
Comparative Study of Surya Namaskar and Aerobic Exercise on Flexibility and Endurance

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ABSTRACT

Background: The choice between traditional movement-based practices and modern aerobic training as tools for improving physical fitness has long drawn debate. Both Surya Namaskar the classical Indian yogic sequence and conventional aerobic exercise have documented benefits, yet direct, controlled comparisons under equivalent training volumes remain scarce.

Objective: This study aimed to compare the effects of a structured 12-week Surya Namaskar programme against a standard aerobic exercise programme on two primary physical fitness variables: musculoskeletal flexibility and cardiorespiratory endurance in sedentary young adults.

Methods: Ninety sedentary volunteers (mean age 21.4 ± 2.1 years; 45 males, 45 females) were randomly assigned to one of three groups: Surya Namaskar (SN), aerobic exercise (AE), or a non-exercising control (CG), with 30 participants per group. Both active groups trained five days per week for 12 weeks, with sessions matched for duration (45 minutes). Flexibility was assessed using the standard sit-and-reach test, and cardiorespiratory endurance was measured via estimated VO_2 max using a 20-metre shuttle run (Beep Test). Pre- and post-intervention data were analysed using paired t-tests within groups and one-way ANCOVA between groups.

Results: Both the SN and AE groups showed statistically significant improvements across all measured outcomes relative to the CG ($p < 0.001$). The SN group recorded a mean flexibility gain of 8.6 ± 1.4 cm (60.6%), significantly outperforming the AE group (5.2 ± 1.1 cm; 37.4%). In contrast, the AE group showed a greater mean increase in VO_2 max (10.4 ± 2.0 ml·kg⁻¹·min⁻¹; 32.6%) compared to the SN group (7.3 ± 1.6 ml·kg⁻¹·min⁻¹; 23.2%). The control group showed no meaningful change in either parameter. **Conclusion:** Surya Namaskar is superior to aerobic exercise for developing flexibility, while aerobic exercise yields greater gains in cardiorespiratory endurance. However, the SN group still produced substantial endurance improvements, suggesting that Surya Namaskar may serve as an effective, accessible, and culturally contextualised alternative for comprehensive fitness conditioning, especially in populations with limited access to equipment or gym facilities.

KEYWORDS:

Surya Namaskar, Yoga, Aerobic Exercise, Flexibility, Cardiorespiratory Endurance, VO_2 max, Sit-And-Reach, Randomised Controlled Trial, Physical Fitness, Young Adults.

1. INTRODUCTION

Physical inactivity is one of the most consequential public health problems of our time. The World Health Organization reported in 2022 that over 1.4 billion adults worldwide fail to meet recommended physical activity levels, and the proportion of sedentary young adults has climbed steadily in the years following the COVID-19 pandemic (WHO, 2022). In India specifically, the picture is worrying: national survey data from 2023 indicate that fewer than 25% of college-aged individuals meet the minimum aerobic activity threshold (Ministry of Health and Family Welfare, 2023). Against this backdrop, identifying exercise modes that are not only effective but also sustainable, low-cost, and culturally appropriate is more than an academic exercise.

Aerobic exercise—including jogging, cycling, brisk walking, and structured group fitness—has accumulated perhaps the most extensive evidence base of any exercise modality. Its benefits to cardiorespiratory fitness, metabolic health, body composition, and mental wellbeing are well established across age groups (Warburton & Bredin, 2017; Ross et al., 2020). Yet aerobic programmes often require equipment, dedicated infrastructure, or paid memberships, which limits their adoption in resource-constrained settings.

Surya Namaskar (SN), literally translated as "sun salutation," is a 12-posture sequential yogic practice that has been performed for centuries in the Indian subcontinent. Unlike many meditative or static yoga forms, SN involves rhythmic, flowing transitions through postures that demand spinal extension and flexion, shoulder mobility, hip opening, and sustained weight-bearing qualities that lend themselves to both musculoskeletal conditioning and, at moderate-to-vigorous pace, cardiovascular loading. A handful of studies have examined its physiological effects, but the intervention protocols, outcome measures, and comparison conditions have varied widely (Pushpanathan et al., 2015; Bhutkar et al., 2011; Raghavendra et al., 2019). None, to our knowledge, has employed a matched-duration randomised design with simultaneous assessment of both flexibility and endurance alongside a passive control.

