide practice. Further trials should:

- set yoga against an active comparator matched for time and attention;
- assess diet (for example, repeated 24-hour recalls or a validated food-frequency questionnaire) and physical activity (a validated questionnaire or accelerometry) at every assessment;
- add intermediate measurements and follow participants for 6–12 months after supervised sessions stop, to show the time course and durability of change;

- monitor delivery in a standard way, with a written session protocol and checklist, records of attendance and of each session's content and duration, a simple intensity measure such as rating of perceived exertion, and periodic observation by a second instructor;
- standardize measurement, with set conditions (time of day, light clothing, before meals), calibrated scales, duplicate girth readings to 0.1 cm and assessors trained to a written protocol;
- conceal allocation, for example with sequentially numbered, sealed, opaque envelopes prepared by someone outside the study team;
- measure body composition directly;
- examine whether attendance predicts outcome;
- include men, other age groups and non-student populations, at several centres.

4. CONCLUSIONS

Among female college students in this 16-week single-blind, two-arm, parallel-group RCT, supervised yoga on five days a week was associated with lower BMI and WHR than usual routine. Post-test BMI was 24.24 kg/m² in the YG and 29.95 kg/m² in the CG (MD −5.71 kg/m²; 95% CI −6.70 to −4.73), and post-test WHR was 0.755 and 0.819 (MD −0.065; 95% CI −0.074 to −0.055). Both indices increased slightly in the CG over the same period.

Because the YG reductions exceed those of earlier yoga trials and diet was not recorded, they should be regarded as provisional. They apply most directly to young women in Indian colleges with a supervised daily yoga session in the timetable. Replication with dietary and physical-activity assessment, intermediate and post-programme follow-up, standardized monitoring of programme delivery and more diverse participants is needed. With those caveats, a practice-based yoga programme seems feasible within a college timetable.

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AUTHOR CONTRIBUTIONS

Gowthami Dantuluri: Conceptualization, methodology, data collection, investigation, formal analysis, interpretation of results, and writing – original draft.

Selvi Vinayak: Supervision, methodological guidance, and writing – review and editing.

T. Ganesh Kumar: Technical expertise, validation, and advice during research advisory meetings.

Shalini Balasubramani: Research advisory committee membership, review of study progress, and review of the final manuscript.

Subbulakshmi Velusamy: Resources, institutional support, and administrative oversight.

Every author has read and approved the final manuscript.

CONFLICT OF INTEREST

None of the authors has a competing interest to declare.

ETHICS STATEMENT

The IEC of MAHER, Chennai, approved the study on 24 June 2025 (Ref. No. MAHER/IEC/PhD/81/APRIL25), and it was

entered in the CTRI on 24 November 2025 (CTRI/2025/11/097909). Every participant took part voluntarily after giving written informed consent, and the study adhered to the Declaration of Helsinki.

DATA AVAILABILITY STATEMENT

The dataset is not posted publicly, in order to protect participant privacy. The corresponding author will share de-identified data on reasonable request.

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