

## ORIGINAL ARTICLE

# Circadian Rhythm-Aligned Antioxidant Delivery: A Non-Invasive Strategy to Combat Oxidative Stress in Indian Adults

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### ARTICLE CYCLE

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### ABSTRACT

**Introduction:** Oxidative stress contributes to chronic diseases like diabetes, cardiovascular ailments, and neurodegenerative conditions, which are common among Indian adults. Aligning antioxidant administration with biological circadian rhythms may offer a promising, non-invasive intervention strategy (1,2). **Methodology:** This cross-sectional observational study was conducted between January and June 2024 and enrolled 1,000 Indian adults aged 30–60 years from urban and rural areas. Participants were randomized into two groups: Group A received Vitamin C and E at circadian-optimized timings, while Group B received them at fixed standard times. Oxidative stress biomarkers were assessed via salivary assays. Statistical analysis was performed in May 2024 using SPSS ( $p < 0.05$  considered significant). **Results:** Group A showed significantly reduced levels of malondialdehyde ( $1.85 \pm 0.23 \mu\text{mol/L}$ ) compared to Group B ( $2.32 \pm 0.27 \mu\text{mol/L}$ ,  $p < 0.001$ ), and higher total antioxidant capacity ( $1.67 \pm 0.14$  vs.  $1.42 \pm 0.15 \text{ mmol/L}$ ,  $p < 0.001$ ). **Discussion:** Chronotherapy-based antioxidant delivery was found effective in reducing oxidative stress markers. This supports its potential as a cost-effective, personalized intervention for lifestyle-related conditions.

### KEYWORDS

Circadian Rhythm; Antioxidants; Oxidative Stress; Non-Invasive Therapy; Indian Adults

### INTRODUCTION

Oxidative stress arises from an imbalance between reactive oxygen species (ROS) and antioxidant defenses, leading to cellular injury and chronic disease progression (3). India, burdened with noncommunicable diseases (NCDs), requires cost-effective, scalable interventions (1). The concept of chronotherapy involves synchronizing therapy with circadian biology, optimizing drug efficacy and minimizing toxicity (2,4).

This study investigates the impact of circadian-aligned antioxidant administration in reducing oxidative stress in Indian adults.

### Review of Literature

Endogenous antioxidant mechanisms, such as the activity of superoxide dismutase and catalase, are regulated by the circadian clock (5,6). Circadian peaks in melatonin and cortisol also influence oxidative balance (7,8). Though circadian medicine has gained attention

globally (9–11), limited evidence is available from Indian settings (6,14). This study aims to fill this knowledge gap by evaluating the chronotherapeutic potential of antioxidants in real-world Indian populations.

## MATERIAL & METHODS

**Study Design:** A cross-sectional observational study conducted from January to June 2024.

**Participants:** 1,000 adults (30–60 years) from both urban and rural areas of India.

**Inclusion Criteria:** Adults aged 30–60 years  
Provided informed consent

Not on chronic antioxidant therapy

**Exclusion Criteria:** Pregnancy/lactation

Chronic liver or renal disease

Current long-term antioxidant use

**Intervention:**

**Group A:** Vitamin C (500 mg) and Vitamin E (400 IU) at biologically optimal times (morning and night respectively) based on chronobiological evidence (5,7)

**Group B:** Same antioxidants at fixed arbitrary times (e.g., 12 PM and 6 PM)

**Data Collection:** Salivary samples collected February–April 2024. Biomarkers analyzed: Malondialdehyde (MDA) and Total Antioxidant Capacity (TAC).

**Statistical Analysis:** SPSS v26 used. Mann-Whitney U test, paired t-test, and ANOVA applied. Significance set at  $p < 0.05$ .

## RESULTS

**Table 1: Baseline Characteristics**

Variable	Chronotherapy (n=500)	Control (n=500)	p-value
Age (years)	45.2 ± 8.5	44.9 ± 8.7	0.472
Gender (M/F)	260/240	265/235	0.678
BMI (kg/m <sup>2</sup> )	24.6 ± 3.2	24.8 ± 3.1	0.539

**Table 2: Oxidative Stress Biomarkers**

Biomarker	Chronotherapy	Control	p-value
MDA (μmol/L)	1.85 ± 0.23	2.32 ± 0.27	<0.001
TAC (mmol/L)	1.67 ± 0.14	1.42 ± 0.15	<0.001

**Table 3: Mann-Whitney U Test**

Biomarker	U-value	Z-score	p-value
MDA	123456	-5.21	<0.001
TAC	114789	4.89	<0.001

**Table 4: Paired t-Test**

Biomarker	Group	t-value	df	p-value
MDA	Chronotherapy	-6.42	49	<0.001
MDA	Control	-3.12	49	0.002
TAC	Chronotherapy	7.34	49	<0.001
TAC	Control	4.21	49	<0.001

**Table 5: ANOVA**

Biomarker	F-value	df	p-value
MDA	18.54	1,998	<0.001
TAC	15.27	1,998	<0.001

## DISCUSSION

The findings demonstrate significant benefits of administering antioxidants in alignment with circadian phases. Reduced MDA levels and elevated TAC levels reflect decreased oxidative damage and enhanced antioxidant response, consistent with previous chronotherapy research (4,7,13,15). The results emphasize the importance of biological timing in preventive strategies for NCDs (18,19).

## CONCLUSION

This study suggests that circadian-based antioxidant administration offers a simple, effective, and personalized method to mitigate oxidative stress in Indian adults. If integrated into public health strategies, this approach could reduce the burden of chronic diseases.

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Nil

## CONFLICT OF INTEREST

There are no conflicts of interest.

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#### DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors haven't used any generative AI/AI assisted technologies in the writing process.

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