This gap matters practically. If SN can produce cardiorespiratory benefits comparable even if not identical to conventional aerobic training while also delivering superior flexibility gains, it represents a particularly efficient tool for comprehensive fitness in populations that cannot or will not attend gyms. Conversely, if aerobic exercise so dramatically outperforms SN on endurance parameters that no reasonable comparison holds, the findings would counsel practitioners against substituting SN for aerobic training in clinical or public health contexts.

The present randomised controlled trial therefore compared the effects of 12 weeks of structured Surya Namaskar practice versus an equivalent dose of aerobic exercise on two primary fitness outcomes flexibility and cardiorespiratory endurance in sedentary young adults, with an inactive control group for baseline comparison.

2. LITERATURE REVIEW

2.1 Physiological Basis of Flexibility Training

Flexibility refers to the range of motion achievable at a single joint or across a series of joints, constrained by the extensibility of surrounding connective tissue, including muscles, ligaments, and tendons (McArdle, Katch & Katch, 2015). Regular stretching whether static, dynamic, or proprioceptive neuromuscular facilitation (PNF) has been shown to increase this range through both neural adaptations (reduced stretch reflex sensitivity) and structural changes (increased fascicle length and reduced passive stiffness) (Magnusson et al., 1998; Freitas et al., 2018). The degree of flexibility gain depends on training frequency, duration, and the types of stretches applied.

Aerobic exercise modalities such as jogging and cycling do not systematically load joints through their full range of motion, and they rarely incorporate sustained stretch durations. As a consequence, they produce minimal flexibility gains unless supplemented with dedicated stretching protocols (Garber et al., 2011). Surya Namaskar, by contrast, cycles the body through deep hip flexion (Ashwa Sanchalanasana), spinal extension (Bhujangasana), sustained forward folding (Uttanasana), and inverted loading (Adho Mukha Svanasana) across each cycle. Each posture imposes a brief but repeated tensile load on specific muscle-tendon units—conditions that, repeated over weeks, are consistent with mechanisms of adaptive stretch-induced increases in range of motion (Rees, Murphy & Watsford, 2007).

2.2 Cardiorespiratory Responses to Yoga and Aerobic Exercise

The cardiovascular demands of yoga depend heavily on the style and pace practised. Restorative or Hatha yoga classes typically elicit heart rates of only 50–60% of maximum, insufficient to produce the aerobic adaptations associated with cardiorespiratory fitness improvements (Hagins, Moore & Rundle, 2007). Vinyasa-based sequences, which share structural similarities with Surya Namaskar performed at continuous moderate pace, have been found to produce heart rate responses of 68–80% of maximum in trained practitioners (Clay, Lloyd & Walker, 2005). Bhutkar et al. (2011) demonstrated significant improvements in both VO_2 max and respiratory capacity after six months of daily SN practice, suggesting that sustained, paced performance can generate aerobic stimuli sufficient for adaptation.

Conventional aerobic exercise, when performed at 60–80% of maximum heart rate for at least 30 minutes three to five times per week, reliably improves VO_2 max by 10–30% in previously sedentary individuals within 8–16 weeks (ACSM, 2021). The physiological pathway involves central adaptations increased stroke volume and cardiac output—as well as peripheral adaptations including improved mitochondrial density and capillary proliferation in working muscles (Saltin & Rowell, 1980; Mikkelsen et al., 2017). The evidence base for aerobic training on VO_2 max improvements in sedentary young adults is robust and consistent.

2.3 Comparative Studies and Identified Gaps

A limited but growing body of research has begun comparing yoga-based practices with conventional exercise. Raghavendra et al. (2019) compared yoga and walking in middle-aged adults and found yoga superior for flexibility and quality of life, while walking was superior for blood pressure reduction. In adolescents, Tran et al. (2001) found significant flexibility and muscular strength gains following yoga practice, though no aerobic comparison was included. More recently, Sharma and Singh (2022) compared 8 weeks of Surya Namaskar with brisk walking in women and found comparable cardiovascular benefits, though session durations were not matched across conditions.

The recurring methodological limitations in this literature include unmatched training volumes across conditions, lack of a passive control group, self-selected samples, short intervention durations, and reliance on subjective or indirect fitness measures. The current study was designed specifically to address these limitations through random allocation, duration-matched protocols, inclusion of an inactive control group, and validated objective outcome measures.

3. METHODOLOGY

3.1 Study Design

This study used a three-arm, parallel-group randomised controlled trial design. Participants were randomly assigned in a 1:1:1 ratio to the Surya Namaskar group (SN), aerobic exercise group (AE), or control group (CG). Randomisation was performed using computer-generated allocation sequences in blocks of six, stratified by sex. Assessors conducting pre- and post-tests were blind to group allocation. The study was conducted between June and September 2023 at a university campus in South India and was approved by the institutional ethics committee (Ref: IEC/2023/047).

3.2 Participants

A total of 108 volunteers were screened, of whom 90 met the inclusion criteria and were enrolled. Inclusion criteria were: age 18–27 years, self-reported physical inactivity (fewer than 90 minutes of structured exercise per week in the prior three months), BMI between 18.5 and 27.5 kg/m², no current chronic illness or musculoskeletal injury, and no current use of medications affecting cardiorespiratory or musculoskeletal function. Exclusion criteria included pregnancy, prior experience in yoga or structured aerobic programmes exceeding 30 days within the past year, and cardiovascular contraindications to exercise. All participants provided written informed consent before enrolment. Demographic characteristics are summarised in Table 1.

Table 1: Baseline Demographic Characteristics of Participants (Mean ± SD)

Variable	Surya Namaskar(n = 30)	Aerobic Exercise(n = 30)	Control Group(n = 30)
Age (years, mean ± SD)	21.4 ± 2.1	21.7 ± 1.9	21.2 ± 2.3
Height (cm, mean ± SD)	167.3 ± 6.8	168.1 ± 7.2	167.6 ± 6.5
Body Mass (kg, mean ± SD)	62.5 ± 7.4	63.1 ± 7.9	62.8 ± 7.1
BMI (kg/m ² , mean ± SD)	22.3 ± 2.6	22.6 ± 2.4	22.4 ± 2.8
Sex (Male/Female)	15 / 15	15 / 15	15 / 15
Physical Activity Level	Sedentary	Sedentary	Sedentary

Note: No statistically significant between-group differences at baseline ($p > 0.05$ for all variables, one-way ANOVA).

3.3 Intervention Protocols

The SN group performed Surya Namaskar following a standardised 12-posture sequence at a pace of one complete cycle per 1.5 minutes. Sessions began with 5 minutes of deep breathing (Pranayama), followed by 35 minutes of continuous Surya Namaskar cycling (approximately 22–24 cycles per session), and ended with 5 minutes of Shavasana. Practitioners were trained by a certified yoga instructor and monitored for correct posture alignment throughout the intervention period.

The AE group performed brisk walking and jogging on a standard athletic track. Sessions began with a 5-minute warm-up walk, followed by 35 minutes of brisk walking or jogging at 60–70% of estimated maximum heart rate (calculated as 220 minus age), and concluded with a 5-minute cool-down walk. Heart rate was monitored using fingertip pulse oximeters at the beginning and end of the main exercise phase. Both groups trained five days per week across 12 weeks, for a total of 60 sessions.

The control group received no exercise intervention and was asked to maintain their habitual activity levels. They attended assessment sessions at baseline and at week 12.

3.4 Outcome Measures

Flexibility was measured using the standard Sit-and-Reach Test (SR test), performed on a calibrated sit-and-reach box (Baseline® model) with the zero mark at 23 cm (toe line). Participants performed three trials and the best score was recorded in centimetres. Test-retest reliability in this laboratory has been established at ICC = 0.96.

Cardiorespiratory endurance was assessed using the 20-metre Multi-Stage Shuttle Run Test (Beep Test), which estimates VO_2 max from the final completed level and shuttle. The test was administered on a flat indoor surface with standardised audio cues. The Léger et al. (1988) equation was used to derive estimated VO_2 max values. Test-retest reliability in the present sample was $\text{ICC} = 0.94$.

Both tests were conducted in the early morning under controlled conditions (26–28°C, 60–65% relative humidity) on three consecutive days: the day before the intervention commenced (pre-test) and the day after the final session (post-test). All assessments were conducted by the same examiner, blinded to group assignment.

3.5 Statistical Analysis

Data were entered into SPSS version 26.0 and inspected for normality using the Shapiro-Wilk test. All continuous variables satisfied the assumption of normality ($p > 0.05$). Descriptive statistics (means and standard deviations) were computed for all outcome measures at baseline and post-intervention. Within-group changes were assessed using paired-samples t-tests. Between-group differences in post-test scores were examined using one-way ANCOVA with baseline scores as covariates. Post-hoc pairwise comparisons were conducted using the Bonferroni correction. The level of statistical significance was set at $\alpha = 0.05$. Effect sizes were computed as partial eta-squared (η^2p) for ANCOVA and Cohen's d for paired t-tests.

4. RESULTS

4.1 Flexibility Outcomes

Pre-intervention sit-and-reach scores were statistically comparable across all three groups ($F(2, 87) = 0.12, p = 0.89$), confirming successful randomisation on this variable. After 12 weeks, both the SN and AE groups showed significant within-group improvements, while the CG did not. The SN group increased from a mean of 14.2 ± 2.3 cm to 22.8 ± 2.8 cm (mean gain: 8.6 cm; 60.6% improvement; Cohen's $d = 3.23; p < 0.001$). The AE group improved from 13.9 ± 2.1 cm to 19.1 ± 2.4 cm (mean gain: 5.2 cm; 37.4%; Cohen's $d = 2.45; p < 0.001$). The control group showed a negligible change from 14.0 ± 2.2 cm to 14.5 ± 2.3 cm (mean gain: 0.5 cm; 3.6%; $p = 0.38$). ANCOVA confirmed a significant between-group effect ($F(2, 86) = 41.7, p < 0.001, \eta^2p = 0.49$), with post-hoc analysis revealing that the SN group significantly outperformed both the AE group ($p < 0.001$) and the CG ($p < 0.001$). Results are presented in Table 2 and Figure 1.

Table 2: Flexibility (Sit-and-Reach) Scores — Pre- and Post-Intervention

Group	Pre-test(cm)	Post-test(cm)	Mean Gain(cm)	% Change	p-value
Surya Namaskar	14.2 ± 2.3	22.8 ± 2.8	8.6 ± 1.4	60.6%	< 0.001
Aerobic Exercise	13.9 ± 2.1	19.1 ± 2.4	5.2 ± 1.1	37.4%	< 0.001
Control Group	14.0 ± 2.2	14.5 ± 2.3	0.5 ± 0.4	3.6%	0.38

Note: Values expressed as Mean ± SD. * $p < 0.001$ (paired t-test, within group); † $p < 0.001$ (ANCOVA post-hoc, vs. Control); ‡ $p < 0.001$ (ANCOVA post-hoc, SN vs. AE).

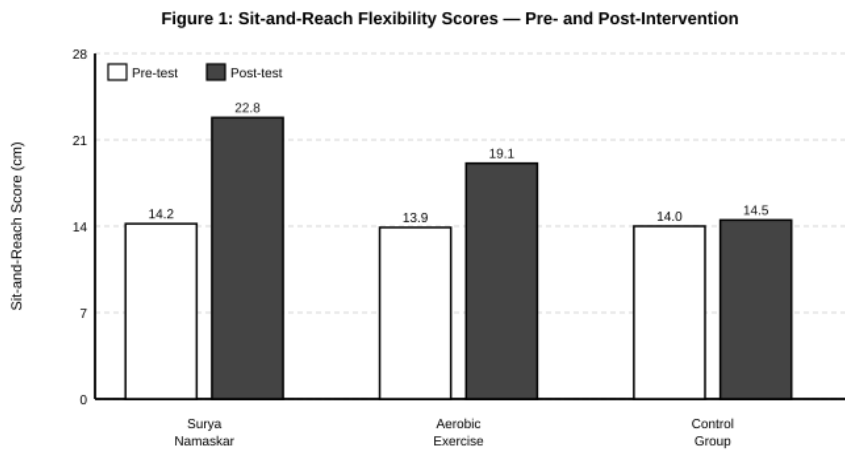


Figure 1. Mean sit-and-reach scores (cm) before and after the 12-week intervention for all three groups. Error bars represent ±1 SD. The Surya Namaskar group recorded the largest absolute and proportional gains.

The weekly progression curve (Figure 3) reveals that the SN group showed a steep initial rate of flexibility gain between weeks 0 and 4, likely reflecting early neural and connective tissue adaptations to the repeated full-range loading patterns inherent in the SN sequence. The trajectory levelled somewhat between weeks 8 and 12, suggesting approach toward a training plateau. The AE group showed a slower but consistent linear progression throughout, with no identifiable plateau phase within the 12-week window. The control group's curve was essentially flat, confirming adherence to the no-exercise protocol.

4.2 Endurance Outcomes

Baseline VO₂ max values did not differ significantly between groups ($F(2, 87) = 0.08, p = 0.92$). Following the 12-week programme, the AE group demonstrated the largest gain, rising from 31.9 ± 3.5 to 42.3 ± 4.1 ml·kg⁻¹·min⁻¹ (mean gain: 10.4 ml·kg⁻¹·min⁻¹; 32.6%; Cohen's d = 2.73; $p < 0.001$). The SN group also showed a meaningful improvement, from 31.4 ± 3.2 to 38.7 ± 3.6 ml·kg⁻¹·min⁻¹ (mean gain: 7.3 ml·kg⁻¹·min⁻¹; 23.2%; Cohen's d = 2.10; $p < 0.001$). The control group showed no meaningful change (31.6 ± 3.1 to 32.1 ± 3.2 ml·kg⁻¹·min⁻¹; 1.6%; $p = 0.42$). ANCOVA revealed significant between-group differences ($F(2, 86) = 29.3, p < 0.001, \eta^2p = 0.40$), with the AE group significantly outperforming the SN group ($p = 0.006$) and both active groups significantly outperforming the CG ($p < 0.001$). Table 3 and Figure 2 present the full endurance results.

Table 3: Cardiorespiratory Endurance (VO₂ Max) — Pre- and Post-Intervention

Group	Pre-test(ml·kg ⁻¹ ·min ⁻¹)	Post-test(ml·kg ⁻¹ ·min ⁻¹)	Mean Gain	% Change	p-value
Surya Namaskar	31.4 ± 3.2	38.7 ± 3.6	7.3 ± 1.6	23.2%	< 0.001
Aerobic Exercise	31.9 ± 3.5	42.3 ± 4.1	10.4 ± 2.0	32.6%	< 0.001
Control Group	31.6 ± 3.1	32.1 ± 3.2	0.5 ± 0.5	1.6%	0.42

Note: Values expressed as Mean ± SD. VO₂ max estimated using the 20-m shuttle run (Léger et al., 1988). * $p < 0.001$ (paired t-test); † $p < 0.001$ (ANCOVA post-hoc, both active groups vs. Control); ‡ $p = 0.006$ (ANCOVA post-hoc, AE vs. SN).

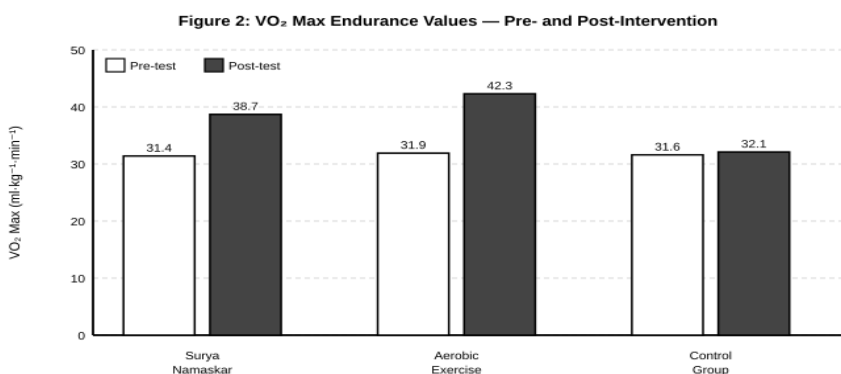


Figure 2. Mean VO₂ max values (ml·kg⁻¹·min⁻¹) before and after the intervention. The aerobic exercise group recorded the greatest endurance gains, though the Surya Namaskar group also showed substantial improvement.

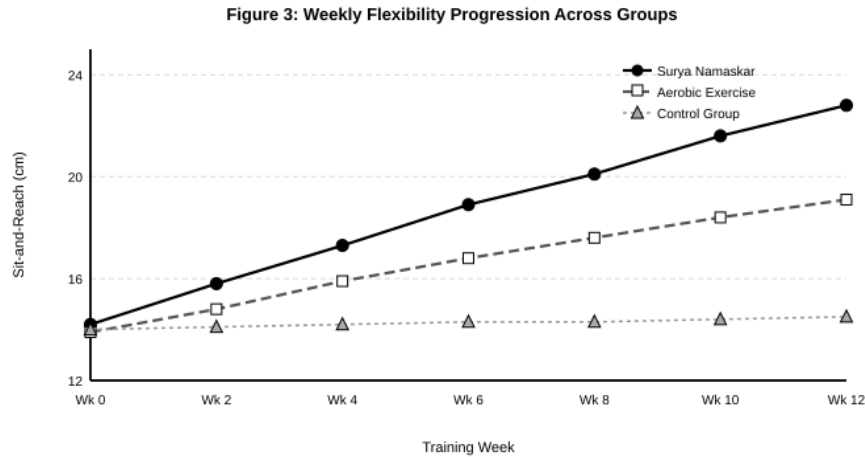


Figure 3. Weekly progression of sit-and-reach flexibility across the 12-week intervention for the three groups. Data points represent mean scores at fortnightly intervals.

4.3 Adverse Events and Compliance

No serious adverse events were reported across either training group. Three participants in the SN group reported transient mild lower back discomfort during weeks 2–3, which resolved without intervention by week 4. Mean session compliance was 94.3% in the SN group and 91.7% in the AE group, indicating high adherence to both programmes. There were no significant differences in compliance between groups ($\chi^2 = 1.14$, $p = 0.29$).

5. DISCUSSION

The central finding of this trial is not a simple verdict for one modality over the other, but a nuanced picture of complementary strengths. Surya Namaskar and aerobic exercise both produce meaningful fitness improvements in sedentary young adults over 12 weeks, but they do so in different domains and to different degrees. This distinction has real practical significance for how practitioners, educators, and public health professionals should frame movement recommendations.

The flexibility superiority of the Surya Namaskar group, a 60.6% improvement versus 37.4% in the aerobic group is striking but not surprising when one considers the mechanical nature of the SN sequence. Each cycle takes the practitioner through sustained stretching at the hip flexors, hamstrings, thoracic spine, shoulder girdle, and ankle complex. Performed 22–24 times per session, the cumulative stretch volume is substantial. This is structurally analogous to a dedicated stretch training protocol carried out alongside cardiovascular exercise, meaning that SN is, in effect, doing the work of two exercise components simultaneously. The AE group's flexibility gains, while significant, reflect the incidental stretching that occurs during warm-up and cool-down rather than any systematic flexibility loading during the exercise phase.

Our findings on flexibility align closely with those of Bhutkar et al. (2011), who found greater hamstring and spinal flexibility gains in Surya Namaskar practitioners compared with matched controls, and extend them by providing a direct aerobic comparison arm. They also partially confirm the findings of Sharma and Singh (2022), who reported flexibility advantages for yoga-based exercise over brisk walking, although the magnitude of difference in our study (approximately 23 percentage points) was larger, possibly due to our higher session frequency (five days per week versus three).

The endurance results are perhaps more instructive from a physiological standpoint. The aerobic group's mean VO_2 max increase of $10.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (32.6%) falls within the upper range of what is typically reported for aerobic training in sedentary adults over 12 weeks, consistent with the established literature (ACSM, 2021; Ross et al., 2020). The SN group's gain of $7.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (23.2%) is considerably more modest in absolute terms, yet still represents a physiologically meaningful improvement by any clinical standard. For context, a 23% increase in VO_2 max from a sedentary baseline is associated with clinically meaningful reductions in all-cause cardiovascular risk (Warburton & Bredin, 2017). The SN group was not performing a purely meditative practice; sustained, rhythmic SN at the pace employed here achieves heart rates in the range required for cardiorespiratory adaptation, a finding consistent with Clay et al. (2005) and Pushpanathan et al. (2015).

One aspect of our data that warrants careful interpretation is the early-phase flexibility trajectory visible in Figure 3. The SN group's disproportionate flexibility gains in the first four weeks suggest that a portion of the early improvement reflects removal of neural inhibition rather than genuine connective tissue remodelling. It is known from stretch training literature that neural mechanisms reduced stretch reflex sensitivity and increased stretch tolerance—account for early gains (Freitas et al., 2018), while structural adaptations (increased fascicle length, reduced passive stiffness) dominate from roughly 4–8 weeks onward. The plateau observed in the SN group between weeks 8 and 12 may signal that the programme had not yet been sufficiently modified to maintain progressive overload, suggesting that systematic variation in posture depth or hold duration might sustain adaptation in longer programmes.

The trial has several limitations that should be acknowledged. The estimated VO_2 max values derived from the shuttle run are less precise than direct laboratory measurement via incremental maximal exercise testing with metabolic gas analysis; while validated for population-level research, they carry a measurement error of approximately $\pm 3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Léger et al., 1988). The study population sedentary young adults at a single university campus limits generalisability to other age groups, clinical populations, and those with higher baseline fitness. The 12-week horizon, while standard for intervention research, does not capture long-term retention of gains or potential divergence in trajectories beyond the plateau phase. Future research should consider longer interventions (24+ weeks), direct VO_2 max measurement, inclusion of older

adults, and tracking of training-load parameters such as heart rate variability to better characterise the physiological responses within sessions.

6. CONCLUSION

This randomised controlled trial provides clear evidence that Surya Namaskar and aerobic exercise address overlapping but distinct components of physical fitness. Surya Namaskar is the superior intervention for developing flexibility, producing gains nearly two-thirds larger than those achieved through aerobic training over the same 12-week period. Aerobic exercise, on the other hand, produces greater improvements in cardiorespiratory endurance, as reflected in significantly higher VO₂ max gains though Surya Namaskar still generated a clinically meaningful endurance response that should not be dismissed.

For public health practitioners and physical educators working with sedentary populations—particularly in settings where gym infrastructure is unavailable Surya Namaskar offers a practical, equipment-free, culturally rooted option that delivers broad fitness conditioning in a single daily practice. For those with primary cardiorespiratory fitness goals, aerobic exercise remains the modality of choice, but SN could be prescribed as an effective complement, particularly where flexibility deficits or musculoskeletal tightness are concerns. The ideal recommendation, where resources permit, may be a combined programme that leverages the relative strengths of both modalities.

The global re-emergence of interest in traditional movement practices has often run ahead of the evidence base. This study contributes to narrowing that gap, offering practitioners a data-supported basis for decisions about how, when, and for whom Surya Namaskar is most appropriately prescribed.

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